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Research paper

Nursing Strategies and Safety Devices for Preventing Parenteral Therapy–Related Iatrogenesis in Low-And Middle-Income Countries: A Scoping Review

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Abstract

Background: Parenteral therapy is a high-risk component of clinical care because injectable and infused medicines bypass physiological barriers, enabling rapid harm when errors occur. In low- and middle-income countries [LMICs], these risks may be intensified by staffing constraints, limited device availability, weak reporting systems, and inconsistent infection prevention infrastructure.
Objective: This scoping review mapped evidence on parenteral therapy–related iatrogenic risks, safety devices, and medication administration technologies, and nursing and system-level determinants of safer parenteral therapy implementation in LMICs.
Methods: A scoping review was conducted in accordance with PRISMA-ScR guidance. PubMed/MEDLINE, Scopus, Web of Science, and CINAHL were searched for English-language publications from 2010 to 2026. Additional sources were identified through citation searching, professional guidance, and relevant reference lists. 71 studies met the inclusion criteria; 68 were mapped to one or more review objectives, while 3 studies supported methodological, conceptual, or background framing. Evidence was synthesized using narrative synthesis and evidence mapping, guided by the SEIPS socio-technical systems framework.
Results: The review found that Iatrogenesis spanned all clinical phases, including preparation errors, glass particulate contamination, wrong infusion rates, catheter-related infections, and unsafe injection practices. These risks were exacerbated by heavy workloads and workflow interruptions. Safety devices addressed specific vulnerabilities: prefilled syringes reduced preparation complexity; filters mitigated particulate exposure; smart pumps reduced programming errors; and BCMA/eMAR systems strengthened verification. However, technology effectiveness depended on training, usability, workflow integration, procurement reliability, and institutional support.
Conclusion: Preventing parenteral therapy–related iatrogenesis in LMICs requires layered, context-sensitive implementation combining nursing competence, standardized protocols, robust infection prevention, safety devices, and organizational governance.

Keywords: *Parenteral Therapy; Medication Safety; Nursing Practice; Safety Devices; Low- and Middle-Income Countries.*

1. Introduction

Medication safety remains a major global patient safety concern, particularly in parenteral therapy, where medications are delivered by injection or infusion and can cause rapid harm when errors occur. Medication administration errors are widely recognized as preventable adverse events in hospital care, and intravenous medication errors are especially concerning because parenteral medicines bypass several physiological protective barriers and enter directly into systemic circulation [1], [2]. Medication preparation and administration are vulnerable to dose calculation errors, incorrect dilution, wrong infusion rates, contamination, drug incompatibility, and inadequate patient monitoring, particularly in high-acuity clinical environments [2–4]. These risks make parenteral therapy one of the most safety-critical areas of nursing practice and clinical governance.

Parenteral therapy is not a single clinical act but a sequence of interdependent processes involving prescription review, dose calculation, reconstitution, dilution, ampoule or vial handling, syringe preparation, labelling, patient identification, injection, infusion programming, line flushing, documentation, and post-administration monitoring [2–4]. Each stage creates opportunities for iatrogenic harm when care is delivered under workload pressure, interruptions, limited resources, device unavailability, poor workspace design, or inconsistent

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adherence to protocols [1–7]. Evidence from medication preparation and administration studies shows that manually prepared infusions are vulnerable to preparation errors, while nursing studies link workload, interruptions, and fragmented workflows with medication administration risk [3–7]. Preventing parenteral therapy–related iatrogenesis, therefore, requires attention not only to individual nursing performance but also to the systems, devices, workflows, and organizational conditions that shape medication safety [1], [2], [5–8].

Nurses occupy a central position in the parenteral therapy pathway because they are directly involved in medication preparation, verification, administration, documentation, and patient monitoring [5–10]. This role places nurses at the final point of contact before a medication reaches the patient, making nursing practice a critical safeguard against preventable harm. However, nurses often perform these responsibilities under difficult clinical conditions, including high workload, time pressure, interruptions, inadequate staffing, and limited access to safety technologies [5–7], [9], [10]. Evidence from workload, interruption, and medication safety studies indicates that environmental and workflow pressures can increase the likelihood of error and reduce adherence to safe medication practices [5–7,10]. These findings support a systems-oriented approach in which medication errors are understood as outcomes of interactions among people, tasks, technologies, organizations, and care environments, rather than as isolated individual failures [8].

The risks associated with parenteral therapy are especially important in low- and middle-income countries [LMICs], where health systems may face persistent constraints in staffing, procurement, infrastructure, training, reporting systems, and access to safety-engineered devices [11–17]. In resource-constrained settings, nurses may rely more heavily on manual preparation, improvised workflows, limited consumables, and locally available equipment. These conditions may increase vulnerability to preventable medication errors, contamination, needlestick injuries, unsafe injection practices, and infusion-related complications [11–17]. Evidence from Nigerian and other LMIC healthcare settings highlights barriers such as limited device availability, inadequate training, weak reporting systems, inconsistent policy implementation, and organizational constraints affecting medication safety, infection prevention, and safe injection practice [11–17]. These implementation challenges suggest that interventions shown to be effective in high-income settings may not automatically translate into safer practice in LMICs unless they are adapted to local resources, workforce capacity, procurement systems, and institutional realities.

Safety devices and medication administration technologies have been introduced to reduce risks across the injection–infusion pathway. Prefilled and ready-to-administer syringes are designed to reduce preparation complexity by minimizing manual manipulation, unnecessary dilution, transfer steps, and bedside preparation variability [18–22]. Evidence suggests that these systems may reduce preparation time, dosing variability, contamination risk, and medication handling errors compared with conventional vial-and-syringe preparation methods [18–22]. Color-coded prefilled syringes have also been associated with faster medication delivery and fewer dosing errors in simulated pediatric emergency and prehospital resuscitation settings [23], [24]. However, the benefits of prefilled and ready-to-administer systems may be constrained by cost, procurement systems, product availability, device compatibility, and supply-chain reliability, particularly in resource-limited healthcare facilities [18–22], [25], [26].

Particulate contamination is another important source of parenteral therapy–related iatrogenic risk, especially when injectable medications are prepared from glass ampoules. Opening glass ampoules can introduce microscopic glass particles into injectable solutions, creating potential risks of vascular irritation, inflammatory response, embolic phenomena, phlebitis, or catheter-related complications [27–32]. Several studies have examined glass particle contamination, ampoule-opening practices, needle types, and the role of filter needles in reducing particulate exposure [27–33]. Recent evidence evaluating ampoule-breaking strategies and compliance with contamination-prevention practices emphasizes that particulate control requires both appropriate safety devices and correct preparation technique [32], [33]. Although filter needles may provide a relatively simple safety intervention, uptake can be limited by knowledge gaps, supply shortages, perceived inconvenience, cost, and absence of institutional protocols [13], [34].

In-line filtration systems provide a downstream safety barrier during intravenous therapy. These systems are used to reduce the infusion of particulate matter, air, and other contaminants, particularly in high-risk settings such as neonatal care, pediatric intensive care, critical care, parenteral nutrition, and multidrug infusion regimens [35–41]. Clinical studies, systematic reviews, and position papers suggest that in-line filtration may reduce particulate contamination, phlebitis, infusion-related complications, and selected markers of organ dysfunction in vulnerable patient groups [35–44]. However, the evidence remains context-dependent, and questions persist regarding filter selection, routine use, cost, staff training, workflow integration, and feasibility of sustained implementation in resource-limited healthcare settings [35–44].

Digital medication administration technologies, including smart infusion pumps, dose error reduction systems, electronic medication administration records, and barcode medication administration systems, represent another important group of safety interventions. Smart infusion pumps are intended to reduce infusion programming errors through drug libraries, dose limits, and alerts that warn clinicians before unsafe infusion parameters reach the patient [45–47]. Barcode medication administration and electronic medication administration records support patient–medication verification, documentation accuracy, and traceability during administration [48–54]. Evidence indicates that these technologies can reduce some medication administration errors, but their effectiveness depends on drug library accuracy, user training, interoperability, infrastructure, workflow fit, and consistent staff adherence [45–54]. Problems such as alert fatigue, barcode scanning workarounds, device overrides, interoperability failures, poor usability, and technological downtime may introduce new safety risks when implementation is weak or poorly aligned with clinical practice [47], [51], [54].

The safe implementation of parenteral therapy interventions, therefore, requires more than device availability. It requires nursing competence, institutional protocols, workflow redesign, infection prevention practice, reporting systems, procurement planning, leadership support, and continuous monitoring [11–17], [55–58]. Aseptic non-touch technique, medication verification, independent double-checking for high-alert medications, safe flushing practices, correct infusion programming, and vigilant patient monitoring remain essential nursing safeguards even when advanced technologies are available [2], [11], [55], [56]. Evidence on prefilled flushing systems, infection prevention interventions, safe injection practices, and quality improvement initiatives suggests that safety gains are strongest when devices are embedded into standardized clinical processes and supported by training, audit, feedback, and organizational commitment [14], [15], [55–58].

Despite the growing literature on medication safety, injection safety, infusion technologies, and nursing practice, the evidence remains fragmented. Existing studies often focus on individual interventions, such as prefilled syringes, filter needles, in-line filters, smart pumps, barcode medication administration, or electronic medication administration records, rather than mapping how these interventions function across the full injection–infusion pathway [18–24], [35–54]. In addition, much of the available evidence comes from high-income settings, while LMIC-specific implementation evidence remains limited and uneven [11–17]. This creates uncertainty about which safety devices are most feasible, which nursing strategies are most important, and which organizational conditions are required to sustain safer parenteral therapy in resource-constrained healthcare systems.

