Review Article

Essential Best Practices for Preventing and Controlling Healthcare-Associated Infections

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Abstract

Introduction: Healthcare-associated infections (HAIs) remain a major global threat, affecting hundreds of millions of patients yearly with high morbidity, mortality, and economic costs. Common types include catheter-associated urinary tract infections, surgical site infections, central line-associated bloodstream infections, ventilator-associated pneumonia, and Clostridioides difficile infections. Evidence shows 30-70% of HAIs are preventable through systematic evidence-based practices, which this narrative review synthesizes across foundational principles, device strategies, stewardship, surveillance, and implementation. Literature was searched comprehensively in PubMed, Cochrane Library, Google Scholar, and Web of Science, focusing on 2010-2025 publications, with key earlier works included. Gray literature from WHO, CDC, ECDC, and SHEA supplemented sources. English-language studies on HAI prevention in healthcare settings were selected, covering guidelines, systematic reviews, trials, quality reports, surveillance data, and consensus statements for a broad evidence overview. Hand hygiene via the WHO Five Moments framework reduces HAI rates by 15-50% with consistent adherence. Device bundles for insertion and maintenance cut central line infections, urinary tract infections, and pneumonia by 50-80%, enabling zero rates in high-fidelity programs. Surgical site prevention via preoperative optimization, timely prophylaxis, sterile technique, and wound care lowers rates by 40-70%. Antimicrobial stewardship reduces inappropriate use by 20-35%. Cleaning high-touch surfaces decreases reservoirs by 30-50%, while precautions interrupt transmission. Multimodal strategies tackle barriers at individual (knowledge gaps), environmental (supplies/staffing), and cultural levels. HAIs are largely preventable using hand hygiene, precautions, cleaning, device bundles, surgical strategies, and stewardship. Multimodal approaches with surveillance address implementation barriers through leadership, resources, education, redesign, and safety cultures. Organizations should prioritize these as ethical and economic imperatives, engaging staff for sustained reductions and enhanced patient safety.

Keywords: Healthcare-associated infections; Infection prevention and control; Hand hygiene; Antimicrobial stewardship; Device-associated infections; Surveillance; Patient safety; Multimodal strategies

Introduction

Healthcare-associated infections (HAIs), also known as nosocomial infections, are infections that patients acquire during the course of receiving healthcare treatment for other conditions within a healthcare setting(1). These infections are neither present nor incubating at the time of admission and typically manifest 48 hours or more after hospital admission or within 30 days after discharge following an invasive procedure (2). HAIs represent one of the most critical patient safety challenges in modern healthcare systems worldwide, affecting hundreds of millions of patients annually and imposing substantial burdens on healthcare infrastructure, economies, and, most importantly, patient outcomes. The significance of HAIs extends far beyond their immediate clinical impact. These infections serve as key indicators of healthcare quality and patient safety, reflecting the effectiveness of infection prevention and control measures within healthcare institutions (3). The occurrence of HAIs can lead to prolonged hospital stays, increased antimicrobial resistance, long-term disability, additional financial burden

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for both patients and healthcare systems, and, in severe cases, preventable mortality (4). HAIs contribute significantly to the global antimicrobial resistance crisis, as infected patients often require treatment with broad-spectrum antibiotics, creating selective pressure for resistant organisms (5). The preventable nature of many HAIs makes their continued prevalence particularly concerning from both ethical and economic perspectives.

Epidemiology and Burden of HAIs

The global epidemiology of HAIs reveals a substantial and persistent public health challenge. According to the World Health Organization, HAIs affect hundreds of millions of patients worldwide each year, with the highest burden in low- and middle-income countries where the prevalence can exceed 15% compared to 7% in high-income nations(6) . In the United States alone, the Centers for Disease Control and Prevention (CDC) estimates that approximately 1 in 31 hospital patients has at least one healthcare-associated infection on any given day, translating to roughly 687,000 HAIs annually (7). European data from the European Centre for Disease Prevention and Control indicates a similar prevalence, with approximately 3.2 million HAI cases occurring annually across European acute care hospitals (8).

The mortality burden associated with HAIs is staggering and often underappreciated. In the United States, HAIs are estimated to contribute to approximately 75,000 deaths annually, with some studies suggesting the figure may be considerably higher when accounting for HAIs as contributing rather than primary causes of death(9). The attributable mortality varies significantly by infection type, with bloodstream infections carrying the highest mortality risk at 12-25%, compared to 1-3% for urinary tract infections(10). Ventilator-associated pneumonia demonstrates particularly high mortality rates, ranging from 20-50% depending on the causative pathogen and patient population (11). The mortality impact is amplified in vulnerable populations, including immunocompromised patients, elderly individuals, and those with multiple comorbidities.

