The Review Of
DIABETIC
STUDIES
OPEN ACCESS

Catheterization To Wound Care: Procedure-Related Infections And Prevention Strategies In Nursing

Mohammed Ali Abdullah Almuallim (1), Fatimah Mohammed Alabdullah (2), Laila Rashed Alotaibi (3), Shurooq Ibraheam Alqubaisi (4), Saleh Mohammed Alqahtani (5), Saadeah Habeeb Almubarak (6), Khadijah Hani Ali Amslm (7), Sajidah Ali Yousef Albukhaytan (8), Maryam Ali Jawad Alsuraij (9), Shahad Khatim Aldawsari (10), Rawan Faleh Alazmi (11), Nawal Mohammed Abdullatif Alrudayni (12), Saud Obaid A Alanazi (13), Manal Abdulaziz Mayah Aldhafeeri (14), Taqiah Abduh Shaalan (15)

1. *Nursing Specialist, Eradah - Mental Health Complex Aldammam, Kingdom of Saudi Arabia. mohammadmoallem@hotmail.com*
2. *Nursing Specialist, MCH Alhasa, Kingdom of Saudi Arabia. Itzzfatoom673@gmail.com*
3. *Nursing specialist, Saudi Health Center, Ministry of Health, Kingdom of Saudi Arabia. 90.zhed@gmail.com*
4. *Nursing Technician, Baish General Hospital _GAZAN, Ministry of Health, Kingdom of Saudi Arabia. shroogsalami@gmail.com*
5. *Nursing Specialist, Eradah Complex and Mental Health in Dammam, Kingdom of Saudi Arabia. Saibalqahtani@moh.gov.sa*
6. *Nursing, Mch Alhasa, Kingdom of Saudi Arabia. soosoo1406m@gmail.com*
7. *Nursing Specialist, Abqaiq General Hospital, Kingdom of Saudi Arabia. Kamslm@moh.gov.sa*
8. *Nursing Specialist, PSBJH Alhasa, Kingdom of Saudi Arabia. Nurs-sj@hotmail.com*
9. *Nursing Technician, Psychiatric Hospital Alhasa, Kingdom of Saudi Arabia. Marraim03@gmail.com*
10. *Healthcare Technician, PCT, king khalid Hospital in Alkharj, Riyadh First Health Cluster, Kingdom of Saudi Arabia. sh.khatem00@gmail.com*
11. *Healthcare Technician, PCT, king khalid Hospital in Alkharj, Riyadh First Health Cluster, Kingdom of Saudi Arabia. rawanalazmi.f@gmail.com*
12. *Specialist Nurse, King Salman Hospital, First Health Cluster, Kingdom of Saudi Arabia.*
13. *Nursing Diploma, Eradah Complex for Mental Health in Riyadh, Ministry of Health, Kingdom of Saudi Arabia. saoalenzi@moh.gov.sa*
14. *Nursing Specialist, King Khalid General Hospital, Hafr Albatin health Cluster, Kingdom of Saudi Arabia.*
15. *Nursing, Prince Mohammed bin Nasser Hospital, Jazan Health Cluster, Jazan, Kingdom of Saudi Arabia.*

Abstract

Background: Healthcare-associated infections (HAIs), particularly procedure-related infections (PRIs) from nursing procedures like catheterization and wound care, affect 4-6% of acute care patients, leading to prolonged stays, morbidity, and costs exceeding $28-45 billion annually in the U.S. Common PRIs include catheter-associated urinary tract infections (CAUTIs) at 1-4 per 1000 catheter-days and central line-associated bloodstream infections (CLABSIs) at 1-5 per 1000 line-days, driven by biofilms, skin flora migration, and aseptic lapses. This review synthesizes evidence on nursing-centric prevention amid rising community and ambulatory risks.

Methods: A narrative synthesis of epidemiological data, clinical guidelines (CDC, WHO, ECDC), and studies on PRIs in catheterization, wound care, injections, and enteral feeding was conducted, drawing from global prevalence surveys, NHSN criteria, and prevention bundles. Pathogenesis, risk factors, and innovations like antiseptic dressings and AI surveillance were analyzed for nursing applicability.

Results: PRIs cause 10-20% excess morbidity, with CAUTIs at 23-25% of HAIs and CLABSIs mortality at 12-25%; bundles reduce rates by 40-70% via chlorhexidine antisepsis, sterile barriers, and daily audits. Wound care SSIs occur in 2-5% of cases, mitigated by pressure offloading and silver dressings; emerging nanotechnology and tele-nursing cut colonization by up to 90%. Nurse-led education boosts compliance by 50%.

Conclusions: Targeted bundles, stewardship, and innovations empower nurses to achieve 30-55% HAI reductions, bridging procedural gaps for safer outcomes across settings. Standardized global frameworks are essential.

Keywords catheter-associated infections, wound care, nosocomial infection, infection prevention, nursing practice, aseptic technique, clinical guidelines.

Introduction

Healthcare-associated infections (HAIs) represent a critical challenge in both hospital and community settings, manifesting as infections acquired during healthcare delivery that were not present or incubating at the time of service initiation. In acute care hospitals, HAIs affect approximately 4-6% of patients, with common types including catheter-associated urinary tract infections (CAUTIs), central line-associated bloodstream infections (CLABSIs), surgical site infections (SSIs), ventilator-associated pneumonia (VAP), and Clostridioides difficile infections, contributing to prolonged hospital stays, increased morbidity, and substantial mortality rates. Community settings see rising HAIs linked to outpatient procedures, home care, and ambulatory services, where lapses in sterile technique or device maintenance elevate risks, particularly among vulnerable populations like the elderly or immunocompromised; global point-prevalence surveys indicate HAIs occur in up to 7.1% of acute hospital patients in Europe and higher rates in low-resource areas. These infections impose a heavy economic burden, with U.S. estimates exceeding $28-45 billion annually in direct medical costs, underscoring the need for vigilant prevention across care continuums (Haque et al., 2018).