A scoping review is therefore appropriate because the field is broad, heterogeneous, and implementation-focused. Rather than estimating a single pooled intervention effect, this review maps the available evidence on parenteral therapy–related iatrogenic risks, safety devices, nursing strategies, and LMIC implementation conditions. Guided by a systems-oriented patient safety perspective, this scoping review aims to map major iatrogenic risks associated with parenteral therapy; identify and categorize safety devices and medication administration technologies used across the injection–infusion pathway; and synthesize nursing strategies, workflow factors, and organizational conditions that support safe implementation and sustainability in LMICs.

2. Methodology

2.1. Review design

This scoping review was conducted to map evidence on nursing strategies and safety devices for preventing parenteral therapy–related iatrogenesis in LMICs. A scoping review design was appropriate because the topic covers a broad and heterogeneous body of literature, including medication preparation safety, injection and infusion devices, digital medication administration technologies, nursing workflow, infection prevention, and implementation challenges in resource-constrained settings.

The review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews guidelines [PRISMA-ScR] [59]. Unlike a systematic review or meta-analysis, this review did not aim to estimate pooled intervention effects. Instead, it aimed to identify key concepts, map available evidence, categorize safety interventions, and highlight gaps relevant to nursing practice and LMIC healthcare systems.

2.2. Review objectives

This scoping review aimed to:

1) map the major iatrogenic risks associated with parenteral therapy, including medication preparation errors, injection-related hazards, infusion-related complications, contamination, and infection risks;
2) identify and categorize safety devices and medication administration technologies used to reduce parenteral therapy–related harm across the injection–infusion pathway; and
3) synthesize nursing strategies, workflow factors, and organizational conditions that support safe implementation and sustainability of parenteral therapy safety interventions in LMICs.

2.3. Review questions

The review addressed the following questions:

1) What iatrogenic risks and safety challenges are reported across the parenteral medication preparation, injection, and infusion pathway?
2) What safety devices and medication administration technologies have been used to prevent or reduce parenteral therapy–related medication errors and adverse events?
3) What nursing strategies and system-level factors influence the implementation, sustainability, and effectiveness of these safety interventions in LMICs?

2.4. Search strategy

A structured literature search was conducted across four electronic databases: PubMed/MEDLINE, Scopus, Web of Science, and CINAHL. These databases were selected because they provide broad coverage of nursing, medication safety, infusion therapy, clinical pharmacology, infection prevention, patient safety, and health-system implementation literature. Additional sources were identified through backward citation searching of included studies, professional guidelines, position papers, and reference lists of relevant systematic reviews.

The search strategy combined controlled vocabulary, where available, and free-text keywords. Search terms were grouped into four conceptual domains: parenteral therapy, safety devices and technologies, medication safety outcomes, and nursing or implementation factors. The search terms included combinations of:

1) "parenteral therapy," "parenteral medication," "intravenous medication," "intravenous therapy," "infusion therapy," "injection safety," "drug infusion," "medication preparation," and "catheter flushing";
2) "prefilled syringe," "ready-to-administer syringe," "filter needle," "in-line filter," "infusion filter," "smart infusion pump," "dose error reduction system," "barcode medication administration," "electronic medication administration record," "safety syringe," "auto-disable syringe," and "needleless connector";
3) "medication administration error," "intravenous medication error," "adverse drug event," "iatrogenesis," "contamination," "particulate contamination," "bloodstream infection," "catheter-related infection," "phlebitis," "needlestick injury," and "infusion-related complication"; and
4) "nursing practice," "nurses," "workflow," "interruptions," "workload," "aseptic technique," "infection prevention," "competency training," "patient safety," "low- and middle-income countries," "resource-limited settings," "implementation barriers," and "implementation enablers."

A representative PubMed/MEDLINE search string was:

["parenteral therapy" OR "parenteral medication" OR "intravenous medication" OR "intravenous therapy" OR "infusion therapy" OR "injection safety" OR "drug infusion" OR "medication preparation" OR "catheter flushing"]

AND

["prefilled syringe" OR "ready-to-administer syringe" OR "filter needle" OR "in-line filter" OR "infusion filter" OR "smart infusion pump" OR "dose error reduction system" OR "barcode medication administration" OR "electronic medication administration record" OR "safety syringe" OR "auto-disable syringe" OR "needleless connector"]

AND

["medication administration error" OR "intravenous medication error" OR "adverse drug event" OR "iatrogenesis" OR "contamination" OR "particulate contamination" OR "bloodstream infection" OR "catheter-related infection" OR "phlebitis" OR "needlestick injury" OR "infusion-related complication"]

AND

["nursing practice" OR "nurses" OR "workflow" OR "interruptions" OR "workload" OR "aseptic technique" OR "infection prevention" OR "competency training" OR "patient safety" OR "low- and middle-income countries" OR "resource-limited settings" OR "implementation barriers" OR "implementation enablers"].

Searches were limited to English-language publications from 2010 to 2026. One foundational conceptual source published before this period was retained to support the SEIPS framework, but was not treated as part of the empirical evidence synthesis.

2.5. Study selection and eligibility criteria

Study selection was conducted in two stages. First, titles and abstracts were screened to identify studies addressing parenteral therapy safety, medication administration errors, injection or infusion technologies, nursing practice, infection prevention, or implementation barriers. Second, potentially eligible full-text articles were assessed against the review objectives.
Studies were included if they met at least one of the following criteria:

1) examined risks, errors, or iatrogenic complications related to parenteral medication preparation, injection, infusion, flushing, or monitoring;
2) evaluated or discussed safety devices or medication administration technologies used in parenteral therapy, including prefilled syringes, filter needles, in-line filters, smart infusion pumps, barcode medication administration, electronic medication administration records, safety syringes, or related systems;
3) investigated nursing strategies, workflow factors, infection prevention practices, competency training, or organizational conditions influencing parenteral therapy safety;
4) addressed medication safety, injection safety, infusion safety, or infection prevention in LMICs or resource-constrained healthcare settings; or
5) provided methodological or policy guidance directly relevant to scoping review reporting, injection safety, or parenteral therapy safety.
6) Studies were excluded if they focused exclusively on non-parenteral medication administration, addressed general patient safety without relevance to medication administration or injection–infusion practice, examined unrelated technologies or clinical topics, lacked sufficient analytical or practice relevance, were unavailable in English, or did not provide enough information to determine relevance to the review objectives.

Disagreements during screening were resolved through discussion among the review team. Where uncertainty remained, inclusion was based on relevance to one or more of the three review objectives.

2.6. Data charting and evidence synthesis

Data from eligible studies were charted using a structured extraction form aligned with the three review objectives. Extracted variables included author and year, country or region, income setting, study design, clinical setting, population, parenteral therapy stage, type of risk or intervention, safety device or technology, nursing strategy, implementation barrier or enabler, reported outcome, and key finding.
Findings were synthesized using structured narrative synthesis and evidence mapping. Studies were grouped into three evidence domains:

1) parenteral therapy–related iatrogenic risks;
2) safety devices and medication administration technologies; and
3) nursing strategies and LMIC implementation conditions.

Within each domain, findings were examined for recurring patterns, reported benefits, implementation barriers, device-related limitations, and evidence gaps. Particular attention was given to whether evidence originated from LMICs, high-income countries, or mixed/global settings, and whether findings were directly transferable to resource-constrained healthcare environments.

2.7. Evidence characterization and methodological scope

Consistent with PRISMA-ScR guidance, a formal risk-of-bias assessment was not conducted because the purpose of this review was to map the scope, characteristics, and distribution of available evidence rather than to generate pooled effect estimates [59]. Instead, the included sources were characterized descriptively by study design, clinical context, intervention type, income setting, and relevance to the three review objectives. This approach allowed the review to distinguish between direct clinical evidence, device-focused evidence, nursing practice evidence, implementation evidence, policy guidance, and broader conceptual evidence.
The methodological scope of the review should be interpreted in line with its scoping purpose. Meta-analysis and pooled effect estimation were not undertaken because the included evidence was heterogeneous in study design, setting, population, intervention type, and outcome measures. In addition, although the review emphasized LMIC implementation, much of the evidence on advanced medication safety technologies originated from high-income settings, which may limit direct transferability to resource-constrained healthcare systems. Only English-language publications were included, which may have excluded relevant studies published in other languages. These issues are addressed further in the Strengths and Limitations section.

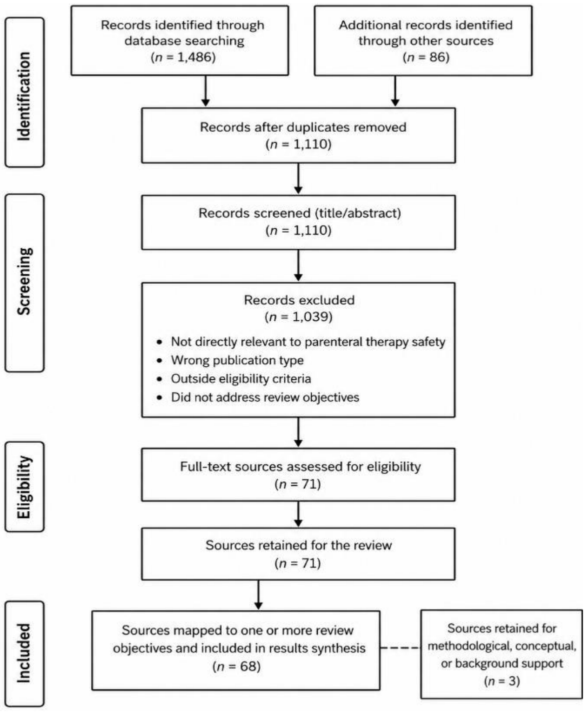

Fig. 1: PRISMA Flowchart for Evidence Selection.

