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Post-Pandemic Nosocomial Defense: A Systematic Review of Nursing-Led Multimodal Strategies for Sustainable Infection Prevention

Elham Nasser Ahmad Hadi, Jameelah Ebrahim Mohammad Ayoub , Zahra Yehia Hadi Abumerai , Fawziah Ahmed Ahmed Jafari , Ohoud Abdullah Mohammed Omeesh , Halimah Mohmmed Bashir , Hanaa Bhees Ali Bhees , Nawal Mohammad Abdullah Basher , Badriah Gassem Hakam , Shagra Jubran Mohammed Abuallh , Nagwa Abduljbar Ali , Ishraq Atia Muhammed Jarab , Fauzea Mohammad Abuhadi , Amna Ahmed Salem , Nawal Ahmed Ayashi

Ministry of Health, Saudi Arabia

Abstract

Background: The COVID-19 pandemic critically exposed and exacerbated vulnerabilities in global healthcare-associated infection (HAI) prevention infrastructures. While infection control is multidisciplinary, nursing, as the constant bedside presence, holds a pivotal and evolving role in the execution and sustainability of fundamental and advanced preventive measures. **Aim:** This narrative review synthesizes current evidence (2015-2024) on effective, nursing-integrated strategies to reduce HAI rates in the post-pandemic context, focusing on multimodal, systems-oriented approaches. **Methods:** A comprehensive search of PubMed, CINAHL, and Scopus databases was conducted for English-language literature. Studies evaluating nursing interventions, education models, technological aids, and organizational support structures impacting HAI metrics (e.g., CLABSI, CAUTI, SSI, MRSA) were thematically analyzed. **Results:** Evidence strongly supports the efficacy of nurse-driven protocols, competency-based education augmented by simulation, and strategic technological integration (e.g., electronic hand hygiene monitoring, clinical decision support). Crucially, success was dependent on foundational elements: sustained nurse staffing and well-being, a just culture of safety, and authentic interdisciplinary collaboration. Post-pandemic, strategies emphasizing antimicrobial stewardship roles for nurses and resilience-building are paramount. **Conclusion:** Moving beyond crisis-mode response, sustainable infection reduction requires empowering nurses through systemic support, education, and technology. The future lies in embedding robust, nurse-led preventive practices into the fabric of standard care, transforming lessons from the pandemic into durable defense mechanisms against HAIs.

Keywords: Healthcare-Associated Infections; Nursing; Infection Prevention and Control; Patient Safety; Post-Pandemic; Multimodal Strategy

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Introduction

The COVID-19 pandemic represented a profound stress test for global health systems, with healthcare-associated infection (HAI) prevention and control (IPC) frameworks facing unprecedented challenges. Pre-pandemic gains in reducing rates of central line-associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), and surgical site infections (SSIs) were jeopardized as resources were diverted, protocols strained, and workforce capacities overwhelmed (Despotovic et al., 2021). However, this period of crisis also functioned as a massive, real-world experiment in IPC, accelerating innovation, highlighting critical vulnerabilities, and unequivocally reinforcing the indispensable role of nursing (Halverson et al., 2022).

Nurses, constituting the largest segment of the healthcare workforce and providing continuous patient care, are the ultimate executants and guardians of IPC practices at the bedside. Their consistent application of hand hygiene, aseptic technique, surveillance, and patient education forms the immutable backbone of infection prevention (Jackson et al., 2014). This narrative review synthesizes evidence from 2015 to 2024 to elucidate effective, nursing-integrated strategies for reducing HAIs in the post-pandemic era. It argues that sustainable progress necessitates moving beyond viewing nurses merely as implementers of protocols, towards a paradigm that embeds them as empowered leaders within multimodal, system-supported frameworks that prioritize both patient safety and clinician well-being.

Methodology

This narrative review was conducted to synthesize and critically appraise the contemporary literature on nursing-led strategies for reducing healthcare-associated infections (HAIs) in the post-pandemic context. Following established guidelines for narrative synthesis, the methodology was designed to be comprehensive and reproducible, capturing a broad spectrum of evidence to build a coherent

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conceptual analysis of the field (Greenhalgh et al., 2018).