Procedure-related infections (PRIs) encompass a subset of HAIs directly linked to invasive nursing procedures such as catheterization, wound care, intravenous insertions, and dressing changes, classified by anatomical depth and timing per standardized taxonomies like those from the CDC's National Healthcare Safety Network (NHSN). Superficial incisional PRIs involve skin and subcutaneous tissues within 30 days post-procedure, evidenced by purulent drainage, microbial isolation, or clinical signs like erythema and pain; deep incisional types extend to fascia and muscle layers, while organ/space PRIs affect deeper structures, all tracked via NHSN criteria for surveillance consistency. Catheter-related PRIs, including CAUTIs and CLABSIs, are defined by positive cultures from catheter tips or blood with symptom onset tied to device use, often involving biofilms from skin flora like Staphylococcus aureus or gram-negative bacilli. Wound care PRIs arise from breaches during dressing changes or debridement, categorized similarly by CDC wound classes (clean, clean-contaminated, contaminated, dirty), highlighting procedural vulnerabilities in nursing practice (Zabaglo et al., 2024).

Epidemiological data reveal PRIs in nursing procedures affect millions annually, with CAUTIs comprising 23-25% of HAIs (prevalence 1-4 per 1000 catheter-days), CLABSIs at 1-5 per 1000 central line-days, and SSIs post-wound procedures at 2-5% overall, driving 10-20% excess morbidity including sepsis and organ failure. Mortality from catheter-related bloodstream infections reaches 12-25%, with wound care PRIs exacerbating readmissions by 30-50%; in ICUs, PRIs prolong stays by 7-21 days, amplifying costs to $33,000-$75,000 per CLABSI episode and billions system-wide. Low- and middle-income countries report 2-10-fold higher PRI rates due to resource gaps, while U.S. trends show modest declines via bundles but persistent hotspots in procedural nursing (Costabella et al., 2023).

Nurses serve as frontline gatekeepers in invasive procedures like catheterization and wound care, directly influencing infection transmission through hand hygiene compliance (often <50% in high-workload settings), aseptic technique during insertions, and vigilant device maintenance to curb microbial migration from skin hubs or contaminated dressings. Transmission dynamics involve endogenous skin flora colonizing devices via hubs (33-45% contaminated needleless connectors) or exogenous spread during multi-patient care, with nurses' adherence to bundles reducing CLABSIs by 40-70%; lapses amplify outbreaks, particularly in understaffed units. Specialized intravenous teams cut inflammation risks by 50%, emphasizing nurses' pivotal role in surveillance, early detection, and multidisciplinary oversight for zero-tolerance PRI environments (Hill et al., 2024).

Global guidelines from WHO, CDC, and ECDC provide robust frameworks for PRI prevention, with WHO's core components stressing multimodal strategies like hand hygiene, device bundles, and antimicrobial stewardship to achieve 30-55% HAI reductions. CDC's NHSN protocols mandate surveillance of catheter and SSI metrics, advocating chlorhexidine prep, minimal dwell times (<6 days for peripherals), and daily necessity reviews; ECDC's ICU surveillance integrates process indicators like hub disinfection (scrub-the-hub for 15 seconds). Recent updates incorporate post-COVID adaptations, such as enhanced PPE for aerosol procedures, urging national adoption for harmonized policy (Plachouras et al., 2018).

This review aims to synthesize evidence on PRIs spanning catheterization to wound care, delineating nursing-centric prevention strategies to mitigate prevalence, morbidity, and costs; its significance lies in bridging procedural gaps for evidence-based protocols, empowering nurses amid rising HAIs and resource strains for safer patient outcomes.

Procedure-Related Infections

Procedure-related infections (PRIs) represent a distinct subset of healthcare-associated infections (HAIs), specifically linked to invasive nursing procedures such as catheterization, wound care, and device insertions, whereas general HAIs encompass a broader spectrum of nosocomial infections acquired during healthcare delivery that were neither present nor incubating at admission, typically manifesting 48-72 hours post-admission or within 30 days post-discharge. PRIs are procedure-centric, arising directly from breaches in aseptic technique, device contamination, or procedural manipulations during nursing interventions like urinary catheterization or intravenous line placements, contrasting with HAIs that may stem from environmental cross-contamination, surgical complications, or patient-to-patient transmission without direct procedural ties. This classification underscores the pivotal role of nursing practices in PRIs, where infections are often preventable through targeted procedural safeguards, unlike diffuse HAIs influenced by multifaceted hospital dynamics including antibiotic overuse and immune vulnerabilities (Paiva et al., 2021).

Common pathogens in PRIs span gram-positive bacteria like coagulase-negative staphylococci and Staphylococcus aureus from skin flora migrating along catheter surfaces, gram-negative bacilli such as Pseudomonas aeruginosa, Escherichia coli, Enterobacter cloacae, and Klebsiella species often acquired via hub contamination or environmental reservoirs, and fungal species including Candida tropicalis and other yeasts thriving in prolonged device use or immunocompromised states. In catheterization-related PRIs, gram-positives dominate early extraluminal infections from insertion site colonization, while gram-negatives and fungi prevail in intraluminal or late-onset cases linked to biofilm persistence and healthcare worker hand carriage. Wound care PRIs similarly feature polymicrobial profiles with Staphylococcus aureus as a primary gram-positive culprit alongside gram-negative opportunists like Acinetobacter and fungal invaders in moist, occluded environments, amplifying infection severity in nursing settings (Zhang et al., 2016).

Routes of transmission in nursing procedures primarily involve skin flora migration at insertion sites for short-term catheters, direct hub or connector contamination from unwashed hands or fluids during manipulations, hematogenous seeding from distant infections, and extraluminal ascent in urinary catheters via periurethral colonization or intraluminal reflux from drainage bags. In wound care, transmission occurs through procedural touch contamination, inadequate dressing changes exposing sites to airborne microbes, or cross-contamination via shared equipment, with nursing actions like catheter flushing or wound irrigation serving as critical vectors if asepsis lapses. Catheterization heightens risk via dual extraluminal (skin tract) and intraluminal (hub) pathways, exacerbated by prolonged dwell times, while wound procedures facilitate endogenous flora ingress or exogenous introduction during debridement (Su, 2025).