3. Conceptual Framework: Application of The SEIPS Model

This scoping review is guided by the Systems Engineering Initiative for Patient Safety [SEIPS] model, which conceptualizes healthcare delivery as a socio-technical system shaped by interactions among people, tasks, tools and technologies, organizations, and care environments [8]. Although the empirical evidence included in this review was limited to publications from 2010 to 2026, the original SEIPS paper was retained as a foundational conceptual source because of its direct relevance to patient safety and work-system design.

The SEIPS model is appropriate for this review because parenteral therapy–related iatrogenesis rarely results from a single isolated failure. Instead, medication errors, contamination events, infusion complications, needlestick injuries, and delayed recognition of adverse reactions often emerge from interactions among clinical tasks, nursing workload, device availability, technology usability, organizational policies, staffing conditions, and the physical care environment [1], [2], [5–8]. This systems perspective is particularly relevant to LMICs, where limited resources, inconsistent access to safety-engineered devices, weak reporting systems, and variable training opportunities may affect safe implementation of parenteral therapy interventions [11–17].

Within the SEIPS framework, nurses represent a central person component because they are directly involved in medication preparation, verification, administration, documentation, and post-administration monitoring. Their clinical competence, aseptic practice, situational awareness, and ability to recognize patient deterioration are essential safeguards against preventable harm [9], [10]. However, safe nursing practice depends on the wider work system. High workload, interruptions, time pressure, inadequate staffing, and limited access to training or safety devices can increase cognitive burden and make deviations from safe medication practice more likely [5–7], [11–17].

The task component includes the sequence of activities required for safe parenteral therapy, such as dose calculation, reconstitution, dilution, ampoule or vial handling, syringe preparation, labelling, patient identification, injection, infusion pump programming, catheter flushing, documentation, and patient monitoring. These tasks are technically demanding and often performed in time-sensitive environments, including emergency departments, intensive care units, neonatal units, oncology settings, and general wards [2–4]. Errors at the preparation stage may propagate into later phases of care, while failures during infusion programming, flushing, or monitoring may lead to incorrect dose delivery, contamination, catheter complications, or delayed intervention.

The tools and technologies component includes safety devices and digital systems designed to reduce risk across the injection–infusion pathway. These include prefilled and ready-to-administer syringes, filter needles, in-line infusion filters, safety syringes, needleless connectors, smart infusion pumps, dose error reduction systems, barcode medication administration, and electronic medication administration records [18–26], [35–54]. These interventions can reduce specific vulnerabilities by minimizing manual preparation steps, filtering particulate matter, supporting dose checking, improving patient–medication verification, and strengthening documentation. However, technologies do not function as independent safety solutions. Their effectiveness depends on usability, training, workflow integration, maintenance, supply reliability, infrastructure, and user adherence. Poorly implemented technologies may introduce new risks, including alert fatigue, scanning bypasses, programming errors, interoperability failures, and unsafe workarounds [47], [51], [54].

The organizational component refers to institutional policies, leadership, staffing systems, procurement processes, training programs, reporting culture, and quality improvement mechanisms. Organizational support determines whether nurses have reliable access to safety devices, standardized medication preparation areas, updated protocols, competency-based training, and non-punitive incident reporting systems [11–17]. In LMICs, organizational barriers such as limited procurement capacity, inconsistent supply chains, weak policy enforcement, inadequate staffing, and insufficient audit systems may reduce the sustainability of parenteral therapy safety interventions.

The environmental component includes the physical and operational conditions in which parenteral medications are prepared and administered. These conditions include workspace design, crowding, noise, lighting, interruptions, patient acuity, time pressure, and availability of sterile supplies. Medication preparation in crowded or interruption-prone environments can increase the risk of calculation mistakes, labelling errors, contamination, and missed verification steps [5–7]. In resource-constrained facilities, environmental pressures may be intensified by overcrowding, limited preparation space, inconsistent consumables, and high patient-to-nurse ratios [11–17].

In this review, the SEIPS model is used to organize and interpret evidence across three domains: parenteral therapy–related iatrogenic risks, safety devices and medication administration technologies, and nursing strategies and LMIC implementation conditions. This framework supports the central argument that preventing parenteral therapy–related iatrogenesis requires alignment between nursing practice, safety devices, workflow design, organizational systems, and resource-sensitive implementation strategies. In LMIC settings, effectiveness depends not only on device efficacy but also on affordability, availability, training, maintenance, workflow compatibility, and institutional commitment.

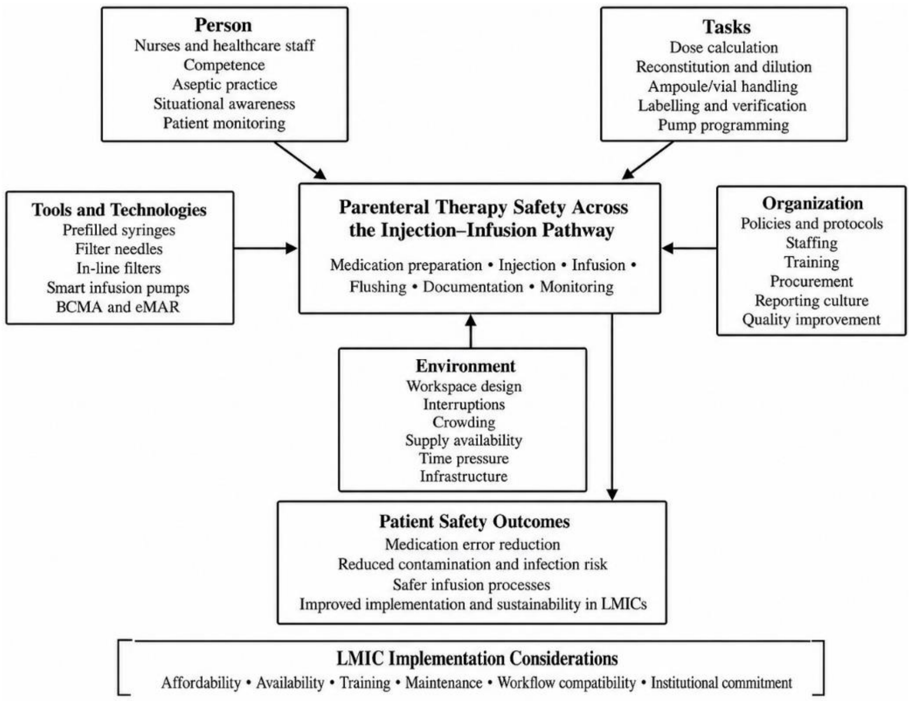

Fig. 2: Conceptual Framework Showing the Application of the SEIPS Model to Parenteral Therapy Safety.

4. Results

4.1. Overview of included evidence

A total of 1,572 records were identified, including 1,486 records through database searching and 86 records from additional sources. After removal of 462 duplicates, 1,110 unique records were screened by title and abstract. Following full-text assessment, 71 sources were retained for the review. Of these, 68 sources were mapped to one or more review objectives and included in the results synthesis, while three sources were retained for methodological, conceptual, or background support [Fig. 1].

The synthesis sources were distributed across three overlapping evidence domains. Twenty-eight sources addressed parenteral therapy–related iatrogenic risks, including medication preparation errors, intravenous medication errors, dilution-related risks, ampoule contamination, unsafe injection practices, catheter-related infection, phlebitis, needlestick injury, workload, and interruptions [1–7], [11], [12], [14–17], [19], [25–33], [55], [56], [61], [64], [71]. Forty-five sources addressed safety devices and medication administration technologies, including prefilled and ready-to-administer syringes, filter needles, in-line filtration systems, safety-engineered syringes, smart infusion pumps, dose error reduction systems, barcode medication administration, electronic medication administration records, and flushing-related safety devices [13], [17–24], [25–32], [34–58], [61], [63], [64], [71]. Thirty-six sources addressed nursing strategies and LMIC implementation conditions, including medication safety education, workflow redesign, interruption reduction, filter-needle adoption, infection prevention, flushing protocols, patient safety governance, procurement constraints, reporting culture, and sustainability [5–7], [9–17], [34], [45–55], [57], [58], [60], [61], [65–70].