The economic burden of HAIs represents a substantial drain on healthcare resources globally. In the United States, the annual direct medical costs attributable to HAIs are estimated to range from $28.4 billion to $45 billion, with individual HAI episodes costing between $1,000 and $111,000 depending on the type of infection and healthcare setting (4). A comprehensive analysis by Zimlichman et al (4) found that central line-associated bloodstream infections incurred the highest costs at approximately $45,814 per case, followed by ventilator-associated pneumonia at $40,144 per case, surgical site infections at $20,785 per case, and catheter-associated urinary tract infections at $896 per case. In Europe, the annual economic burden is estimated at approximately €7 billion, with an additional 16 million extra hospital days attributed to HAIs. These costs encompass direct medical expenses such as extended hospital stays, additional diagnostic testing, antimicrobial therapy, surgical interventions, and intensive care unit admissions, as well as indirect costs including lost productivity and long-term disability. The economic impact extends beyond healthcare systems to affect patients and families through out-of-pocket expenses, lost wages, and reduced quality of life.

Common Types of HAIs

HAIs encompass a diverse range of infections affecting different body sites and systems, with five primary types accounting for the majority of cases in acute care settings. Understanding the epidemiology and characteristics of these common HAI types is essential for developing targeted prevention strategies.

Catheter-associated urinary tract infections (CAUTIs) represent the most frequently reported HAI in acute care hospitals, accounting for approximately 30-40% of all nosocomial infections (12). CAUTIs occur when pathogens, most commonly Escherichia coli, Enterococcus species, Pseudomonas aeruginosa, and Candida species, enter the urinary tract via indwelling urethral catheters. The risk of developing a CAUTI increases by 3-7% for each day of catheterization, with nearly universal bacteriuria occurring after 30 days of continuous catheterization. While CAUTIs typically have lower attributable mortality compared to other HAI types, they contribute significantly to antimicrobial use, antimicrobial resistance, and secondary bloodstream infections, which carry mortality rates of 10-30%.

Surgical site infections (SSIs) occur following invasive surgical procedures and are classified as superficial incisional, deep incisional, or organ/space infections based on the anatomical depth of involvement. SSIs account for approximately 20-25% of all HAIs and represent the most costly HAI type overall due to their high frequency and substantial treatment expenses (13). The incidence of SSIs varies widely depending on the surgical procedure type, patient risk factors, and wound classification, ranging from less than 2% for clean procedures to over 20% for contaminated or dirty procedures (14). Common causative organisms include Staphylococcus aureus (including methicillin-resistant strains), coagulase-negative staphylococci, Enterococcus species, and gram-negative bacilli (13). SSIs result in substantial morbidity, with affected patients experiencing prolonged hospitalization (average 7-10 additional days), increased risk of readmission, and mortality rates of 2-11% depending on the infection severity and surgical site.

Central line-associated bloodstream infections (CLABSIs) occur when pathogens enter the bloodstream through central venous catheters, which are commonly used in intensive care units and for patients requiring long-term venous access. Despite representing only 5-10% of HAIs, CLABSIs carry the highest mortality and cost burden of any device-associated infection, with attributable mortality ranging from 12-25% and costs exceeding $45,000 per episode (4). Common causative organisms include coagulase-negative staphylococci, Staphylococcus aureus, Candida species, and gram-negative bacilli such as Klebsiella pneumoniae and Escherichia coli. Patients with CLABSIs experience significantly prolonged hospital stays (average 10-20 additional days), increased antimicrobial exposure, and risk of complications, including septic thrombophlebitis, endocarditis, and metastatic infections.

Ventilator-associated pneumonia (VAP) develops in mechanically ventilated patients more than 48 hours after endotracheal intubation and represents one of the most serious HAIs in intensive care settings (15). VAP accounts for approximately 10-15% of all HAIs but carries disproportionately high mortality, with attributable mortality ranging from 20-50% depending on the causative pathogen (11). The incidence of VAP ranges from 6 to 20 episodes per 1,000 ventilator days, with risk increasing by 1-3% per day of mechanical ventilation. Common early-onset VAP pathogens include Streptococcus pneumoniae and Haemophilus influenzae, while late-onset VAP is frequently caused by multidrug-resistant organisms, including Pseudomonas aeruginosa, Acinetobacter baumannii, and methicillin-resistant Staphylococcus aureus. VAP significantly extends the duration of mechanical ventilation (average 4-6 additional days) and intensive care unit length of stay (average 4-9 additional days), resulting in substantial healthcare costs estimated at $40,000 per episode.

Clostridioides difficile infections (CDI), formerly known as Clostridium difficile infections, have emerged as one of the most urgent antimicrobial resistance threats in healthcare settings(16) . CDI is caused by toxin-producing strains of C. difficile and typically manifests following disruption of normal intestinal microbiota by antimicrobial therapy, resulting in diarrhea ranging from mild to severe pseudomembranous colitis (17). The incidence of healthcare-associated CDI in the United States is approximately 4-5 cases per 10,000 patient days, with nearly 500,000 infections occurring annually (17). The emergence of hypervirulent strains, particularly the BI/NAP1/027 strain, has led to increased disease severity, recurrence rates of 15-30%, and mortality rates reaching 5-10% in hospitalized patients. CDI imposes a substantial economic burden, with estimated costs of $4.8 billion annually in the United States alone(18). The infection is particularly challenging due to high recurrence rates, environmental persistence of spores, and resistance to standard alcohol-based hand sanitizers, necessitating soap and water hand hygiene.