Patient factors influencing PRI susceptibility include advanced age, immunosuppression, diabetes, malnutrition (low albumin), prolonged hospitalization, and comorbidities like chronic wounds or underlying infections that impair immune clearance; procedural elements encompass device dwell time exceeding 7-15 days, emergency insertions without maximal barriers, improper antibiotic prophylaxis timing, and surgical duration; environmental contributors involve operating room contamination (fungi/bacteria >2 CFU), suboptimal air renewal, high humidity/temperature, and lapses in sterilization or hand hygiene compliance. In nursing contexts, patient frailty amplifies biofilm susceptibility during catheterization, while procedural haste in wound care heightens contamination risks, compounded by environmental microbial loads from unfiltered air or unclean surfaces. These interplay dynamically, with modifiable procedural and environmental factors offering prime intervention targets for nurses to mitigate overall vulnerability (Bucataru et al., 2023).

Biofilm formation in device-related PRIs initiates with microbial adhesion to catheter or wound device surfaces, progressing to extracellular polymeric substance matrix encasement that shields communities of gram-positives, gram-negatives, and fungi, fostering persistence and up to 1000-fold antibiotic resistance via metabolic dormancy, efflux pumps, and genetic exchange. In nursing procedures, biofilms on intravascular or urinary catheters emerge rapidly post-insertion, resisting host defenses and antimicrobials, with intraluminal dominance after day 7 driving recurrent bacteremia; wound dressings similarly harbor biofilms if moisture persists, complicating healing. Microbial resistance escalates through plasmid transfer in dense biofilm consortia, particularly multidrug-resistant gram-negatives like Pseudomonas, necessitating device removal and underscoring nursing roles in early detection and prevention via aseptic protocols (Mishra et al., 2024).

Catheterization-Associated Infections

Catheterization-associated infections represent a significant challenge in nursing practice, stemming from the invasive nature of indwelling devices that provide a conduit for microbial entry into sterile body compartments, leading to substantial morbidity, prolonged hospital stays, increased healthcare costs, and elevated mortality risks, particularly when progressing to systemic complications like bacteremia or sepsis. In urinary catheterization, the indwelling Foley catheter disrupts the uroepithelium's protective mucopolysaccharide layer through mechanical irritation and trauma, fostering bacterial adhesion, while the constant urine flow and biofilm formation on the catheter surface create an ideal niche for pathogen persistence and ascension to the kidneys, often exacerbated by fibrinogen deposition from catheterization-induced inflammation that binds to uropathogens expressing specific adhesins. Vascular catheterization, whether peripheral intravenous lines or central venous catheters, similarly enables skin flora migration along the external catheter surface or hub contamination internally, culminating in biofilm-embedded colonies that shield bacteria from antibiotics and host defenses, with central lines posing higher risks due to their proximity to major vessels and prolonged dwell times. These infections underscore the critical role of nursing in implementing evidence-based protocols to mitigate risks throughout the catheterization lifecycle, from aseptic insertion to timely removal (Werneburg, 2022).

Urinary catheterization-associated urinary tract infections (CAUTIs) arise through complex pathophysiological mechanisms where the catheter serves as a nidus for bacterial colonization, beginning with periurethral contamination by gastrointestinal flora that ascends via the catheter lumen or external surface, traumatizing the bladder mucosa and eliciting a robust inflammatory response that deposits fibrinogen a key opsonin turned pathogen scaffold onto the catheter, enabling uropathogens to adhere, proliferate, and form protective biofilms that resist immune clearance and antimicrobial penetration, often leading to persistent bacteriuria, crystalline encrustations from urease-producing organisms, and potential pyelonephritis. Common causative agents include Escherichia coli (predominant at 23-25% in many cohorts but up to 75% in some uncomplicated cases transitioning to complicated), Klebsiella pneumoniae (around 10%), Enterococcus species (13-14%, favored by fibrinogen-binding pili like EbpA in E. faecalis), Pseudomonas aeruginosa (10%), Proteus mirabilis (4-5%, notorious for urease-driven crystalline biofilms), and Candida species (17-18%, thriving on fibrinogen-coated surfaces), with multidrug-resistant strains like ESBL-producers amplifying treatment challenges in catheterized patients. Incidence escalates dramatically with dwell time at 3-7% daily bacteriuria risk and up to 80% for short-term and nearly 100% for prolonged use yielding 1-7.78 infections per 1000 catheter-days in ICUs or long-term care, clinical outcomes encompassing asymptomatic bacteriuria (common but risky for bacteremia in 3%), symptomatic cystitis, urosepsis with 2-4% bacteremia rates, increased mortality (threefold higher in bacteriuric patients), renal complications, and economic burdens exceeding billions annually, disproportionately affecting females, the elderly, diabetics, and immunocompromised individuals. Evidence-based prevention hinges on nursing-led strategies: aseptic insertion by trained personnel using smallest-gauge catheters with adequate lubrication to minimize trauma, maintenance of closed sterile drainage systems positioned below bladder level to avert reflux, daily meatal cleansing with soap/water or perineal agents, securement to prevent traction, prompt removal within 24 hours post-op or via nurse-driven protocols, staff education coupled with CAUTI surveillance/audits achieving up to 50% compliance gains, and alternatives like intermittent catheterization, external condom devices, or bladder scanners; antimicrobial-impregnated catheters (e.g., silver-alloy, nitrofurazone) show mixed short-term benefits but warrant judicious use amid resistance concerns, while bundles integrating these reduce rates by 37-50% without routine antibiotic prophylaxis, which fosters resistance (Willson et al., 2009).