Search Strategy and Data Sources

A systematic search was performed across three major electronic databases: PubMed/MEDLINE, CINAHL (via EBSCOhost), and Scopus. The search timeframe was limited to studies published between January 2015 and July 2024 to capture the most relevant and current evidence, including the pivotal pandemic and post-pandemic years. The search strategy employed a combination of Medical Subject Headings (MeSH) terms and keywords related to three core concepts: (1) Nursing (e.g., "nurs*," "nursing role," "nurse-driven"), (2) Infection Prevention (e.g., "infection control," "cross infection," "healthcare-associated infection," "HAI"), and (3) Interventions/Strategies (e.g., "patient safety," "bundled interventions," "hand hygiene," "staffing," "education," "technology"). Boolean operators (AND, OR) were used to combine these concepts. An example search string for PubMed was: (("Nurs*"[Mesh] OR "Nursing Staff"[Mesh]) AND ("Cross Infection"[Mesh] OR "Infection Control"[Mesh]) AND ("Patient Care Bundles"[Mesh] OR "Education, Nursing"[Mesh] OR "Workload"[Mesh])).

Eligibility Criteria and Study Selection

Inclusion criteria were: (a) primary research studies (quantitative, qualitative, mixed-methods) and high-quality systematic reviews/meta-analyses; (b) focused on interventions where nursing played a defined or central role in implementation; (c) reporting outcomes related to HAI rates (e.g., CLABSI, CAUTI, SSI, MRSA), process compliance (e.g., hand hygiene, bundle adherence), or key enablers (e.g., staffing, safety culture); and (d) published in English. Exclusion criteria included: editorials, opinion pieces without original data, studies not specific to the role of nursing, and studies published before 2015.

Data Extraction and Synthesis

A standardized data extraction template was used to catalogue information from the 42 studies ultimately included for in-depth synthesis. Extracted data included: author(s), publication year, study design, setting, sample size, description of the nursing-integrated intervention, primary outcomes measured, and key findings. Given the narrative design and the heterogeneity of study designs and outcomes, a meta-analysis was not feasible. Instead, a thematic synthesis approach was employed. Extracted data were iteratively analyzed to identify recurrent themes, conceptual categories, and patterns of effectiveness or implementation challenge. These themes were then organized into the logical structure of the review: foundational systemic factors (staffing, culture), direct clinical interventions (protocols), educational approaches, technological aids, and overarching multimodal frameworks. This process allowed for the integration of diverse evidence types—from large-scale observational studies on staffing to qualitative work on safety culture and controlled trials of specific technologies—into a unified narrative on the multifactorial role of nursing in post-pandemic IPC.

Staffing, Well-being, and Safety Culture

The correlation between nurse staffing levels, burnout, and HAI rates is one of the most robust findings in health services research, a relationship starkly illuminated during the pandemic. Multiple studies have demonstrated that higher patient-to-nurse ratios are significantly associated with increased incidence of CLABSI, CAUTI, SSI, and hospital-acquired pneumonia (Lasater et al., 2021; Shin et al., 2018). Understaffing forces task saturation, compromises adherence to time-intensive IPC protocols like meticulous central line care or proper urinary catheter management, and reduces surveillance capacity (Han et al., 2021). The pandemic exacerbated chronic staffing shortages, leading to widespread nurse burnout—a state of emotional exhaustion, depersonalization, and reduced personal accomplishment. Burnout directly erodes cognitive attention and procedural compliance, making lapses in hand hygiene or aseptic technique more likely (Bartmess et al., 2021).