Rationale and Objectives of the Review

Despite the significant advances in medical science and infection prevention knowledge over the past several decades, HAIs continue to pose a substantial threat to patient safety and healthcare quality worldwide. While numerous evidence-based interventions have been developed and validated for HAI prevention, their implementation remains inconsistent across healthcare settings, contributing to the persistent burden of these largely preventable infections(10). The gap between knowledge and practice represents a critical challenge that requires renewed attention to identifying, synthesizing, and promoting the adoption of essential best practices for HAI prevention and control.

The rationale for this narrative review stems from several key considerations. First, the healthcare landscape has evolved considerably in recent years, with emerging evidence supporting novel prevention strategies, a refined understanding of transmission dynamics, and recognition of the importance of implementation science in translating evidence into practice (19). Second, the increasing prevalence of multidrug-resistant organisms has heightened the urgency of effective infection prevention, as treatment options for HAIs become progressively limited. Third, healthcare systems globally are facing mounting pressure to improve quality while reducing costs, making the prevention of HAIs both a clinical and economic imperative. The COVID-19 pandemic has highlighted both the critical importance of infection prevention and control measures and the challenges of maintaining adherence to best practices during periods of healthcare system strain(20).

The primary objective of this narrative review is to comprehensively synthesize and present the essential best practices for preventing and controlling healthcare-associated infections based on current evidence and expert guidance. Specific aims include identifying and describing evidence-based interventions for preventing the most common types of HAIs, including CAUTIs, SSIs, CLABSIs, VAP, and CDI; examining the fundamental principles of infection prevention that apply across all healthcare settings, including hand hygiene, standard precautions, environmental hygiene, and antimicrobial stewardship; exploring organizational and systems-level approaches that support successful implementation of HAI prevention strategies, including surveillance systems, quality improvement methodologies, and culture change initiatives; discussing special considerations for high-risk populations and emerging challenges such as multidrug-resistant organisms; and identifying barriers to implementation and strategies for overcoming these challenges to facilitate the translation of evidence into practice.

Methodology

Search Strategy and Databases

A comprehensive literature search was conducted to identify relevant evidence on best practices for preventing and controlling healthcare-associated infections. Multiple electronic databases were systematically searched, including PubMed, Cochrane Library, Google Scholar, and Web of Science. The search strategy employed a combination of Medical Subject Headings (MeSH) terms and keywords related to healthcare-associated infections, including but not limited to: "healthcare-associated infections," "nosocomial infections," "hospital-acquired infections," "infection prevention," "infection control," "catheter-associated urinary tract infections," "surgical site infections," "central line-associated bloodstream infections," "ventilator-associated pneumonia," "Clostridium difficile," and "Clostridioides difficile". Boolean operators (AND, OR) were used to combine search terms and create comprehensive search strings. Additionally, gray literature sources were explored, including websites of major health organizations such as the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), European Centre for Disease Prevention and Control (ECDC), and the Society for Healthcare Epidemiology of America (SHEA), to identify relevant guidelines, policy documents, and technical reports.

Inclusion and Exclusion Criteria

Studies and documents were included in this review if they met the following criteria: focused on prevention and control strategies for healthcare-associated infections in acute care, long-term care, or ambulatory healthcare settings, addressed one or more of the major HAI types (CAUTI, SSI, CLABSI, VAP, CDI) or general infection prevention principles, provided evidence-based recommendations, interventions, or outcomes related to HAI prevention and were published in English language. Inclusion was not restricted by study design, allowing for the incorporation of randomized controlled trials, quasi-experimental studies,

cohort studies, case-control studies, systematic reviews, meta-analyses, and quality improvement initiatives.

Exclusion criteria were applied and they are: studies focusing exclusively on community-acquired infections without healthcare setting relevance, articles addressing infections in highly specialized populations or settings with limited generalizability, studies published in languages other than English due to resource constraints, opinion pieces, editorials, or commentaries without substantial empirical evidence or systematic analysis, and outdated guidelines or recommendations that had been superseded by more recent evidence-based guidance. Duplicate publications and conference abstracts without full-text availability were also excluded to ensure comprehensive data extraction and quality assessment.