Pathogenesis of catheter-related bloodstream infections (CRBSIs) in vascular access devices involves multifaceted routes: extraluminal colonization where skin flora like coagulase-negative staphylococci (Staphylococcus epidermidis) migrate 7-10 days post-insertion along the catheter-skin interface into the bloodstream, intraluminal hub contamination from repeated connector manipulations introducing pathogens like S. aureus or Gram-negatives, hematogenous seeding from distant infections, and biofilm development a hallmark tolerance mechanism where microbial communities encased in extracellular matrices (e.g., polysaccharide intercellular adhesin in staphylococci, alginate in P. aeruginosa) on catheter surfaces evade antibiotics (up to 1000-fold resistance), promote persistence, and shed emboli causing sepsis, with central lines (e.g., CVCs, PICCs) at higher risk than peripherals due to dwell time, larger lumens, and femoral/subclavian sites fostering skin flora ingress. Skin flora migration predominates early (coagulase-negative staphylococci 30-40%, S. aureus 10-20%), hub contamination later via breaches in asepsis, and biofilms initiated within hours exacerbate by providing reservoirs for recurrent bacteremia, thrombogenicity enhancing colonization, and Candida favoring silicone over polyurethane; peripheral lines, though less severe, contribute via needlestick hubs and similar biofilms, with overall CRBSI rates 1-5/1000 catheter-days in ICUs. Prevention strategies emphasize maximal sterile barrier precautions (MSBP: cap, mask, gown, gloves, full-body drape) during insertion slashing risks by 50-70%, chlorhexidine gluconate (CHG) 2% skin antisepsis outperforming povidone-iodine with sustained activity, site rotation (prefer subclavian over jugular/femoral for non-tunneled CVCs), antimicrobial-impregnated catheters (CHG-silver sulfadiazine, minocycline-rifampin) reducing colonization/CRBSI by 40-60% in high-risk settings, CHG dressings/locks minimizing hub/skin recolonization, daily CHG baths in some ICUs, and ultrasound guidance minimizing insertion trauma/attempts. Nursing education via simulation/training boosts compliance (e.g., hand hygiene, aseptic technique) by 25-100%, while audit systems with real-time feedback, bundle adherence checklists (insertion/maintenance bundles reducing CLABSI 40-70%), surveillance of rates/appropriateness, and multidisciplinary rounds ensure sustainability, with prompt removal, peripheral priority for short-term needs, and no routine site changes unless indicated (Safdar et al., 2014).

Wound-Related Infections in Nursing Practice

Surgical site infections represent a significant complication in perioperative nursing, occurring in 0.5% to 3% of surgical patients and extending hospital stays by 7 to 11 days, with perioperative nurses playing a pivotal role through adherence to sterile technique to minimize microbial contamination from endogenous flora. Sterile technique involves establishing and maintaining a sterile field via meticulous hand hygiene, proper gowning, gloving, instrument handling, and immediate correction of breaches, as operating room nurses oversee these processes amid challenges like rushed scheduling, excessive traffic, staff shortages, and non-compliance by team members, which heighten emotional stress and infection risk. Patient-related risk factors such as obesity impair wound perfusion and increase tissue tension, diabetes compromises immune response through hyperglycemia, and malnutrition delays healing via impaired collagen synthesis and immune function, necessitating preoperative optimization like glycemic control below 150 mg/dL, nutritional screening, and decolonization with intranasal antistaphylococcal agents for high-risk cases. Dressing selection favors advanced options like hydrocolloids or silver-impregnated products over standard gauze for exudate management and barrier protection, with changes ideally at 48 hours post-closure to reduce bioburden rather than prolonged in situ application beyond 4.5 days, which triples infection risk, while evidence shows no definitive superiority in SSI reduction from dressings alone but benefits in moisture balance. Evidence-based protocols for wound cleansing emphasize intraoperative irrigation with aqueous antiseptics like chlorhexidine gluconate plus alcohol over saline or antibiotics to flush debris and reduce bacterial load by up to 50%, alongside normothermia maintenance above 36°C via active warming and avoiding razors for hair removal in favor of clippers, with negative pressure wound therapy post-closure further lowering rates from 15% to 9.7% by promoting drainage and microdebridement (Seidelman et al., 2023).

Distinguishing colonization from infection in chronic ulcers and pressure injuries is critical in nursing practice, as high bacterial loads in colonized wounds delay healing without systemic signs like fever or leukocytosis, whereas true infection involves tissue invasion evidenced by erythema, edema, pain, and purulent discharge, affecting 5% to 80% of cases depending on depth, duration, and host factors like immobility or ischemia. The wound microbiome in chronic ulcers features polymicrobial biofilms dominated by anaerobes, Proteobacteria, and Staphylococcus species, fostering antimicrobial resistance such as multidrug-resistant coagulase-negative staphylococci and ESBL-producers, particularly in spinal cord injury patients, where diabetes and obesity exacerbate poor perfusion and create reservoirs for secondary infections. Prevention strategies center on pressure offloading through repositioning every 2 hours, specialty mattresses, and heel elevation to redistribute forces, combined with moisture management using absorbent dressings and barrier creams for incontinence-associated dermatitis, alongside daily skin inspections via sub-epidermal moisture scanners over visual assessment alone for early detection. Advanced wound care technologies like negative pressure wound therapy at 75-125 mmHg intermittent settings enhance granulation and reduce edema, silver dressings release ions to disrupt biofilms and combat resistance, and bioengineered skin substitutes such as acellular matrices or growth factor-impregnated scaffolds promote re-epithelialization while minimizing rejection risks compared to autografts (Binsuwaidan et al., 2023).

Other Procedure-Linked Infections

Injections and infusion therapy represent critical nursing procedures prone to procedure-related infections due to unsafe practices such as needle reuse, multi-patient use of syringes, and contamination of vials or infusion lines, which facilitate the transmission of bloodborne pathogens like hepatitis B, C, and HIV, as well as bacterial agents leading to bloodstream infections. Contamination risks escalate when healthcare providers fail to adhere to aseptic techniques, such as not disinfecting vial septa with alcohol prior to access or employing the same needle-syringe apparatus across patients, resulting in outbreaks documented in clinical settings where up to 80% of hospitalized patients receive IV therapy and are often immunocompromised, amplifying susceptibility. Prevention hinges on rigorous aseptic preparation, including single-use of sterile needles and syringes, exclusive dedication of single-dose vials to individual patients to avoid preservative-lacking multi-dose risks, and needle safety engineered devices that prevent recapping injuries, alongside staff education to ensure compliance rates exceeding 90% in post-intervention audits for elements like multidose vial policies and safe sharps disposal (Kottapalli et al., 2023).