Therefore, any strategy aimed at reducing HAIs must first address this foundational crisis. Post-pandemic strategies must include enforceable safe-staffing legislation, investment in nurse recruitment and retention, and institution-wide programs to promote mental health and resilience (Galanis et al., 2021). Furthermore, a supportive safety culture—a "just culture" that balances accountability with system-focused learning—is essential. Nurses must feel psychologically safe to report near-misses or protocol deviations without fear of punitive action, thereby enabling proactive system improvement rather than reactive blame (van Marum et al., 2022; Murray et al., 2023). This cultural foundation enables the successful deployment of specific clinical and educational interventions. Figure 1 presents the foundational pillars supporting sustainable hospital infection prevention systems.

Figure 1: Pillars of Sustainable Nosocomial Defense: Structural and Educational Foundations of Infection Prevention

Nurse-Driven Protocols and Empowerment

Nurse-driven protocols (NDPs) represent a powerful model for decentralizing decision-making and leveraging nursing expertise to improve outcomes, particularly for device-associated infections (Jones et al., 2023). The most established examples are nurse-driven urinary catheter removal protocols, which empower nurses to assess daily continuation necessity without awaiting physician orders. Systematic reviews confirm that such protocols significantly reduce catheter utilization days and CAUTI rates by facilitating timely removal (Carter et al., 2018; Durant, 2017). Similarly, nurse-led initiatives for vascular access device management, including standardized insertion and maintenance bundles, audit and feedback, and prompt removal of unnecessary lines, are central to CLABSI prevention (Ista et al., 2016).

The post-pandemic evolution of this concept extends to broader antimicrobial stewardship (AMS) (Bobbitt et al., 2023). Nurses are pivotal in monitoring for signs of infection, ensuring appropriate culture collection before antibiotic administration, and facilitating timely intravenous-to-oral switch, yet their role in AMS has been historically underutilized (Monsees et al., 2017). Formalizing nursing roles in AMS through education, protocol development, and inclusion in stewardship teams is an emerging and crucial strategy. These empowerment models increase nurse engagement, foster ownership of patient outcomes, and streamline care processes, making prevention a proactive rather than reactive endeavor (Mittal et al., 2023).

Competency-Based Education and Simulation Training

Traditional, lecture-based IPC education has a limited impact on long-term practice change. The post-pandemic era demands a shift towards competency-based education (CBE) and high-fidelity simulation, which have demonstrated superior efficacy in improving knowledge retention and technical skill performance. Simulation training for sterile procedures like central line dressing changes, urinary catheter insertion, and personal protective equipment (PPE) donning/doffing allows nurses to practice and master skills in a risk-free environment, receiving immediate feedback (Jansson et al., 2016; Ozdemir & Kaya, 2023). This was particularly valuable during the pandemic for rapidly training staff in new IPC protocols for respiratory pathogens.

Furthermore, CBE moves away from measuring attendance to assessing demonstrated proficiency, ensuring all nurses, including new hires and float staff, meet a minimum standard of IPC capability. Strategies like "just-in-time" training, peer-to-peer coaching, and mobile-based micro-learning modules can reinforce these competencies at the point of care (Cerles et al., 2021). Education must also transcend technical skills to include critical thinking for clinical surveillance—training nurses to identify early, subtle signs of infection, a skill vital for sepsis prevention and antibiotic stewardship (Rossley, 2023).

Technological Augmentation and Environmental Hygiene

Technology offers transformative tools to augment, not replace, nursing clinical judgment and consistency in IPC. Electronic hand hygiene monitoring systems (EHHMS), using sensors or video analytics, provide objective, continuous data on compliance at the room entry/exit level, moving beyond unreliable direct observation. While ethical and logistical considerations exist, studies show EHHMS, when implemented as part of a multimodal program with feedback to staff, can lead to significant and sustained improvements in compliance and reductions in HAIs (Zhang et al., 2023; Shen et al., 2017).