Time Frame of Literature Reviewed

The primary search focused on literature published within the past 15 years (2010-2025) to capture the most current evidence, contemporary prevention strategies, and recent advances in infection control practices. This timeframe was selected to ensure the inclusion of modern approaches to HAI prevention, including bundle-based interventions, implementation science frameworks, and updated antimicrobial stewardship strategies that have emerged in the last decade and a half. However, seminal studies and landmark guidelines published before 2010 were also included when they represented foundational evidence or established standards of practice that continue to inform current recommendations. Classic studies on hand hygiene, central line insertion bundles, and infection control principles were incorporated regardless of publication date when they provided essential context or formed the basis for contemporary practice. The search was conducted in December 2024, with literature reviewed through January 2025 to ensure the most up-to-date information available at the time of writing.

Types of Sources Considered

This narrative review incorporated a diverse range of evidence sources to provide a comprehensive overview of best practices for HAI prevention and control. Clinical practice guidelines from authoritative organizations were prioritized, including those published by the CDC, WHO, SHEA, Infectious Diseases Society of America (IDSA), and other recognized professional societies. These guidelines represent expert consensus based on systematic evidence review and provide actionable recommendations for clinical practice Systematic reviews and meta-analyses were extensively utilized to synthesize evidence from multiple primary studies and identify robust intervention effects. These secondary sources offered a valuable synthesis of evidence quality and strength of recommendations across different HAI prevention strategies.

Primary research studies, including randomized controlled trials, quasi-experimental studies, prospective and retrospective cohort studies, and case-control studies, were incorporated to provide detailed evidence on specific interventions and their outcomes. Quality improvement reports and implementation studies were included to illustrate the real-world application of evidence-based practices and identify factors influencing successful implementation in diverse healthcare settings. Surveillance reports and epidemiological studies from national and international health agencies provided essential data on HAI burden, trends, and emerging challenges

Hand Hygiene

Hand hygiene is universally recognized as the single most critical measure for preventing healthcare-associated infections and reducing the transmission of antimicrobial-resistant organisms in healthcare settings (6). Contemporary evidence has consistently reinforced this principle, with systematic reviews demonstrating that improved hand hygiene compliance can reduce HAI rates by 15-50% across various healthcare settings. Hand hygiene involves cleaning hands thoroughly with soap and water or using alcohol-based hand sanitizers, ensuring all surfaces such as between fingers and under nails are addressed.

The World Health Organization (WHO) outlines a six-step process for effective hand hygiene: rubbing palms together, interlacing fingers, cleaning the backs of hands, focusing on thumbs, and rinsing thoroughly (21).

The "5 Moments for Hand Hygiene"

The WHO has identified the "5 Moments for Hand Hygiene," which highlight critical times for healthcare workers to perform hand hygiene to prevent HAIs:

1. **Before touching a patient:** To protect the patient from harmful germs.
2. **Before performing a clean or aseptic procedure:** To prevent infection during invasive procedures.
3. **After exposure to bodily fluids and glove removal:** To avoid transferring pathogens.
4. **After contact with a patient and their immediate surroundings:** To reduce cross-contamination.
5. **After touching inanimate objects in the patient's environment:** Hand hygiene remains crucial, even without direct patient contact (21).

Implementation of the Five Moments framework has been associated with significant improvements in hand hygiene compliance and HAI reduction globally. The model's strength lies in its patient-centered approach, clear indication structure, and ease of integration into clinical workflow, making it applicable across diverse healthcare settings and cultural contexts (6). The framework has been adopted in over 120 countries and translated into more than 40 languages, becoming the international gold standard for hand hygiene practice and education.

Standard precautions represent the foundation of infection prevention in healthcare settings and are designed to protect healthcare workers and prevent the transmission of pathogens among all patients, regardless of their known or suspected infection status. This approach recognizes that many patients harbor infectious agents without apparent symptoms and that relying solely on diagnosis-based precautions would miss many transmission opportunities. Standard precautions are based on the principle that blood, all body fluids (except sweat), non-intact skin, and mucous membranes may contain transmissible infectious agents and therefore require protective measures during healthcare activities. The appropriate use of personal protective equipment (PPE) is a key component in preventing the transmission of infections in healthcare settings. PPE includes gloves, gowns, masks, face shields, and goggles designed to protect healthcare workers from exposure to infectious agents.

Guidelines for Appropriate Use of PPE

The CDC advises that PPE should be used based on the level of risk associated with specific procedures or patient interactions. For example:

- **Gloves** should be worn when there is potential contact with blood or bodily fluids.
- **Gowns** are recommended for procedures that might involve splashes or sprays.
- **Masks and eye protection** are necessary when caring for patients with respiratory infections or during aerosol-generating procedures. N95 respirators provide filtration efficiency of at least 95% for particles $\geq$0.3 micrometers and must form a tight seal with the face, requiring fit-testing to ensure proper seal and protection (22). Powered air-purifying respirators (PAPRs) offer higher levels of protection and may be more comfortable for prolonged use, but are more expensive and require maintenance. Training healthcare workers in proper donning (putting on) and doffing (removing) techniques is essential to minimize self-contamination during PPE use.