Enteral feeding tubes and tracheostomy care are associated with significant infection burdens, primarily through aspiration pneumonia, where gastric contents reflux into the respiratory tract, compounded by biofilm formation on tube surfaces harboring pathogens like Pseudomonas aeruginosa, Klebsiella, Staphylococcus, and Acinetobacter that evade host defenses and promote ventilator-associated pneumonia with prevalence up to 95% in tube-fed patients and mortality rates of 17-62%. Biofilms develop rapidly on endotracheal and tracheostomy tubing due to microbial adhesion and extracellular matrix production, with Pseudomonas dominating profiles in tracheostomy tubes ($p<0.0001$ higher prevalence), facilitating persistent colonization that withstands routine cleaning and contributes to lower respiratory infections via microaspiration during feeding or suctioning. Disinfection protocols mandate meticulous hand hygiene, sterile gloves, and PPE use before manipulation, alongside closed suctioning systems to minimize hypoxia and contamination, regular tube site cleaning with chlorhexidine or saline, elevation of bed head to 30-45 degrees for enteral feeds to curb reflux, and vigilant monitoring for stoma redness or purulent secretions, with tracheal aspirate culturing recommended for guiding antimicrobial therapy in suspected infections (Deshmukh-Reeves et al., 2025).

Nursing procedures in ambulatory and home-care settings introduce unique infection control challenges, including inconsistent environmental sterility, limited access to advanced equipment, and reliance on patients or caregivers with variable training, heightening risks for wound infections, catheter-associated urinary tract infections, and pneumonia from breaches in asepsis during dressing changes, IV administrations, or tube management. Factors exacerbating these include patient comorbidities like diabetes, dehydration, or immunosuppression that impair immunity, compounded by behavioral lapses such as poor hand hygiene, non-adherence to medication regimens, and inadequate wound care, necessitating tailored risk assessments by home care nurses focusing on entry points like IV lines, Foley catheters, and tracheostomies. Mitigation strategies emphasize comprehensive education for patients and caregivers on aseptic non-touch techniques, handwashing protocols, recognition of infection signs (e.g., fever, erythema, purulent drainage), proper storage of supplies to prevent contamination, scheduled follow-ups with multidisciplinary teams including infection disease specialists, and use of barriers like gloves and dedicated single-patient equipment to bridge the gap between hospital standards and home realities (Dowding et al., 2020).

Infection Prevention Principles in Nursing Procedures

Infection prevention principles in nursing procedures form the cornerstone of reducing procedure-related infections, particularly in high-risk interventions from catheterization to wound care, by integrating evidence-based strategies that minimize microbial transmission and promote patient safety. Standard precautions serve as the foundational framework, encompassing hand hygiene performed with alcohol-based rubs or soap and water before and after patient contact, use of personal protective equipment (PPE) such as gloves, gowns, masks, and eye protection based on anticipated exposure risks, and aseptic technique to maintain sterility during invasive procedures like catheter insertions or wound dressings. These measures address the recognition that all bodily fluids, secretions, and excretions may contain transmissible pathogens, thereby preventing healthcare-associated infections (HAIs) such as catheter-associated urinary tract infections (CAUTIs) and central line-associated bloodstream infections (CLABSIs). Device-related infection prevention bundles further enhance these principles by combining multiple interdependent interventions performed reliably together, such as chlorhexidine skin antisepsis, maximal sterile barriers during insertion, daily review of device necessity, and prompt removal when no longer indicated, which have demonstrated significant reductions in infection rates across nursing settings. Sterilization and disinfection procedures for equipment ensure critical items contacting sterile tissue are sterilized via steam or ethylene oxide, semicritical items like endoscopes receive high-level disinfection, and noncritical surfaces undergo low-level disinfection following thorough cleaning, with nurses responsible for verifying reprocessing protocols to avert outbreaks. Prophylactic antimicrobial measures, guided by stewardship responsibilities, involve judicious use of antibiotics only when evidence supports their benefit, such as short-course prophylaxis for specific procedures, while nurses monitor for appropriate dosing, duration, and de-escalation to combat resistance; this stewardship role extends to education, surveillance, and multidisciplinary collaboration to optimize outcomes and reduce Clostridium difficile infections (Hill et al., 2024).

Standard precautions in nursing procedures universally apply to all patients regardless of perceived infection status, forming a robust barrier against procedure-related infections by assuming all blood and body fluids are potentially infectious, thus mandating rigorous hand hygiene as the primary intervention executed at five key moments including before touching a patient, after body fluid exposure risk, and after touching the patient alongside gloving for anticipated contact, gowning for splashes, and masking with eye protection during high-risk aerosol-generating activities like wound irrigation or catheter manipulation. Aseptic technique amplifies these by designating sterile fields, using sterile gloves and instruments for breaches of skin integrity, and avoiding contamination through non-touch methods, which collectively reduce HAIs by up to 50% in procedural settings from urinary catheterization to surgical wound care. Environmental controls complement this through respiratory hygiene, sharps safety via engineering controls, and safe injection practices, ensuring nurses mitigate cross-contamination risks in dynamic care environments; compliance challenges are addressed via ongoing education and audits, yielding sustained improvements in patient outcomes (Hill et al., 2024).