Clinical decision support (CDS) integrated into electronic health records can prompt nurses for daily catheter necessity assessments or flag breaches in bundle compliance (Wang et al., 2021). Ultraviolet-C (UVC) disinfection robots and antimicrobial surface coatings can supplement, but never supplant, manual cleaning by environmental services staff, with nurses often playing a key role in ensuring rooms are properly prepared for terminal cleaning. The Internet of Things (IoT) with smart beds or wearables can monitor patient movement and incontinence, prompting timely nursing interventions to prevent moisture-associated skin damage and pressure injuries, and a portal for infection (Holbrook et al., 2021). The post-pandemic lesson is that technology is most effective when designed with nurse input, integrated seamlessly into workflow, and paired with human factors education (Floyd et al., 2021).

Multimodal Strategies and Interprofessional Collaboration

The World Health Organization and the Centers for Disease Control and Prevention have long championed multimodal strategies for IPC, which combine several interconnected elements: system change (providing the necessary tools and infrastructure), education and training, monitoring and feedback, reminders and communications, and culture change (Storr et al., 2017). The success of such strategies is inherently dependent on authentic interprofessional collaboration. Infection prevention is not the sole domain of the IPC specialist; it requires a shared mental model across medicine, nursing, pharmacy, environmental services, and leadership.

Daily interprofessional rounds that include bedside nurses in discussions about device necessity, antibiotic choice, and discharge planning foster this collaboration and improve outcomes (Ashcraft et al., 2017). For example, a multimodal CAUTI prevention program might include: providing portable bladder

scanners and catheter kits with all necessary components (system change); simulation training on aseptic insertion (education); nurse-driven removal protocols (empowerment); unit-level feedback on catheter days and infection rates (monitoring); and visual reminders in patient charts (communications). prevention.

This integrated approach, led collaboratively at the unit level by engaged nurse champions and supported by management, consistently proves more effective than single interventions (Dunn et al., 2017). Figure 2 illustrates an integrated, nurse-centered multimodal framework for healthcare-associated infection (HAI)

Table 1: Summary of Key Nursing-Integrated Strategies for HAI Reduction

Strategy Category	Specific Interventions	Targeted HAIs/Outcomes	Key Evidence & Considerations
Structural & Cultural	Safe staffing models; Burnout mitigation programs; Just culture implementation; Nurse well-being initiatives.	All HAIs, Nurse turnover, and Compliance rates.	Foundational prerequisite. High nurse-to-patient ratios & burnout directly increase HAI risk (Lasater et al., 2021). Requires organizational commitment.
Empowerment & Protocols	Nurse-driven catheter removal protocols; Nurse-led vascular access teams; Nursing roles in antimicrobial stewardship (e.g., IV-to-oral switch, culture follow-up).	CAUTI, CLABSI, Antimicrobial resistance, C. *difficile*.	Empowers frontline staff. Protocols reduce device days (Durant, 2017). AMS integration is an evolving, crucial frontier (Monsees et al., 2017).
Education & Training	Competency-based checklists; High-fidelity simulation (PPE, aseptic technique); Just-in-time peer coaching; Micro-learning platforms.	CLABSI, CAUTI, SSI, Respiratory infections.	Superior to traditional lectures. Ensures proficiency, not just attendance. Vital for rapid pandemic protocol training (Ozdemir & Kaya, 2023).
Technological Augmentation	Electronic hand hygiene monitoring systems (EHHMS); Clinical decision support (CDS) prompts; UVC/ Hydrogen peroxide vapor disinfection; IoT for skin integrity monitoring.	Cross-transmission (via hands), CAUTI, CLABSI, Environmental pathogens, Pressure injuries/infection.	Provides objective data. Must be part of a multimodal program with feedback. Should complement, not complicate, nursing workflow.
Multimodal & Collaborative	WHO/CDC multimodal bundles; Interprofessional rounds with nursing; Nurse infection prevention champions; Audit & feedback with frontline staff.	All HAIs, particularly device-associated.	Most effective framework. Success hinges on breaking down silos and engaging nursing leadership in design and implementation (Storr et al., 2017).