Environmental Cleaning and Disinfection

Environmental surfaces in healthcare settings serve as reservoirs for pathogens and contribute significantly to healthcare-associated infection transmission, with studies demonstrating that 20-40% of HAIs may be attributed to contaminated environmental surfaces (10). Terminal cleaning, performed after patient discharge or transfer, involves comprehensive cleaning and disinfection of all surfaces, fixtures, and equipment in the patient room to eliminate residual pathogens before the next patient occupancy. This process requires systematic removal of all portable equipment, thorough cleaning of all horizontal and vertical surfaces including walls up to touch-height, disinfection of high-touch surfaces, and environmental assessment to verify cleaning adequacy (23).

Strategies for Maintaining Cleanliness

- **Regularly cleaning high-touch surfaces:** This includes bedrails, doorknobs, and medical equipment.
- **Using effective disinfectants:** Ensure disinfectants are capable of eliminating a wide range of pathogens.
- **Training staff on proper cleaning techniques:** Providing adequate training ensures compliance with established cleaning protocols

Selection of Appropriate Disinfectants

Selecting appropriate disinfectants requires consideration of pathogen spectrum, contact time, material compatibility, safety profile, and regulatory compliance (23). The Environmental Protection Agency (EPA) classifies disinfectants into three levels: high-level disinfectants that eliminate all microorganisms except high numbers of bacterial spores, intermediate-level disinfectants effective against mycobacteria, vegetative bacteria, most viruses, and most fungi, and low-level disinfectants that kill most vegetative bacteria, some fungi, and some viruses(23). For environmental surface disinfection in patient care areas, EPA-registered hospital-grade disinfectants with intermediate-level activity are generally recommended, including quaternary ammonium compounds, phenolic compounds, improved hydrogen peroxide, and sodium hypochlorite (bleach) solutions (23).

Pathogen-specific considerations influence disinfectant selection. For routine environmental cleaning, quaternary ammonium compounds offer broad-spectrum activity, low toxicity, and good material compatibility, though concerns about reduced efficacy against certain pathogens and potential for microbial adaptation have emerged (24). Sodium hypochlorite (bleach) at concentrations of 1000-5000 ppm (0.1-0.5%) provides rapid, broad-spectrum activity including sporicidal action and is recommended for C. difficile contaminated environments and during outbreaks of norovirus or other non-enveloped viruses (25). Accelerated hydrogen peroxide products combine broad-spectrum efficacy with improved safety profiles and shorter contact times (30 seconds to 5 minutes), making them increasingly popular for routine use (26). Critical factors affecting disinfectant efficacy include adequate contact time (typically 1-10 minutes depending on product), proper dilution and preparation, presence of organic soil that can inactivate disinfectants, and adherence to manufacturer's instructions for use(23).

Role of Environmental Services in Infection Prevention

Environmental services (EVS) personnel are essential members of the infection prevention team, yet their contributions are often underrecognized and undervalued (23). EVS staff require comprehensive initial training covering microbiology fundamentals, transmission pathways, cleaning and disinfection principles, proper product use, personal protective equipment, and quality monitoring. Ongoing education, competency assessment, and incorporation into interdisciplinary rounds enhance EVS staff knowledge and engagement in infection prevention efforts (27).

Device-Associated Infection Prevention

Central Line-Associated Bloodstream Infection (CLABSI) Prevention Bundles

CLABSI prevention bundles represent evidence-based, multifaceted interventions implemented together to achieve superior results compared to individual interventions alone(28). The landmark Michigan Keystone ICU project demonstrated that implementation of a five-component insertion bundle reduced CLABSI rates by 66% across 103 ICUs, with sustained reductions maintained for 18 months. The insertion bundle components include: hand hygiene before catheter insertion, maximal barrier precautions during insertion (sterile gown, gloves, cap, mask, and large sterile drape), chlorhexidine skin antisepsis, optimal catheter site selection (avoiding femoral vein in adults), and daily review of line necessity with prompt removal when no longer essential(28).

Catheter-Associated Urinary Tract Infection (CAUTI) Prevention Strategies

CAUTI prevention prioritizes avoiding unnecessary catheter insertion and ensuring prompt removal when catheters are no longer indicated, as duration of catheterization represents the strongest modifiable risk factor for infection (12).Appropriate indications for indwelling urinary catheter use include acute urinary retention or bladder outlet obstruction, need for accurate urine output monitoring in critically ill patients, perioperative use for selected surgical procedures, assistance with healing of open sacral or perineal wounds in incontinent patients, prolonged immobilization due to unstable spine or pelvic fractures, and patient comfort during end-of-life care (Gould et al., 2010). Implementing nurse-driven or automated catheter removal protocols, where catheters are removed based on standardized criteria without requiring physician orders, has reduced inappropriate catheter days by 30-50% and CAUTI rates by 20-60%(19) .