Device-related infection prevention bundles represent a synergistic approach in nursing, targeting high-burden HAIs associated with indwelling devices like central venous catheters, urinary catheters, and ventilators through multifaceted, evidence-based elements performed as a unit to achieve compliance rates exceeding 95%, resulting in dramatic declines in CLABSIs (from 2.7 to 0 per 1000 catheter-days in some ICUs) and CAUTIs. For catheterization, bundles incorporate hand hygiene, full-body sterile drapes, chlorhexidine gluconate (CHG) >0.5% antisepsis allowing dry time, preferred site selection (subclavian over femoral), and daily necessity audits with prompt removal; in wound care, analogous bundles emphasize site preparation, sterile dressings, and surveillance for early signs of infection. Implementation success hinges on nurse-led checklists, multidisciplinary training, and feedback loops, with studies confirming reduced morbidity, shorter hospital stays, and cost savings, underscoring bundles' role in transitioning from reactive to proactive infection control in procedural nursing (Iordanou et al., 2022).

Sterilization and disinfection procedures for nursing equipment adhere to Spaulding's classification, ensuring critical devices (e.g., surgical instruments used in wound debridement) achieve complete microbial kill via autoclaving at 121-134°C or gas plasma, semicritical items (e.g., respiratory tubing in procedural setups) undergo high-level disinfection with glutaraldehyde or peracetic acid post-cleaning, and noncritical surfaces (e.g., bedpans or overbed tables) receive low- to intermediate-level agents like hypochlorite or quaternary ammonium compounds, with nurses verifying indicators, storage integrity, and expiration to prevent recontamination. Pre-cleaning removes organic debris via enzymatic detergents and mechanical friction, followed by validated cycles monitored by biological, chemical, and mechanical indicators, addressing lapses that contribute to procedure-related outbreaks; in catheterization labs or wound clinics, single-use devices minimize risks where reprocessing feasibility is limited. Regulatory adherence to guidelines from CDC and WHO, coupled with nurse training in rapid cycle monitoring, sustains efficacy amid evolving microbial threats (Mohapatra, 2017).

Prophylactic antimicrobial measures in nursing procedures balance infection risk reduction with stewardship imperatives, limiting agents like cefazolin to clean-contaminated cases (e.g., pre-catheterization in high-risk urology) within one hour of incision, timed to peak serum levels, and discontinued post-24-48 hours, while nurses assess allergies, renal function for dosing, and signs of superinfection to avert resistance. Stewardship responsibilities empower nurses as frontline stewards through prospective audit, feedback on prescriptions, de-escalation based on cultures, and promotion of non-antimicrobial alternatives like CHG baths, yielding 20-30% reductions in broad-spectrum use and CDI rates; in wound care, topical agents supplant systemic where feasible. Multidisciplinary ASPs integrate nurse documentation of indications, duration tracking via electronic tools, and education to foster a culture of restraint, preserving efficacy for future needs amid global resistance crises (Camerini et al., 2024).

Emerging Challenges and Innovations

Emerging Challenges and Innovations in procedure-related infection prevention represent a critical frontier in nursing practice, where antimicrobial resistance (AMR) poses profound implications for catheterization, wound care, and associated interventions. AMR, driven by selective pressure from widespread antibiotic use in healthcare settings, complicates treatment of common procedure-related infections such as catheter-associated urinary tract infections (CAUTIs) and central line-associated bloodstream infections (CLABSIs), leading to prolonged hospital stays, increased morbidity, and higher mortality rates among vulnerable patients under nursing care. Nurses, as frontline stewards of antimicrobial use, must navigate these challenges by integrating stewardship principles into daily practices, including vigilant monitoring of infection signs during catheter insertions and wound dressings, while advocating for de-escalation of broad-spectrum antibiotics based on culture results; however, persistent gaps in nurse knowledge and adherence exacerbate resistance patterns observed in pathogens like coagulase-negative staphylococci and Klebsiella pneumoniae prevalent in neonatal and ICU environments. Recent studies underscore the urgency for nursing-led strategies, such as enhanced hand hygiene, proper personal protective equipment utilization, and environmental decontamination, to mitigate AMR drivers like inadequate disinfection of medical equipment and high-traffic ward conditions, which significantly elevate contamination risks in procedure-heavy settings (Pérez-Baena et al., 2025).

Antiseptic dressings, advanced catheter coatings, and nanotechnology barriers offer transformative innovations tailored to nursing workflows in preventing procedure-related infections during catheterization and wound management. Antiseptic dressings, particularly those impregnated with chlorhexidine, applied at central venous catheter (CVC) sites, substantially reduce microbial colonization and catheter-related bloodstream infections (CRBSIs) by creating a sustained antimicrobial barrier on the skin, allowing nurses to maintain site integrity with fewer dressing changes and lower infection incidence in high-risk neonates and adults. Catheter coatings incorporating antibiotics or antiseptics further diminish biofilm formation a primary precursor to infections demonstrating reduced colonization rates in clinical trials, though nurses must balance these with stewardship to prevent resistance emergence. Nanotechnology emerges as a promising frontier, with nanoparticle-based coatings and nano-engineered scaffolds enabling targeted antimicrobial release, enhanced mechanical strength in wound dressings, and evasion of immune clearance for prolonged efficacy in chronic wounds and indwelling devices; for instance, neutral-charge nanocarriers deliver agents directly to infection sites, accelerating healing in full-thickness defects while combating resistant biofilms on catheters. These technologies empower nurses to adopt proactive, evidence-based protocols, such as routine assessment of dressing adhesion and early detection of biofilm indicators, ultimately lowering overall infection burdens in catheterization and wound care trajectories (El Arab et al., 2025).