Figure 2: Multimodal Nursing-Led Strategies for Reducing Healthcare-Associated Infections in the Post-Pandemic Era

The Post-Pandemic Imperative

The post-pandemic landscape presents both a reckoning and an opportunity. The reckoning involves addressing the exhausted workforce and repairing strained systems. The opportunity lies in harnessing the heightened awareness of infection transmission to "hardwire" IPC into all aspects of care. Future strategies must focus on building resilient systems that can maintain core IPC functions during future crises. This includes creating adaptable nurse-led rapid response teams for outbreak management and investing in scalable education platforms (Yoshikawa et al., 2022). Furthermore, the integration of IPC principles into value-based care models and nursing-sensitive indicators is crucial, tying prevention directly to reimbursement and quality metrics. Research must continue to explore the cost-effectiveness of nurse-led interventions and

the optimal models for sustaining them (Qureshi et al., 2022).

Future Directions for Research and Practice

To consolidate and advance the gains in nursing-led infection prevention, a focused agenda for research and practice innovation is essential. Future efforts must pivot from simply proving the efficacy of isolated interventions to understanding how to implement, scale, and sustain them within complex, real-world healthcare ecosystems. This requires a dedicated focus on implementation science to identify the most effective strategies for embedding evidence-based bundles across diverse settings, from resource-rich academic hospitals to long-term care facilities and low-resource environments. Crucially, this agenda must be underpinned by a commitment to health equity, examining how social determinants of health and implicit bias affect infection risk and the delivery of preventive nursing care.

Simultaneously, the rapid evolution of technology presents both promise and challenge; research must rigorously evaluate the real-world impact and ethical integration of artificial intelligence for clinical surveillance, predictive analytics for early intervention, and next-generation environmental monitoring. Finally, the inextricable link between nurse well-being and patient safety demands that future models of care formally integrate resilience-building and safe staffing as non-negotiable components of infection prevention programs, rather than separate administrative concerns. The following table outlines specific priority areas to guide this necessary work.

Table 2: Future Directions and Research Priorities for Nursing in IPC

Priority Area	Key Questions for Future Research	Potential Impact
Workforce & Well-being	What are the most effective and scalable interventions to reduce nurse burnout and its impact on IPC compliance? How do flexible staffing models impact HAI rates?	Foundation for all other interventions. Directly addresses the root cause of compliance failures.
Antimicrobial Stewardship	What are the optimal models for integrating nurses into AMS teams? What educational competencies are needed? How can nurse-driven protocols for assessment and de-escalation be best implemented?	Expands the nursing role in a critical arena. Potential to reduce C. *difficile*, resistance, and adverse drug events.
Technology Integration	How can AI and predictive analytics support nursing surveillance for early infection? What are the ethical frameworks and workflow designs for effective EHHMS? How can IoT data be leveraged for preventive nursing interventions?	Moves from retrospective to proactive prevention. Enhances precision and consistency of care.
Implementation Science	What are the most effective strategies for implementing and sustaining multimodal bundles in diverse care settings (e.g., long-term care, low-resource settings)? What is the role of nurse champions?	Ensures evidence-based practices are successfully adopted in real-world contexts, closing the know-do gap.
Health Equity	How do social determinants of health and implicit bias influence nursing assessment for infection and access to preventive care? How can nurse-led IPC interventions be designed to advance equity?	Ensures equitable HAI reduction across all patient populations.

Conclusion

The COVID-19 pandemic irrevocably demonstrated that the chain of infection prevention is only as strong as its most stressed link, often the frontline nurse. Sustainable reduction of HAIs in its aftermath requires a fundamental recognition that nursing is not merely a vector for protocol implementation but the central agent of preventive care. Effective strategies are multimodal, intertwining systemic support for staffing and well-being, empowerment through protocols, innovative education, intelligent technological augmentation, and genuine interprofessional collaboration. The path forward is to institutionalize the lessons learned under duress, embedding robust, nurse-led IPC practices into the standard architecture of healthcare delivery. By doing so, healthcare systems can transform the traumatic experience of the pandemic into a durable legacy of safer care for patients and a more sustainable practice environment for the nursing profession.

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