When catheters are necessary, appropriate insertion and maintenance practices minimize infection risk (12). Aseptic insertion technique using sterile equipment, hand hygiene, and cleaning of the urethral meatus with antiseptic solution is essential, with studies showing that breaks in aseptic technique during insertion increase CAUTI risk 2-4 fold (12) . The smallest bore catheter appropriate for drainage should be used to minimize urethral trauma, and the catheter should be secured to prevent movement and urethral traction (12) .

Maintenance of a closed drainage system is critical, as breaking the system for sampling or irrigation dramatically increases infection risk; urine samples should be obtained aseptically through the sampling port using needle and syringe or luer-lock devices. Daily cleansing of the urethral meatus with soap and water during routine bathing is sufficient antiseptic cleansing provides no additional benefit (12). Keeping the collection bag below the level of the bladder, ensuring unobstructed urine flow, and emptying the collection bag regularly using a separate, clean collection container for each patient prevents urinary stasis and cross-contamination (12).

Ventilator-Associated Pneumonia (VAP) Prevention Measures

VAP prevention bundles incorporate multiple evidence-based interventions addressing the pathophysiology of ventilator-associated pneumonia, which primarily occurs through microaspiration of oropharyngeal secretions containing pathogenic bacteria (29). The Institute for Healthcare Improvement VAP bundle includes: elevation of the head of the bed to 30-45 degrees unless contraindicated, which reduces aspiration risk by approximately 50%; daily sedation vacations and assessment of readiness to extubate, reducing unnecessary ventilator days; peptic ulcer disease prophylaxis when indicated; deep vein thrombosis prophylaxis; and daily oral care with chlorhexidine (29). Subsequent evidence has refined these recommendations, with some components showing limited benefit in preventing VAP specifically but maintaining value for preventing other complications (29)

Surgical Site Infection Prevention

Surgical site infection prevention requires a comprehensive, multifaceted approach spanning the preoperative, intraoperative, and postoperative periods. Preoperative patient optimization addresses modifiable risk factors, with perioperative glycemic control (maintaining blood glucose below 200 mg/dL) reducing SSI risk by 50-75% in high-risk patients, smoking cessation 4-8 weeks before surgery decreasing infections by 30-60%, and nutritional supplementation with immunonutrition formulas reducing SSI by 30-50% in malnourished patients(30). Appropriate surgical antibiotic prophylaxis, administered within 60 minutes before incision and discontinued within 24 hours postoperatively, represents one of the most effective interventions, reducing infection rates by 40-60% when implemented correctly, with first-generation cephalosporins providing appropriate coverage for most procedures (13) (14). Intraoperative infection prevention centers on meticulous sterile technique, including surgical hand antisepsis, use of sterile gowns and gloves with double-gloving for high-risk procedures, and proper skin preparation using alcohol-based antiseptics containing chlorhexidine gluconate, which reduce SSI by 40-50% compared to aqueous preparations (14). Hair removal, when necessary, should be performed using clippers rather than razors to avoid microscopic skin abrasions that increase bacterial colonization and infection risk 2-4 fold (14). Postoperative care involves protecting primarily closed incisions with sterile dressings for 24-48 hours, educating patients about signs of infection (increasing pain, erythema, warmth, purulent drainage, fever), implementing post-discharge surveillance to identify the 40-60% of SSIs that occur after hospital discharge, and considering negative pressure wound therapy for high-risk incisions, which reduces SSI by 30-50% in obese patients and contaminated wounds (14,31–33). Implementation of comprehensive SSI prevention bundles incorporating these evidence-based practices, supported by computerized decision support systems and multidisciplinary quality improvement initiatives, has achieved SSI reductions of 20-50% across diverse surgical settings (13,34).

Antimicrobial Stewardship

Principles of Antimicrobial Stewardship Programs

Antimicrobial stewardship programs (ASPs) represent coordinated interventions designed to improve antimicrobial use, optimize patient outcomes, reduce antimicrobial resistance, and decrease unnecessary healthcare costs (35). The Centers for Disease Control and Prevention identifies ASPs as a core component of healthcare-associated infection prevention, recognizing that 30-50% of antimicrobial use in hospitals is inappropriate or suboptimal regarding choice, dose, duration, or indication (36). Effective ASPs require institutional leadership commitment, accountability through a single leader responsible for program outcomes, drug expertise through a pharmacist trained in infectious diseases, collaborative multidisciplinary action including infectious disease physicians and infection preventionists, and tracking of antimicrobial prescribing and resistance patterns (35).

The two core stewardship strategies are prospective audit and feedback, where stewards review antimicrobial prescriptions and provide recommendations to prescribers, and formulary restriction with preauthorization, requiring prescribers to obtain approval before using specific broad-spectrum or restricted antimicrobials. Both strategies achieve similar improvements in antimicrobial use and patient outcomes, with selection often based on institutional culture and resources (35). Supplementary strategies include facility-specific treatment guidelines and clinical pathways that standardize empiric therapy for common infections, dose optimization based on pharmacokinetic and pharmacodynamic principles, antimicrobial cycling or mixing programs, parenteral to oral conversion protocols, and computerized clinical decision support systems (35). Systematic reviews demonstrate that comprehensive ASPs reduce inappropriate antimicrobial use by 20-35%, decrease antimicrobial costs by 25-35%, reduce *Clostridium difficile* infection incidence by 30-50%, and lower antimicrobial resistance rates without adversely affecting patient outcomes (37,38).