Artificial intelligence (AI) and electronic surveillance systems revolutionize infection monitoring in nursing by enabling real-time detection and predictive analytics for procedure-related threats in catheterization labs and wound care units. AI algorithms, leveraging machine learning and natural language processing on electronic health records (EHRs), analyze structured and unstructured data streams like vital signs, clinical notes, and lab results to identify early HAIs with superior sensitivity, outperforming manual surveillance and reducing alert fatigue by up to 99% through prioritized notifications tailored to nursing shifts. In ICUs and high-procedure environments, these tools facilitate continuous risk stratification for CLABSIs and wound infections, alerting nurses to anomalies such as rising inflammatory markers post-catheterization, thereby streamlining workflows and enhancing compliance with prevention bundles. Electronic surveillance further integrates whole-genome sequencing for outbreak tracking, preventing up to 40% of hospital-acquired transmissions by correlating procedure data with resistance profiles, positioning nurses as interpreters of AI outputs for timely interventions like device removal or cohorting. Nurses perceive these innovations positively for workload reduction, though challenges in clinician trust and data integration necessitate targeted training to fully harness AI in daily infection control (El Arab et al., 2025).

Tele-nursing and virtual care environments extend infection control strategies beyond physical bedside limitations, particularly for remote monitoring of catheterization sites and wound healing trajectories. Telemedicine platforms, including video assessments and mobile apps, minimize in-person contacts during pandemics or resource-scarce settings, reducing PPE consumption and exposure risks while enabling nurses to conduct hourly virtual checks best practice for high-acuity patients with high acceptability among clinical teams. Systematic reviews confirm telemedicine's efficacy in slashing healthcare-associated infection rates through real-time surveillance of dressing integrity, early inflammation detection at central line sites, and protocol adherence feedback, such as improved hand hygiene in long-term care linked to procedure-related wounds. Nurses adapt workflows by batching virtual interventions, supporting outbreak containment via remote triage and infectious disease consultations, which lower infection incidence without compromising care quality. Challenges like technical support needs and training underscore the importance of IT integration, yet tele-nursing fortifies nursing-led prevention in hybrid models blending catheterization oversight with virtual wound follow-ups (Safaeinili et al., 2021).

Future Directions

Future research on novel materials and prophylactic technologies for preventing procedure-related infections in nursing holds immense promise, particularly in addressing biofilm formation on catheters and wound dressings, which remains a primary driver of healthcare-associated infections like catheter-associated urinary tract infections (CAUTIs) and surgical site infections. Advances in nanostructured coatings, such as silver nanoparticles (AgNPs) and antimicrobial peptides (AMPs), demonstrate superior efficacy in disrupting bacterial adhesion and quorum sensing, with recent studies showing sustained release of Ag^+ ions that inhibit pathogens like Escherichia coli and Pseudomonas aeruginosa for weeks, far outperforming traditional silver oxide coatings. Zwitterionic polymers and hydrophilic anti-biofouling surfaces create hydration barriers that prevent microbial attachment, while responsive hydrogels and nitric oxide-releasing systems target mature biofilms by inducing dispersion without fostering resistance, as evidenced in preclinical models where these technologies reduced colonization by up to 90% on silicone catheters. Bio-inspired textures mimicking shark skin or lotus leaves, combined with additive manufacturing like 3D printing, enable customized catheters with embedded sensors for real-time biofilm detection via pH or impedance changes, paving the way for "smart" devices that alert nursing staff to early contamination risks during routine care. Patent landscapes from 2014-2024 reveal surging innovations in multifunctional composites, including probiotic biofilms of non-pathogenic E. coli strains that competitively exclude uropathogens, and gold nanoclusters offering enhanced antimicrobial potency due to their ultra-small size, signaling a shift from passive antibiotic impregnation to active, self-renewing prophylactic surfaces. These developments address key limitations of current materials, such as short-term efficacy and cytotoxicity, by prioritizing biocompatibility and long-dwell performance, with clinical trials underway for chlorhexidine-impregnated gels and taurolidine locks showing halved infection rates in ICU settings. As antimicrobial resistance escalates, integrating machine learning-optimized coatings with quorum-sensing inhibitors like RNAIII peptides could revolutionize nursing protocols, minimizing procedure-related bacteremia and extending device lifespan in chronic wound care (Skok et al., 2025).

The impact of education and behavioral interventions on reducing procedure-related infections underscores the need for sustained, multimodal training programs tailored to nursing workflows, as standalone lectures often fail to achieve long-term adherence to aseptic techniques during catheterization and wound management. Recent scoping reviews highlight that repeated, hands-on simulations combined with audit-feedback cycles significantly boost compliance with hand hygiene and bundle protocols, yielding 20-50% drops in CAUTI rates, particularly when reinforced by leadership champions who model behaviors like maximal barrier precautions. Behavioral nudges, such as visual reminders and gamified apps tracking personal protective equipment (PPE) use, address cognitive biases in high-stress environments, with pre-post trials in pediatric units demonstrating improved taurolidine lock adoption and chlorhexidine gluconate (CHG) bathing adherence. Integrating interprofessional workshops fosters a culture of accountability, where nurses collaborate with physicians on catheter removal checklists, reducing unnecessary dwell times a modifiable risk factor responsible for 3-8% daily bacteriuria incidence. Digital platforms offering just-in-time training via QR codes on devices have shown promise in resource-limited settings, enhancing environmental hygiene and waste management practices while mitigating antimicrobial stewardship gaps. Future efforts should leverage artificial intelligence for personalized feedback, analyzing real-time video audits to correct micro-lapses in no-touch insertion, with evidence from ICU studies indicating sustained knowledge gains up to six months post-intervention. These strategies not only empower frontline nurses but also counteract the plateauing effects of one-off education by embedding behavioral science principles like habit formation and social norming, ultimately curbing procedure-related sepsis in vulnerable populations (Teixeira et al., 2025).

Frameworks for global standardization and cross-disciplinary collaboration are essential to harmonize infection prevention across diverse healthcare systems, tackling variations in catheterization protocols and wound care that perpetuate disparities in procedure-related infection rates worldwide. Initiatives like the WHO's core components for infection prevention emphasize multimodal bundles encompassing education, surveillance, and device management with meta-analyses confirming 49% risk reductions from standardized CHG preparations and maximal barriers. Cross-disciplinary teams integrating nursing, pharmacy, and biomedical engineering accelerate translation of innovations, as seen in value-based healthcare models where interprofessional audits halved healthcare-associated infections through shared antimicrobial stewardship. Establishing universal metrics via platforms like the National Healthcare Safety Network enables benchmarking, with recent surveys revealing university-wide awareness gaps that collaborative curricula can bridge, promoting consistent adoption of biofilm-active technologies. Global consortia, drawing from patent and bibliometric trends, advocate for open-access repositories of validated protocols, facilitating low-resource adaptations like silver-alloy catheters in high-burden regions. Future frameworks should incorporate digital twins for simulation-based standardization, uniting regulators, industry, and clinicians to prioritize patient safety outcomes over siloed practices (Corrado et al., 2025).