The included synthesis evidence was methodologically diverse. Systematic reviews and evidence syntheses contributed direct evidence on medication administration errors, intravenous medication errors, prefilled syringes, unsafe injection practices, in-line filtration, nursing medication-error interventions, BCMA/eMAR usability, and adherence to patient safety principles [1], [2], [9], [17], [18], [38], [54], [56], [69]. Randomized, quasi-experimental, simulation, and intervention studies contributed direct evidence on infusion preparation errors, prefilled syringe use, color-coded syringes, in-line filtration, phlebitis reduction, catheter flushing, and nursing education [3], [22–24], [40], [42], [43], [55], [58]. Observational, cross-sectional, qualitative, and quality improvement studies contributed evidence on medication workload, interruptions, filter-needle use, medication safety barriers, infection prevention implementation, safe injection and infusion practice, smart pump use, barcode medication administration, and LMIC implementation challenges [4–7], [11–16], [31], [32], [46], [51], [52], [64], [67], [68], [70], [71]. Guidelines, position papers, practice alerts, clinical perspectives, and economic evaluations contributed evidence on safety-engineered syringes, parenteral nutrition filters, in-line filters, smart pumps, perioperative medication safety, prefilled syringe economics, and device-related safety concerns [20], [21], [25], [26], [35–37], [45], [57], [62], [63], [66].

The evidence base was unevenly distributed by income setting. Evidence on advanced safety devices and digital medication technologies was concentrated mainly in high-income settings, including studies on prefilled syringes, in-line filters, smart pumps, barcode medication administration, electronic medication administration records, and prefilled safety syringe–related sharps injuries [18–24], [35–54], [62–64], [71]. In contrast, LMIC-specific evidence focused more strongly on medication safety barriers, nursing practice, unsafe injection practices, filter-needle use, infection prevention implementation, flushing education, and health-system constraints [11–17], [31], [55], [58], [60], [61], [67], [70]. This imbalance is important because technologies evaluated in high-income settings may require adaptation before they can be implemented safely and sustainably in resource-constrained health systems.

The evidence also differed in maturity across domains. Evidence on medication administration errors, intravenous medication safety, prefilled syringes, in-line filtration, smart pumps, and barcode-assisted medication administration was comparatively well developed but largely HIC-based [1–4], [18–24], [35–54], [71]. In contrast, LMIC-specific evidence was highly relevant but more limited, with fewer controlled studies evaluating feasibility, cost-effectiveness, scalability, sustainability, and long-term safety outcomes for parenteral therapy safety interventions [11–17], [55], [58], [60], [61], [67], [70].

4.2. Characteristics of included evidence

The characteristics of the included evidence are summarized in Table 1. The evidence base reflected the broad clinical and implementation scope of parenteral therapy safety. Included sources comprised systematic reviews, randomized studies, simulation studies, observational studies, cross-sectional studies, qualitative studies, quality improvement studies, economic evaluations, professional guidelines, position papers, practice alerts, and clinical perspectives. These designs directly mapped medication preparation, injection safety, infusion systems, digital medication administration, infection prevention, nursing workflow, and implementation in resource-constrained health systems [1–7], [9–24], [35–58], [60–71].

The clinical settings represented in the included evidence included intensive care units, neonatal care, emergency care, oncology, clinical wards, operating room and anaesthesia settings, public hospitals, teaching hospitals, vascular access settings, and general medication administration environments [3–7], [11–16], [22–24], [40–46], [50], [55], [56], [63], [64], [67], [70], [71]. These settings are clinically important because parenteral therapy is frequently performed in them, and errors may lead to rapid or severe patient harm. The evidence captured both high-acuity contexts, such as critical care, neonatal care, emergency care, anaesthesia, and oncology, and routine care contexts, such as ward-based medication administration, injection practice, catheter flushing, and infection prevention [3–7], [11–16], [22–24], [40–46], [50], [55], [56], [63], [64], [67].

In terms of income setting, studies from high-income countries contributed much of the evidence on advanced safety technologies, including smart infusion pumps, barcode medication administration, electronic medication administration records, prefilled syringes, in-line filtration systems, and prefilled safety syringe–related sharps injuries [18–24], [35–54], [62–64], [71]. Evidence from LMICs and resource-constrained settings was more concentrated around medication safety barriers, nursing practice, unsafe injection practices, filter-needle use, infection prevention, knowledge gaps, procurement constraints, and implementation barriers [11–17], [31], [55], [58], [60], [61], [67], [70]. This uneven distribution suggests that while device-effectiveness evidence is relatively developed, the implementation evidence needed to guide LMIC adoption remains less mature.

The main intervention areas included prefilled and ready-to-administer syringes, color-coded prefilled syringes, filter needles, in-line filters, smart infusion pumps, dose error reduction systems, barcode medication administration, electronic medication administration records, safety-engineered syringes, aseptic non-touch technique, prefilled saline flush syringes, medication verification, and workflow redesign [13], [18–24], [27–39], [45–58], [61], [63], [64], [71]. Across these intervention areas, reported outcomes included medication administration errors, intravenous medication errors, preparation errors, dose variability, particulate contamination, bloodstream infection, phlebitis, catheter occlusion, needlestick injury, workflow interruption, usability problems, and implementation barriers [1–7], [14], [17], [19], [25–33], [40–44], [46–55], [64], [68], [71].

Overall, the evidence base indicates that parenteral therapy–related iatrogenesis is both a patient safety and occupational safety issue. Patient safety concerns included medication errors, dose variability, contamination, bloodstream infection, phlebitis, catheter occlusion, infusion-related complications, and delayed monitoring [1–7], [14], [19], [27–33], [40–44], [55], [64]. Occupational safety concerns included unsafe injection practice, syringe reuse, needlestick injury, device incompatibility, and device-related sharps exposure [17,25,26,57,61,71]. The evidence also shows that parenteral therapy safety depends on interactions among devices, nursing competence, workflow conditions, institutional policies, procurement systems, infection prevention capacity, and implementation support [8], [10–17], [34], [55–58], [60], [65–70].

Table 1: Characteristics of Included Evidence

Characteristic	Category	Summary
Evidence type	Systematic reviews, randomized studies, simulation studies, observational studies, cross-sectional studies, qualitative studies, quality improvement studies, economic evaluations, guidelines, position papers, practice alerts, and clinical perspectives	The evidence base was methodologically diverse and reflected the broad clinical and implementation scope of parenteral therapy safety.
Clinical settings	Intensive care, neonatal care, emergency care, oncology, clinical wards, operating room/anaesthesia, public hospitals, teaching hospitals, vascular access settings, and medication administration settings	Evidence was concentrated in settings where parenteral medication preparation, administration, infusion, flushing, and monitoring are safety-critical
Income setting	HIC, LMIC, mixed, and global evidence	Advanced device and digital technology evidence was mostly from HICs, while LMIC evidence focused mainly on barriers, nursing practice, injection safety, infection prevention, filter-needle use, and implementation constraints.
Main intervention areas	Prefilled and ready-to-administer syringes, color-coded prefilled syringes, filter needles, in-line filters, smart infusion pumps, dose error reduction systems, BCMA, eMAR, safety-engineered syringes, ANTT, flushing protocols, medication verification, and workflow redesign.	The included evidence mapped both device-based and nursing-led strategies across the injection–infusion pathway.
Main outcome areas	Medication administration errors, IV medication errors, preparation errors, dose variability, particulate contamination, bloodstream infection, phlebitis, catheter occlusion, needlestick injury, workflow interruption, usability problems, and implementation barriers	Outcomes reflected both patient safety and occupational safety dimensions of parenteral therapy–related iatrogenesis.
LMIC relevance	Direct, indirect, or limited	LMIC-specific evidence was strongest for implementation barriers, nursing practice, unsafe injection practices, filter-needle use, flushing education, and infection prevention; evidence was weaker for controlled evaluation of advanced safety devices and digital medication systems.

4.3. Evidence mapping by review objective

The included evidence was mapped against the three review objectives to clarify how each source contributed to the synthesis. Objective 1 focused on parenteral therapy–related iatrogenic risks, including preparation errors, intravenous medication errors, contamination, infection, unsafe injection practices, needlestick injury, workload, and interruptions. Evidence directly addressing this domain showed that medication administration and intravenous medication errors are shaped by system causes, manual preparation complexity, workload, interruptions, and high-acuity clinical conditions [1–7]. Additional risk-specific evidence identified dilution-related harm, ampoule-related particulate contamination, contaminated flush syringes, unsafe injection practices, device incompatibility, needlestick injury, and catheter-related infection risks as important iatrogenic concerns within the injection–infusion pathway [17], [19], [25–32], [55], [56], [64], [71].
Objective 2 focused on safety devices and medication administration technologies. Direct evidence in this domain showed that prefilled and ready-to-administer syringes reduce preparation complexity and manual manipulation; filter needles and ampoule-safety practices address glass particulate contamination; in-line filters reduce particulate infusion and selected infusion-related complications; smart pumps and dose error reduction systems reduce infusion programming risks; and BCMA/eMAR systems support verification and documentation [18–24], [27–39], [45–54], [57].
Objective 3 focused on nursing strategies, workflow factors, and LMIC implementation conditions. Direct implementation evidence showed that safe implementation depends on nursing competence, standardized protocols, infection prevention practices, reliable device supply, leadership support, training, audit systems, reporting culture, workflow compatibility, and sustainability planning [11–16], [34], [55], [57], [58], [60], [65–70]. Across the three domains, evidence maturity varied: device-effectiveness evidence was stronger but largely HIC-based, whereas LMIC-specific evidence was more focused on barriers, implementation conditions, and practice constraints.