Monitoring and Surveillance

Monitoring of healthcare-associated infections is crucial for identifying risk factors, enabling prompt follow-up on transmission pathways, and improving patient safety through necessary interventions, with modern approaches incorporating surveillance systems, digitalization, and artificial intelligence to enhance detection and response capabilities (39). Surveillance programs are fundamental to understanding HAI epidemiology by providing vital data that track infection rates over time, identify outbreaks, evaluate prevention measure effectiveness, and enable healthcare organizations to benchmark their performance against national standards, thereby fostering continuous quality improvement (40). Surveillance methodologies can be categorized as active surveillance, which involves proactively identifying HAIs through systematic chart reviews, laboratory data analysis, and targeted screening cultures for specific pathogens, and passive surveillance, which relies on healthcare providers to voluntarily report infections as they occur; while active surveillance is more comprehensive in capturing cases that might otherwise go unreported, it is resource-intensive, whereas passive surveillance is less labor-intensive but potentially subject to underreporting (41). Effective surveillance relies on key performance indicators such as device-associated infection rates expressed as infections per 1,000 device-days, the NHSN Standardized Infection Ratio comparing observed to predicted infection counts, and process measures including hand hygiene compliance and central line insertion bundle adherence that provide immediate feedback enabling real-time course correction (28,40). Feedback mechanisms are essential components of effective surveillance programs, providing healthcare workers with timely, individualized, and constructive insights into their performance that significantly enhance motivation and compliance with infection prevention measures when delivered in a supportive, non-punitive manner that fosters a culture embracing feedback as a tool for improvement rather than criticism (42). Despite robust evidence supporting HAI prevention practices, implementation remains inconsistent due to barriers operating at individual levels (inadequate knowledge, skills deficits, competing priorities), work environment levels (inadequate staffing, lack of accessible supplies, poor facility design, absence of decision support systems), and organizational culture levels, with facilities demonstrating strong safety cultures characterized by leadership commitment, psychological safety, and transparency achieving significantly better outcomes (43) . Addressing these barriers requires comprehensive, multilevel strategies including education and training employing simulation-based methods with real-time feedback, systems redesign interventions such as point-of-care supply placement and standardized protocols, clinical decision support embedded in electronic health records, and leadership engagement demonstrating visible commitment through accountability structures and adequate resource allocation (43). Successful implementation ultimately requires cultivating organizational cultures that normalize prevention practices as expected standards, embrace collective accountability where team members support one another in maintaining prevention standards, adopt continuous learning orientations treating failures as improvement opportunities, and maintain patient-centeredness that keeps prevention focused on protecting patients from preventable harm.

Multimodal Strategies and Organizational Approaches to Infection Prevention

Multimodal implementation strategies represent a cornerstone of effective Infection Prevention and Control (IPC) programs, combining multiple evidence-based interventions to influence healthcare workers' behaviors and improve patient outcomes(6,44). The World Health Organization emphasizes that successful multimodal strategies incorporate five key components working synergistically to create sustainable change: system change to modify the healthcare environment through infrastructure upgrades and ensuring availability of necessary equipment and supplies at the point of care; training and education to continuously enhance healthcare workers' knowledge and skills in proper hand hygiene techniques, appropriate personal protective equipment use, and cleaning and disinfection protocols; monitoring and feedback to regularly track infection rates and compliance with IPC practices while identifying areas requiring improvement; reminders and communication through effective visual and verbal strategies that reinforce desired IPC behaviors; and cultivation of a culture of safety that prioritizes IPC, encourages open communication, and sustains long-term improvements (3,44). Evidence from diverse healthcare settings demonstrates the effectiveness of multimodal approaches in reducing healthcare-associated infections. The WHO Multimodal Improvement Strategy, promoted worldwide particularly during the COVID-19 pandemic, achieved remarkable success in Kenya where the Ministry of Health established a national IPC committee that coordinated training for over 69,000 healthcare workers, conducted facility readiness assessments to identify and address gaps in IPC measures, and achieved improved hand hygiene compliance with corresponding reductions in infection rates (6,45). Integration of antibiotic stewardship programs with IPC efforts exemplifies successful multimodal collaboration, with facilities combining expertise from both disciplines to implement targeted interventions addressing both infection prevention and appropriate antibiotic use, resulting in significant reductions in Clostridioides difficile infections through coordinated monitoring of antibiotic prescriptions and enhanced hygiene practices (35,37). Comprehensive multimodal IPC interventions targeting carbapenem-resistant Klebsiella pneumoniae in intensive care units, incorporating active surveillance cultures, strict hand hygiene protocol adherence, environmental cleaning with effective disinfectants, and staff education on infection control measures, have achieved marked reductions in colonization rates (27). Similarly, multimodal programs addressing catheter-associated urinary tract infections through staff education on proper insertion techniques, regular catheter use audits, timely removal reminders, and enhanced cleaning protocols have demonstrated significant infection rate decreases over sustained implementation periods (19).