Table 2: Evidence Mapping by Review Objective

Review Objective	Evidence Focus	Representative sources	Main Findings	Key Evidence Gaps
Objective 1: Map parenteral therapy–related iatrogenic risks	Medication preparation errors, IV medication errors, dilution errors, ampoule contamination, unsafe injection practices, needlestick injury, catheter-related infection, phlebitis, workload, and interruptions	Keers et al. [1]; Kuitunen et al. [2]; Adapa et al. [3]; Hermanspann et al. [4]; Magalhães et al. [5]; Bower et al. [6]; Flynn et al. [7]; Ali Khan et al. [17]; Degnan et al. [19]; Aschenbrenner [25,26]; Unahalekhaka and Nuthong [27]; Chiannilkulchai and Kejkornkaew [28]; Lee et al. [29]; Yorioka et al. [30]; Söğüt and Erkoç [31]; van den Berg et al. [32]; Gerçeker et al. [55]; Costa et al. [56]; Brooks et al. [64]; Grimmond et al. [71]	Parenteral therapy risks occur across preparation, injection, infusion, flushing, documentation, and monitoring. These risks are shaped by manual preparation, system factors, workload, interruptions, dilution practices, ampoule contamination, unsafe injection practices, catheter-related infection, device incompatibility, sharps injury, and contaminated flushing products.	Limited LMIC-specific outcome studies quantify parenteral therapy–related harm, especially preparation errors, particulate contamination, infusion-related complications, catheter-related infection, and device-related occupational injury.
Objective 2: Identify and categorize safety devices and medication administration technologies	Prefilled and ready-to-administer syringes, filter needles, in-line filters, safety-engineered syringes, smart infusion pumps, dose error reduction systems, BCMA, eMAR, and barcode-supported unit-dose systems	Benhamou et al. [18]; Degnan et al. [19]; Larmené-Beld et al. [20]; Borms et al. [21]; Mehta et al. [22]; Moreira et al. [23]; Stevens et al. [24]; Aschenbrenner [25,26]; Unahalekhaka and Nuthong [27]; Chiannilkulchai and Kejkornkaew [28]; Lee et al. [29]; Söğüt and Erkoç [31]; van den Berg et al. [32]; Cassista et al. [34]; Worthington et al. [35]; Gill et al. [36]; Foster et al. [38]; Perez et al. [39]; Giuliano [45]; Schnock et al. [46]; Borrelli et al. [47]; Westbrook et al. [48]; Seibert et al. [49]; Macias et al. [50]; Mulac et al. [51]; Jessurun et al. [52]; Owens et al. [53]; Pruitt et al. [54]; WHO [57]; Grimmond et al. [71]	Safety devices reduce specific risks at different pathway stages: prefilled syringes reduce preparation complexity, filter needles reduce particulate exposure, in-line filters reduce infusion-related particulate risk, safety-engineered syringes reduce unsafe injection and sharps injury risks, smart pumps reduce programming errors, and BCMA/eMAR improve verification and documentation.	Most device-effectiveness and digital technology evidence comes from HICs. Evidence on affordability, procurement, maintenance, interoperability, usability, scalability, and sustainability in LMICs remains limited.
Objective 3: Synthesize nursing strategies and LMIC implementation conditions	ANTT, medication verification, flushing protocols, competency training, workflow redesign, interruption reduction, audit and feedback, reporting culture, procurement systems, infection prevention, and safety culture	Adhikari et al. [10]; Lawal et al. [11]; Jafaru and Abubakar [12]; Olayiwola et al. [13]; Kottapalli et al. [14]; Kalule et al. [15]; Rezaee et al. [16]; Cassista et al. [34]; Gerçeker et al. [55]; WHO [57]; Gu et al. [58]; Tamuno-opubo et al. [60]; Ayyad et al. [65]; Speth [66]; Oliveira et al. [67]; Sessions et al. [68]; Vaismoradi et al. [69]; Kgadima et al. [70]	Safe implementation depends on nursing competence, standardized protocols, reliable device supply, leadership support, training, audit systems, reporting culture, workflow compatibility, infection prevention systems, and sustainability planning. LMIC barriers include cost, device shortages, weak reporting systems, inadequate staffing, infrastructure limitations, and inconsistent policy enforcement.	Few controlled LMIC implementation studies evaluate the real-world effectiveness, cost-effectiveness, scalability, and sustainability of safety devices or digital medication technologies.

4.4. Safety devices and technologies across the injection–infusion pathway

Safety devices and medication administration technologies were mapped according to their position and function across the injection–infusion pathway. Direct evidence showed that no single device addresses all risks associated with parenteral therapy. Instead, each device targets a specific vulnerability: prefilled and ready-to-administer syringes reduce preparation complexity and unnecessary manipulation; filter needles and ampoule-safety practices address glass particulate contamination; in-line filters provide downstream infusion protection; smart infusion pumps reduce infusion programming errors; and BCMA/eMAR systems strengthen patient–medication verification and documentation [18–24], [27–39], [45–54], [57].
At the medication preparation stage, prefilled and ready-to-administer syringes were associated with reduced manual manipulation, fewer dilution steps, lower preparation variability, improved workflow efficiency, and potential reduction in medication handling risks [18–22]. In emergency and prehospital contexts, color-coded prefilled syringes supported faster medication delivery and reduced dosing errors in simulated pediatric resuscitation studies [23], [24]. During injection preparation, filter needles and ampoule safety practices were used to

reduce particulate contamination from glass ampoules, although uptake was influenced by staff knowledge, device availability, behavioural factors, and institutional protocols [13], [27–34].

At the infusion stage, in-line filtration systems were used to reduce particulate infusion and selected infusion-related complications, including phlebitis, organ dysfunction, hypersensitivity reactions, and severe complications in neonatal, pediatric, critical care, parenteral nutrition, and complex infusion contexts [35–44]. Digital technologies also played an important role. Smart infusion pumps and dose error reduction systems were used to reduce programming errors through drug libraries, dose limits, alerts, and interoperability, but their effectiveness depended on training, drug library maintenance, interoperability, alert management, and infrastructure readiness [45–47]. BCMA and eMAR systems improved verification, traceability, documentation, and medication administration accuracy, although workarounds, usability problems, scanning bypasses, and workflow burden remained important implementation concerns [48–54].

Overall, device evidence supports a pathway-based safety approach in which different technologies act at different stages of parenteral therapy. However, implementation barriers such as cost, procurement, staff training, maintenance, compatibility, infrastructure, alert fatigue, usability, and workflow integration were repeatedly identified as constraints, especially when these technologies are considered for resource-constrained settings [11–13], [15], [16], [34], [47], [51], [54], [57], [60], [65], [70].

Table 3: Safety Devices and Technologies Across the Injection–Infusion Pathway

Pathway Stage	Device/Technology	Main Safety Function	Representative sources	Key Implementation Concern
Medication preparation	Prefilled and ready-to-administer syringes.	Reduce manual preparation, dilution steps, dose variability, contamination risk, and preparation time.	Benhamou et al. [18]; Degnan et al. [19]; Larmené-Beld et al. [20]; Borms et al. [21]; Mehta et al. [22]	Cost, procurement, product availability, compatibility, and risk of unnecessary manipulation
Emergency preparation and injection	Color-coded prefilled medication syringes	Improve rapid drug identification, reduce dosing error, and shorten time to medication delivery.	Moreira et al. [23]; Stevens et al. [24]	Evidence mainly from simulation studies; limited LMIC evidence
Injection preparation	Filter needles and ampoule safety practices	Reduce glass particle contamination during aspiration from ampoules	Olayiwola et al. [13]; Unahalekhaka and Nuthong [27]; Chiannilkulchai and Kejkornkaew [28]; Lee et al. [29]; Yorioka et al. [30]; Söğüt and Erkoç [31]; van den Berg et al. [32]; Cassista et al. [34]	Knowledge gaps, inconsistent use, lack of protocols, device shortage, and perceived workflow burden
Injection safety	Safety-engineered and auto-disable syringes	Reduce syringe reuse, unsafe injection practices, and occupational exposure.	Ali Khan et al. [17]; Aschenbrenner [25,26]; WHO [57]; Srivastav [61]; Grimmond et al. [71]	Procurement cost, training, safe disposal, regulation, device design limitations, and persistent unsafe practices despite device availability
Infusion	In-line filtration systems	Reduce particulate infusion and selected infusion-related complications, including phlebitis and organ dysfunction.	Worthington et al. [35]; Gill et al. [36]; Ayres and Mahler [37]; Foster et al. [38]; Perez et al. [39]; Jack et al. [40]; Schmitt et al. [41]; Villa et al. [42]; Boehne et al. [43]; Ronsley et al. [44]	Filter selection, staff training, cost, availability, maintenance, and context-specific benefit
Infusion programming	Smart infusion pumps and dose error reduction systems	Reduce infusion programming errors through drug libraries, dose limits, alerts, and interoperability	Giuliano [45]; Schnock et al. [46]; Borrelli et al. [47]	Alert fatigue, overrides, drug library maintenance, interoperability, training, and infrastructure
Verification and documentation	BCMA and eMAR	Improve patient–drug verification, documentation accuracy, traceability, and medication administration safety	Westbrook et al. [48]; Seibert et al. [49]; Macias et al. [50]; Mulac et al. [51]; Jessurun et al. [52]; Owens et al. [53]; Pruitt et al. [54]	Scanning workarounds, usability problems, workflow burden, system downtime, and infrastructure requirements
Flushing and catheter care	Prefilled saline flush syringes and ANTT	Standardize flushing, reduce manual preparation, support aseptic technique, and reduce catheter-related complications.	Gerçeker et al. [55]; Imam et al. [63]; Brooks et al. [64]	Training, supply continuity, catheter-care compliance, and limited LMIC outcome evidence

4.5. LMIC implementation barriers and enablers for parenteral therapy safety

Implementation evidence showed that the safe use of parenteral therapy devices and nursing strategies in LMICs depends on more than clinical effectiveness. Direct LMIC evidence identified recurring barriers such as device shortages, limited resources, weak reporting systems, inadequate training, staffing pressure, infrastructure limitations, weak policy implementation, and poor institutional support [11–16], [60], [70]. Evidence specifically on filter-needle use in Nigeria further showed that knowledge gaps, limited training, and device availability can restrict the adoption of preparation-stage safety devices [13].

Implementation enablers included leadership support, standardized protocols, training, audit and feedback, non-punitive reporting, quality improvement systems, procurement planning, and context-sensitive intervention design [11–16], [55], [57], [58], [60], [69], [70]. Evidence from nursing education and practice-focused sources also supported competency development, interdisciplinary medication safety education, and guideline-based practice as important conditions for safer implementation [10], [34], [65–68]. The findings suggest that LMIC implementation should prioritize interventions that are affordable, supply-resilient, compatible with nursing workflow, supported by institutional governance, and sustainable beyond initial adoption.

Table 4: LMIC Implementation Barriers and Enablers for Parenteral Therapy Safety

Implementation Area	Barriers Identified	Enablers Identified	Representative sources	Implication for LMIC Practice
Device availability and procurement	High cost, inconsistent supply chains, limited procurement systems, lack of safety-engineered devices, shortage of filter needles, and prefilled syringes	Procurement planning, phased implementation, prioritization of high-risk units, policy support, and local adaptation of device standards	WHO [57]; Ali Khan et al. [17]; Olayiwola et al. [13]; Lawal et al. [11]; Jafaru and Abubakar [12]	Safety devices should be introduced using context-sensitive and sustainable procurement strategies, prioritizing high-risk clinical areas first.
Training and competency	Knowledge gaps, limited continuing education, poor familiarity with safety devices, inconsistent adherence to protocols, and weak procedural competence	Competency-based training, mobile learning, refresher courses, supervision, interdisciplinary medication safety education	Adhikari et al. [10]; Olayiwola et al. [13]; Cassista et al. [34]; Gu et al. [58]; Speth [66]; Kgadima et al. [70]	Device introduction should be paired with structured education, competency assessment, and continuing professional development.
Workflow and workload	High patient-to-nurse ratios, interruptions, multitasking, time pressure, fragmented preparation processes, and competing clinical demands	Protected medication preparation time, interruption reduction, workflow redesign, standard operating procedures, and staffing optimization	Magalhães et al. [5]; Bower et al. [6]; Flynn et al. [7]; Mohanna et al. [9]; Oliveira et al. [67]; Sessions et al. [68]	Medication safety interventions should simplify nursing tasks and reduce workflow disruption rather than adding extra procedural burden.
Infrastructure and technology readiness	Weak digital infrastructure, poor interoperability, limited maintenance capacity, system downtime, and usability problems	Technical support, system integration, updated drug libraries, usability testing, staff training, monitoring of overrides and workarounds	Giuliano [45]; Schnock et al. [46]; Borrelli et al. [47]; Westbrook et al. [48]; Mulac et al. [51]; Pruitt et al. [54]	Advanced technologies such as smart pumps, BCMA, and eMAR require infrastructure readiness and workflow compatibility before scale-up.
Policy and institutional support	Weak policy enforcement, limited reporting systems, non-standardized practice, inadequate audit, poor safety culture, inconsistent leadership commitment	Leadership support, non-punitive reporting, audit and feedback, quality improvement systems, standardized protocols, patient safety governance	Lawal et al. [11]; Jafaru and Abubakar [12]; Kottapalli et al. [14]; WHO [57]; Tamuno-opubo et al. [60]; Vaismoradi et al. [69]	Institutional commitment is essential for sustaining safety gains and embedding parenteral therapy safety into routine clinical governance.
Infection prevention and aseptic practice	Poor supplies, overcrowding, inconsistent ANTT, limited catheter-care resources, weak IPC implementation, unsafe vial or flushing practices	IPC bundles, aseptic non-touch technique, standardized flushing protocols, sterile supplies, audit, catheter-care monitoring	Kottapalli et al. [14]; Kalule et al. [15]; Rezaee et al. [16]; Gerçeker et al. [55]; Imam et al. [63]; Brooks et al. [64]	Infection prevention should be embedded into routine injection, infusion, flushing, and vascular access workflows.
Sustainability and scale-up	Recurring cost, consumable shortages, staff turnover, limited maintenance, inconsistent training continuity, dependence on external procurement	Phased implementation, local ownership, recurring budget lines, refresher training, procurement monitoring, implementation evaluation	Lawal et al. [11]; Jafaru and Abubakar [12]; Olayiwola et al. [13]; Rezaee et al. [16]; WHO [57]; Kgadima et al. [70]	Safety interventions should be designed for long-term use, not one-time adoption, with attention to affordability, supply continuity, and institutional ownership.

5. Discussion

5.1. Principal findings and interpretation

This scoping review mapped evidence on nursing strategies and safety devices for preventing parenteral therapy–related iatrogenesis, with particular attention to LMICs. The findings show that parenteral therapy safety is not a single-device or single-behaviour problem, but a pathway-based and systems-dependent challenge involving medication preparation, injection, infusion, flushing, documentation, and monitoring. Risks were distributed across multiple points of the injection–infusion pathway, indicating that interventions focused on only one stage, such as syringe preparation or infusion programming, may reduce one category of harm while leaving other safety vulnerabilities unresolved.

Three principal findings emerged. First, parenteral therapy–related iatrogenesis is shaped by interactions among technical complexity, manual preparation, nursing workload, interruptions, contamination, unsafe injection practice, catheter-related infection, device design, and organizational weaknesses [1–7], [17], [19], [25–32], [55], [56], [64], [71]. Second, safety devices and medication administration technologies provide stage-specific rather than universal protection: prefilled syringes, filter needles, in-line filters, safety-engineered syringes, smart infusion pumps, barcode medication administration, and electronic medication administration records each address different failure points in the pathway [18–24], [27–39], [45–54], [57]. Third, implementation in LMICs is shaped not only by clinical effectiveness but also by procurement capacity, workforce training, infrastructure readiness, policy enforcement, reporting culture, and sustainability planning [11–16], [55], [57], [58], [60], [65–70].

These findings support the SEIPS-based interpretation that parenteral therapy safety depends on interactions among people, tasks, tools and technologies, organizations, and care environments [8]. A nurse may perform a high-risk parenteral task competently, yet safety can still be compromised if the work system lacks appropriate devices, sterile supplies, standardized protocols, protected preparation time, functioning infusion equipment, or reliable reporting mechanisms. Conversely, procurement of safety devices alone may not produce sustained safety gains if nurses are not trained, devices are incompatible with existing workflows, or supply continuity is poor. The central implication is therefore that parenteral therapy safety requires a layered safety system rather than isolated interventions.

5.2. Why is parenteral therapy a high-risk nursing process

Parenteral therapy is intrinsically high risk because medications delivered by injection or infusion bypass several physiological barriers and may produce rapid systemic effects. Evidence on medication administration errors and intravenous medication errors shows that risk is rarely explained by individual negligence alone; rather, errors are associated with system causes, task complexity, communication failures, workload, interruptions, and weaknesses in local medication systems [1], [2]. This distinction is important because nurses often represent the final point of defence before parenteral medicines reach the patient, yet their performance is shaped by the systems in which they work.

The preparation stage is particularly vulnerable. Drug infusion preparation requires calculation, reconstitution, dilution, syringe preparation, labelling, and verification, often under time pressure. Evidence on infusion preparation errors shows that mistakes can occur during manual preparation, especially when clinicians must manipulate drug concentrations and prepare infusions without strong standardization [3]. ICU-focused evidence also indicates that preparation and administration processes require quality improvement because intensive care environments combine high medication complexity with high patient acuity [4]. These findings are especially relevant to LMIC settings, where bedside or ward-based preparation may be common and access to pharmacy-prepared or ready-to-administer formulations may be limited.

Nursing workload and interruptions further compound this risk. Evidence from clinical wards and critical care studies shows that workload, interruptions, and fragmented workflows are associated with medication administration vulnerability [5–7]. Mechanistically, these factors increase cognitive load, divide attention, disrupt task sequencing, and may lead to missed checks or documentation gaps. Because parenteral therapy involves sequential and interdependent steps, a failure at one stage can propagate into later harm: a calculation error may become a wrong-dose infusion, a missed verification step may become wrong-patient administration, and poor documentation may delay recognition of an adverse event. Nursing workflow should therefore be treated as a safety intervention, not merely as a background condition.

5.3. Preparation-stage safety: dilution, ampoule handling, and particulate contamination

One of the clearest insights from this review is that preparation-stage risks require greater attention in LMIC parenteral therapy safety. Much medication safety literature focuses on administration errors, but the evidence mapped in this review shows that harm may begin before administration, during preparation, manipulation, and device handling.

Unnecessary dilution of ready-to-administer prefilled syringes illustrates this problem. Ready-to-administer products are intended to reduce manual manipulation, simplify preparation, and reduce variability. When these products are unnecessarily diluted, their safety advantage may be lost because additional manipulation reintroduces opportunities for contamination, dose variability, and medication handling error [19]. This has direct implications for nursing education and protocol development: procurement of ready-to-administer products must be accompanied by clear guidance on when dilution is clinically indicated and when it is unnecessary or unsafe.