Despite the availability of evidence-based prevention practices, several persistent challenges hinder effective IPC implementation across healthcare settings. Compliance issues represent a major barrier, with inconsistent adherence to IPC protocols resulting from insufficient training, inadequate knowledge of IPC guidelines, lack of positive role models within healthcare organizations, high workloads and fatigue that contribute to lapses in IPC practice, and healthcare workers' perceptions that certain protocols are unnecessary or pose low personal risk. Resource limitations significantly impact IPC efforts through shortages of personal protective equipment, cleaning supplies, and hand hygiene products, as well as insufficient staffing levels that force overburdened staff to prioritize immediate patient care over IPC adherence (43). Organizational barriers further complicate implementation, including lack of leadership support resulting in insufficient prioritization of IPC initiatives, poor communication regarding IPC policies creating confusion among staff and difficulty maintaining adherence to best practices, and absence of robust surveillance systems hindering timely identification and management of outbreaks (46). Patient-related barriers also contribute to prevention challenges when patients lack awareness about IPC measures and engage in behaviors increasing infection risk or demonstrate non-cooperation during treatment and failure to adhere to follow-up care instructions after discharge (47).

Overcoming these multifaceted barriers requires fostering a culture of safety within healthcare organizations that prioritizes IPC, encourages open communication, and allows staff to report lapses without fear of punishment, thereby enabling facilities to identify problem areas and implement timely corrective actions (45). Leadership commitment is essential for cultivating a culture of safety, with leaders demonstrating their commitment by providing adequate resources, offering training opportunities, communicating the importance of IPC protocols, and actively prioritizing IPC measures while setting examples that reinforce their importance among staff members(43). Continuous education and training remain crucial for improving adherence to IPC protocols, with regular training sessions updating healthcare workers on best practices and emerging trends in infection control, thereby empowering staff with the knowledge and skills needed to implement effective IPC measures consistently. Establishing mechanisms for healthcare workers to report near misses or breaches in infection control without fear of punishment is vital for fostering a safety culture, with constructive feedback focused on improving practices rather than assigning blame, and open dialogue about challenges allowing collaborative problem-solving that enhances compliance and improves overall IPC efforts (42). Recognition and support through acknowledging and rewarding adherence to IPC practices motivate healthcare workers to prioritize infection prevention in their daily routines, while ensuring adequate staffing levels and providing necessary resources demonstrate the organization's commitment to creating a safe environment for both patients and staff (43). Technology further enhances feedback mechanisms by providing real-time data on infection control practices through electronic monitoring systems that track hand hygiene compliance, alert staff to lapses, enable immediate corrective actions, and facilitate benchmarking against national standards or peer institutions, thereby adding motivation for improvement and highlighting areas for targeted intervention (39,48,49).

Limitation

This narrative review has several limitations that warrant acknowledgement. As a narrative review rather than a systematic review, the literature search and selection process were not exhaustive or formally structured, potentially leading to selection bias and omission of relevant studies that could provide additional perspectives on healthcare-associated infection prevention strategies. The inclusion of primarily English-language publications may have excluded valuable evidence and innovative practices reported in non-English literature, particularly from regions with unique healthcare challenges and successful infection prevention approaches. The review relied heavily on studies conducted in high-income countries, which may limit the generalizability of findings to low- and middle-income settings where resource constraints, infrastructure challenges, and infection epidemiology differ substantially. The rapidly evolving nature of healthcare-associated infection prevention, particularly regarding emerging pathogens, antimicrobial resistance patterns, and novel prevention technologies, means that some recommendations may require updating as new evidence becomes available.

Finally, the effectiveness of many infection prevention interventions is highly context-dependent, influenced by factors such as organizational culture, resource availability, staffing levels, and patient populations, which may affect the applicability of these best practices across diverse healthcare settings.

Conclusion

Healthcare-associated infections pose a major global threat to patient safety, affecting millions annually with high morbidity, mortality, and costs, yet 30-70% are preventable through evidence-based practices. Hand hygiene using the WHO Five Moments framework can reduce rates by 15-50%. Standard precautions, environmental cleaning, device bundles, surgical protocols, and antimicrobial stewardship further interrupt transmission and cut infections dramatically. Multimodal approaches combining system changes, training, monitoring, and culture shifts overcome barriers like resource limits. Strong leadership, surveillance, and safety-focused redesign ensure sustained success. Prioritize these practices as an ethical and economic imperative to adapt to emerging threats, engage staff, and achieve "first, do no harm."

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