Glass ampoule-related particulate contamination is another important preparation-stage hazard. Evidence from ampoule contamination studies shows that opening glass ampoules can introduce particulate matter into injectable solutions, with contamination influenced by ampoule material, opening method, needle type, and preparation technique [27–32]. The clinical concern is not merely procedural. Particulate contamination may contribute to vascular irritation, inflammatory responses, phlebitis, embolic phenomena, or catheter-related complications, particularly when repeated injections or infusions occur in vulnerable patients. Ampoule handling should therefore be treated as a patient safety process rather than a minor technical step.

Filter needles and ampoule safety practices offer a practical control measure, but implementation is not automatic. Nigerian evidence on filter-needle knowledge and barriers shows that limited awareness, training gaps, and device availability can restrict use [13]. Behavioural evidence also suggests that nurses' intention to use filter needles is influenced by knowledge, perceived usefulness, norms, and institutional support [34]. Filter-needle adoption should therefore be treated as an implementation intervention, not merely a procurement decision. Facilities need protocols specifying when filter needles are required, staff training on ampoule-related particulate risks, supply-chain planning, and audit of use in high-risk injectable medications.

For LMICs, this is particularly important because filter needles may be more feasible than expensive digital medication systems. However, low cost does not guarantee implementation. Even simple safety devices can fail if the supply is inconsistent, protocols are absent, or staff do not perceive the risk as clinically significant.

5.4. Injection safety: patient harm and occupational harm

This review frames parenteral therapy–related iatrogenesis as both a patient safety and occupational safety problem. Unsafe injection practices, syringe reuse, needlestick injury, and device-related sharps exposure threaten patients and healthcare workers [17], [25], [26], [57], [61], [71]. This dual burden is especially relevant in LMICs, where unsafe injection practices may be sustained by resource shortages, inadequate disposal systems, weak supervision, and inconsistent enforcement of injection safety standards.

Evidence on auto-disable and safety-engineered syringes supports their role in reducing syringe reuse and occupational exposure, but also shows that unsafe practices may persist where implementation systems are weak [17], [57], [61]. Safety-engineered syringes reduce risk through design, but they do not independently solve problems such as inadequate training, poor sharps disposal, unreliable supply, or unsafe reuse culture. They should therefore be embedded within broader injection safety systems that include procurement, training, waste management, supervision, and incident reporting.

Device design can also introduce or fail to prevent occupational risk. Practice alerts on prefilled syringes without needle safety guards and incompatibility between some prefilled glass syringes and needleless connectors show how device procurement and compatibility can become safety issues [25], [26]. Retrospective evidence on sharps injuries with prefilled safety syringes further suggests that occupational injuries may persist despite the presence of safety features [71]. LMIC procurement should therefore consider not only price and availability but also safety features, connector compatibility, packaging, sharps protection, user training requirements, and disposal systems.

5.5. Infusion safety and the targeted role of in-line filtration

In-line filtration emerged as an important infusion-stage safeguard, but its role should be targeted and context-sensitive. The included studies and position papers indicate that in-line filters can reduce particulate infusion and selected complications in specific settings, including parenteral nutrition, neonatal care, pediatric intensive care, adult critical care, postoperative peripheral venous cannulation, and pediatric oncology [35–44]. Reported benefits include reduced particulate contamination, fewer severe complications in pediatric intensive care, reduced postoperative phlebitis, and potential reduction in organ dysfunction or hypersensitivity-related outcomes in selected populations [39–44].

The scientific rationale is that in-line filters act as a downstream barrier. If particulate matter enters the infusion pathway through drug preparation, incompatibility, container particles, or multidrug infusion processes, filtration can reduce the amount reaching the patient. This makes in-line filtration particularly relevant where patients are vulnerable, infusion regimens are complex, or parenteral nutrition and lipid emulsions are used. However, the evidence does not support indiscriminate implementation in every setting. Filter type, pore size, drug compatibility, infusion fluid, lipid use, flow rate, staff training, and maintenance requirements all influence effectiveness and feasibility [35–37].

For LMICs, in-line filtration should therefore be prioritized strategically. Immediate universal adoption may not be feasible because of cost and supply requirements. A more realistic approach is risk-based prioritization in neonatal intensive care, pediatric intensive care, oncology, parenteral nutrition, and complex multidrug infusion settings. This would allow facilities to target patients most likely to benefit while building staff competence and supply reliability over time.

5.6. Digital medication technologies: safety gains and new failure modes

Smart infusion pumps, dose error reduction systems, barcode medication administration, and electronic medication administration records represent higher-technology approaches to parenteral medication safety. These systems can reduce specific errors, but they also introduce implementation-dependent risks.

Smart infusion pumps reduce infusion programming risk through drug libraries, dose limits, alerts, and interoperability functions [45–47]. Their value is strongest when drug libraries are accurate, regularly updated, and aligned with local prescribing practices. However, smart pump safety can be weakened by alert fatigue, inappropriate overrides, incomplete drug libraries, poor interoperability, and inadequate training [45–47]. In LMIC settings, these challenges may be amplified by infrastructure limitations, limited biomedical engineering support, and weak integration with prescribing or pharmacy systems.

BCMA and eMAR systems support patient–medication verification, documentation accuracy, and traceability [48–54]. However, evidence on barcode medication administration shows that scanning workarounds, policy deviations, and usability problems can undermine intended safety benefits [51], [54]. This is critical for implementation because digital systems do not simply remove human error; they redistribute work and create new interaction points among nurses, devices, software, medication packaging, and documentation systems. If the system is poorly designed, nurses may bypass scanning, delay documentation, or develop workarounds to cope with workflow pressure.

Digital medication systems should therefore be evaluated not only by whether they reduce medication errors, but also by whether they fit clinical workflow. In LMICs, technology readiness should be assessed before implementation, including power reliability, internet connectivity, barcode availability on medicines, technical support, maintenance capacity, user training, interoperability, and governance for monitoring overrides and workarounds. Without these conditions, advanced technologies may generate new risks while consuming resources that could otherwise support more basic safety interventions.

5.7. Nursing strategies as the foundation of parenteral therapy safety

A central finding of this review is that nursing strategies remain foundational even when safety devices are available. Devices can reduce specific risks, but nurses remain responsible for preparation, verification, administration, flushing, documentation, monitoring, and recognition of adverse events. Nursing competence is therefore not replaced by technology; it becomes more important as devices and workflows become more complex.

Aseptic non-touch technique and standardized flushing practices are particularly important because flushing links medication administration, vascular access maintenance, and infection prevention. Evidence on prefilled flush syringes and aseptic non-touch technique showed relevance to catheter occlusion and bloodstream infection outcomes [55]. Evidence on contaminated saline flush syringes also demonstrates that flushing products themselves can become sources of bloodstream infection when contamination occurs [64]. Flushing should therefore not be treated as a routine minor task. It is a safety-critical procedure requiring aseptic practice, product integrity, correct technique, and monitoring.

Education and competency development were also central implementation themes. Evidence supports the importance of medication safety education, device-specific training, patient safety knowledge, and knowledge translation into practice [10,58,65,66,70]. However, education alone is insufficient if the work environment prevents safe practice. A nurse may be trained to use filter needles, but use will remain inconsistent if devices are unavailable. Similarly, a nurse may understand the importance of barcode scanning, but workarounds may occur if scanning disrupts emergency workflow or devices fail. Competency must therefore be paired with reliable supplies, workflow design, supervision, and institutional accountability.

5.8. LMIC implementation: from evidence transfer to contextual adaptation

The LMIC focus of this review is not simply about applying evidence from high-income countries to resource-limited settings. The findings show that implementation requires contextual adaptation. Many safety devices and digital technologies were evaluated mainly in high-income settings, while LMIC-specific studies focused more on barriers, practice constraints, infection prevention, filter-needle use, patient safety systems, and resource limitations [11–17], [31], [55], [58], [60], [61], [67], [70]. This mismatch creates a translational gap.

Direct LMIC evidence identified recurrent barriers such as limited resources, weak reporting systems, inadequate training, device shortages, staffing pressure, infrastructure constraints, and weak policy implementation [11–16], [60], [70]. Nigerian studies highlighted medication safety barriers, perceived barriers among nurses, and limited filter-needle knowledge or availability [11–13]. Evidence from India, Uganda, Iran, and South Africa further emphasized unsafe injection and infusion practices, infection prevention challenges, resource constraints, and barriers to knowledge translation [14–16], [70]. These findings suggest that LMIC implementation cannot be reduced to purchasing devices; it requires strengthening the system around the device.

A staged approach may be most realistic. The first stage should prioritize high-feasibility interventions such as standard operating procedures, medication safety education, protected preparation time, safe injection policies, filter-needle protocols, aseptic non-touch technique, standardized flushing, and non-punitive incident reporting. The second stage could prioritize targeted device adoption in high-risk units, such as filter needles for glass ampoule medications, prefilled flush syringes for central venous catheter care, and safety-engineered syringes where unsafe injection risk is high. The third stage could involve advanced technologies such as smart pumps, BCMA, and eMAR, but only where infrastructure, maintenance, interoperability, and training systems are adequate.

This staged model avoids two extremes: doing nothing because advanced technologies are expensive, and adopting technology without the system capacity to sustain it. It also aligns with the SEIPS framework by recognizing that safety emerges from the alignment of people, tasks, tools, organizations, and environments.

6. Implications

6.1. Implications for nursing practice

The findings indicate that nurses should approach parenteral therapy as a high-risk, multi-stage safety process rather than a routine technical task. Nursing practice should therefore control risk across medication preparation, dilution, ampoule handling, labelling, patient identification, injection, infusion programming, catheter flushing, documentation, and post-administration monitoring. Evidence from medication administration and intravenous medication error studies shows that errors are often shaped by system factors, preparation complexity, workload, interruptions, and high-acuity clinical conditions [1–7]. Safe nursing practice, therefore, requires standardized procedures, protected medication preparation processes, and work environments that reduce avoidable disruption, rather than reliance on individual vigilance alone.

Medication preparation should be protected from avoidable interruptions and excessive workload. Studies on nursing workload and medication administration interruptions show that disrupted workflows can compromise medication safety, particularly in clinical wards and critical care settings [5–7]. Nursing units should therefore consider protected preparation areas, interruption-reduction strategies, standardized preparation checklists, and escalation procedures for high-risk medications. These measures are especially relevant for parenteral therapy because errors during preparation or verification may progress into wrong-dose administration, wrong-rate infusion, contamination, or delayed recognition of adverse reactions.

Nurses also require device-specific competence. Prefilled syringes, filter needles, in-line filters, smart pumps, BCMA, eMAR systems, safety-engineered syringes, and prefilled flush syringes have different safety functions and different failure modes [18–24], [27–39], [45–58]. Training should therefore move beyond general medication safety to include device indications, compatibility, correct use, common user errors, troubleshooting, and reporting of device-related incidents. For example, filter-needle use requires knowledge of glass ampoule contamination and correct aspiration technique [13], [27–34], while smart pump and BCMA/eMAR use requires competence in alert handling, scanning compliance, documentation, and avoidance of unsafe workarounds [45–54].

Nurses should also be involved in device procurement and implementation decisions. As primary users of many parenteral therapy devices, nurses are well-positioned to assess usability, workflow fit, compatibility, training requirements, and local barriers to adoption. Evidence on filter-needle uptake, barcode medication administration, eMAR usability, smart pump implementation, and knowledge translation shows that safety interventions may fail or be weakened when they are poorly aligned with clinical workflow or insufficiently supported by training and institutional systems [13], [34], [45–54], [70].

6.2. Implications for policy and health-system planning

At the policy level, parenteral therapy safety should be integrated into medication safety, infection prevention, occupational safety, and patient safety governance. The findings show that injection safety, infusion safety, medication administration, catheter flushing, documentation, and incident reporting are interconnected rather than separate safety concerns. Policies should therefore address the full injection–infusion pathway, including safe preparation, dilution control, ampoule handling, filter-needle use, aseptic technique, infusion programming, flushing practice, sharps safety, documentation, and learning from incidents.

For LMICs, procurement policies should prioritize risk reduction, feasibility, affordability, and sustainability. Lower-cost and potentially scalable interventions, such as filter needles, safety-engineered syringes, standardized flushing protocols, aseptic non-touch technique, and safe injection practices, may offer practical early gains when supported by training and reliable supply systems [13], [17], [55], [57], [61]. More advanced technologies, such as smart pumps, BCMA, and eMAR, should be introduced only after infrastructure readiness, interoperability, maintenance capacity, staff training, and workflow compatibility have been assessed [45–54]. This staged approach is important because much of the evidence for advanced digital medication technologies comes from high-income settings, whereas LMIC-specific evidence is concentrated around resource constraints, training gaps, weak reporting systems, infection prevention barriers, and implementation challenges [11–16], [60], [70].

Health systems should also strengthen reporting and learning systems. LMIC evidence identified weak reporting culture, limited institutional support, resource constraints, and poor policy implementation as barriers to medication safety and patient safety improvement [11], [12], [60]. Non-punitive reporting systems can help identify recurrent failures such as preparation errors, contamination events, device shortages, needlestick injuries, infusion programming problems, barcode workarounds, and catheter-related complications. Without reliable reporting and feedback, facilities may underestimate the frequency, causes, and preventability of parenteral therapy–related iatrogenesis.

6.3. Implications for research

The review identifies a need for LMIC-based intervention studies evaluating the effectiveness, acceptability, cost, and sustainability of parenteral therapy safety interventions. Although evidence supports the use of prefilled syringes, filter needles, safety-engineered syringes, prefilled flush syringes, in-line filters, smart pumps, BCMA, and eMAR systems, much of the device-effectiveness evidence comes from high-income settings [18–24], [35–54]. Future LMIC studies should therefore examine whether these interventions are feasible, affordable, usable, acceptable to nurses, and sustainable within resource-constrained clinical environments.

Preparation-stage risks require stronger empirical investigation in LMICs. Future studies should measure dilution errors, dose calculation errors, labelling errors, ampoule-handling practices, particulate contamination, and contamination during bedside preparation. These risks were identified in evidence on infusion preparation, unnecessary dilution, and glass ampoule contamination, but remain under-measured in many resource-constrained settings [3], [19], [27–32].

Implementation research is also needed for digital medication technologies in LMICs. Rather than focusing only on whether smart pumps, BCMA, or eMAR systems reduce medication errors, future studies should examine infrastructure readiness, usability, workflow fit, staff acceptance, maintenance capacity, alert fatigue, scanning compliance, workarounds, cost, and long-term sustainability [45–54]. This is important because poorly implemented technologies may introduce new risks even when they are designed to prevent errors.

Finally, future research should use systems-based frameworks such as SEIPS to examine how nurses, tasks, devices, organizations, and clinical environments interact to influence parenteral therapy safety [8]. This would move the evidence beyond isolated device evaluation and help explain why interventions succeed, fail, or require adaptation in different LMIC contexts.

7. Strengths and Limitations of The Review

A key strength of this review is its pathway-based scope. Rather than focusing only on medication administration errors or a single safety device, the review mapped risks and interventions across medication preparation, injection, infusion, flushing, verification, documentation, and monitoring. This approach made it possible to show where different safety devices act within the injection–infusion pathway and why layered protection is required to prevent parenteral therapy–related iatrogenesis.

Another strength is the use of the SEIPS model as a conceptual lens. SEIPS supported interpretation of parenteral therapy safety as a socio-technical system involving nurses, clinical tasks, safety devices, organizational structures, and care environments [8]. This was particularly relevant to the LMIC focus of the review because resource constraints often affect several work-system components simultaneously, including staffing, procurement, training, infrastructure, reporting systems, and device availability.

The review also has limitations. First, the included evidence was heterogeneous in design, setting, population, intervention type, and outcome measurement, which limited direct comparison across studies. Second, much of the evidence on advanced safety devices and digital medication technologies originated from high-income countries, limiting direct transferability to LMIC healthcare systems. Third, consistent with the purpose of a scoping review, formal risk-of-bias assessment and meta-analysis were not conducted. Fourth, the review was restricted to English-language publications, which may have excluded relevant studies from some LMICs. Finally, some included sources, such as practice alerts, clinical perspectives, position papers, and conference abstracts, provided useful safety signals but had weaker evidentiary strength than controlled empirical studies.

8. Conclusion

This scoping review shows that preventing parenteral therapy–related iatrogenesis in LMICs requires a systems-based and pathway-specific approach rather than reliance on isolated devices or individual vigilance. The evidence indicates that risks arise across medication preparation, injection, infusion, flushing, documentation, and monitoring, and are shaped by manual preparation, workload, interruptions, contamination, unsafe injection practices, device limitations, infection prevention gaps, and organizational constraints. Safety devices such as prefilled syringes, filter needles, in-line filters, safety-engineered syringes, smart pumps, BCMA, and eMAR systems can reduce specific risks, but their effectiveness depends on nursing competence, protocol adherence, infrastructure readiness, procurement reliability, workflow compatibility, and sustained institutional support. For LMICs, the most practical strategy is staged implementation, beginning with affordable nursing-led and infection prevention interventions, then expanding to device-based and digital technologies where resources, training, maintenance, and governance systems can support safe and sustainable use.

Abbreviations

ANTT – Aseptic Non-Touch Technique
BCMA – Barcode Medication Administration
DERS – Dose Error Reduction System
eMAR – Electronic Medication Administration Record
HIC – High-Income Country
ICU – Intensive Care Unit
IPC – Infection Prevention and Control
IV – Intravenous
LMICs – Low- and Middle-Income Countries
PRISMA-ScR – Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews
RTA – Ready-to-Administer
SEIPS – Systems Engineering Initiative for Patient Safety
SOPs – Standard Operating Procedures
WHO – World Health Organization

Declarations

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Competing interests

The authors declare that they have no known competing financial or non-financial interests that could have influenced the work reported in this manuscript.

Ethics approval

Not applicable. This study is a scoping review based exclusively on previously published literature and publicly available sources. No human participants, animals, or identifiable personal data were involved.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Data availability

No new data or code were generated or analyzed for this study. All information synthesized in this review was derived from previously published and publicly accessible sources cited in the reference list.

Code availability

Not applicable.

Clinical trial registration

Not applicable. This study was not a clinical trial.

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Appendix A

Supplementary Data Extraction Files
Full Data Extraction for All Eligible Studies

- Extraction_Obj_1
- Extraction_Obj_2
- Extraction_Obj_3