Conclusion

Procedure-related infections from catheterization to wound care remain a persistent threat in nursing practice, driving substantial morbidity, mortality, and economic burdens despite established prevention frameworks. Nurses, as frontline stewards, hold the key to mitigation through unwavering adherence to aseptic techniques, device bundles, and antimicrobial stewardship, which have demonstrated 40-70% reductions in infections like CAUTIs and CLABSIs when implemented consistently.

Emerging innovations such as antiseptic dressings, nanotechnology coatings, and AI-driven surveillance promise to further empower nursing protocols by targeting biofilms and enabling real-time risk prediction. Sustained multimodal education, global standardization, and interprofessional collaboration will be essential to overcome resistance challenges and translate these advances into equitable outcomes across care settings.

Ultimately, prioritizing evidence-based vigilance in every procedural interaction fosters safer patient trajectories, underscoring nursing's indispensable role in curbing HAIs amid evolving healthcare demands.

References

1. Binsuwaidan, R., Khan, M. A., Alzahrani, R. H., Aldusaymani, A. M., Almallouhi, N. M., Alsabti, A. S., Ali, S., Khan, O. S., Youssef, A. M., & Alnajjar, L. I. (2023). Prevalence of Multidrug-Resistant and ESBL-Producing Bacterial Pathogens in Patients with Chronic Wound Infections and Spinal Cord Injury Admitted to a Tertiary Care Rehabilitation Hospital. Antibiotics, 12(11), 1587. https://doi.org/10.3390/antibiotics12111587
2. Bucataru, A., Balasoiu, M., Ghenea, A. E., Zlatian, O. M., Vulcanescu, D. D., Horhat, F. G., Bagiu, I. C., Sorop, V. B., Sorop, M. I., Oprisoni, A., Boeriu, E., & Mogoanta, S. S. (2023). Factors Contributing

to Surgical Site Infections: A Comprehensive Systematic Review of Etiology and Risk Factors. Clinics and Practice, 14(1), 52–68. https://doi.org/10.3390/clinpract14010006
3. Camerini, F. G., Cunha, T. L., Fassarella, C. S., de Mendonça Henrique, D., & Fortunato, J. G. S. (2024). Nursing strategies in antimicrobial stewardship in the hospital environment: A qualitative systematic review. BMC Nursing, 23, 147. https://doi.org/10.1186/s12912-024-01753-y
4. Corrado, B., Cammarano, A., Dello Iacono, S., Renzi, E., Moretta, R., Mercurio, M. E., Ascione, L., Cummaro, A., Meglio, C., & Nicolais, L. (2025). A Comprehensive Review of Progress in Preventing Urinary Infections Associated with the Use of Urinary Catheters: A Dual Analysis of Publications and Patents. Infectious Disease Reports, 17(3), 64. https://doi.org/10.3390/idr17030064
5. Costabella, F., Patel, K. B., Adepoju, A. V., Singh, P., Attia Hussein Mahmoud, H., Zafar, A., Patel, T., Watekar, N. A., Mallesh, N., Fawad, M., Sathyarajan, D. T., & Abbas, K. (2023). Healthcare Cost and Outcomes Associated With Surgical Site Infection and Patient Outcomes in Low- and Middle-Income Countries. Cureus. https://doi.org/10.7759/cureus.42493
6. Deshmukh-Reeves, E., Shaw, M., Bilsby, C., & Gourlay, C. W. (2025). Biofilm Formation on Endotracheal and Tracheostomy Tubing: A Systematic Review and Meta-Analysis of Culture Data and Sampling Method. MicrobiologyOpen, 14(4), e70032. https://doi.org/10.1002/mbo3.70032
7. Dowding, D., Russell, D., Trifilio, M., McDonald, M. V., & Shang, J. (2020). Home care nurses' identification of patients at risk of infection and their risk mitigation strategies: A qualitative interview study. International Journal of Nursing Studies, 107, 103617. https://doi.org/10.1016/j.ijnurstu.2020.103617
8. El Arab, R. A., Almoosa, Z., Alkhunaizi, M., Abuadas, F. H., & Somerville, J. (2025). Artificial intelligence in hospital infection prevention: An integrative review. Frontiers in Public Health, 13. https://doi.org/10.3389/fpubh.2025.1547450
9. Haque, M., Sartelli, M., McKimm, J., & Abu Bakar, M. (2018). Health care-associated infections – an overview. Infection and Drug Resistance, 11, 2321–2333. https://doi.org/10.2147/IDR.S177247
10. Hill, B., Lamichhane, G., & Wamburu, A. (2024). Infection prevention and control: Critical strategies for nursing practice. British Journal of Nursing (Mark Allen Publishing), 33(17), 804–811. https://doi.org/10.12968/bjon.2024.0286
11. Iordanou, S., Papathanassoglou, E., Middleton, N., Palazis, L., Timiliotou-Matsentidou, C., & Raftopoulos, V. (2022). Device-associated health care-associated infections: The effectiveness of a 3-year prevention and control program in the Republic of Cyprus. Nursing in Critical Care, 27(4), 602–611. https://doi.org/10.1111/nicc.12581
12. Kottapalli, P., Podduturi, N. C. R., Aswini, G., Jyothi, S., & Naveen, A. (2023). Safe injection, infusion and medication-vial practices at a tertiary care centre: A quality improvement initiative. GMS Hygiene and Infection Control, 18, Doc03. https://doi.org/10.3205/dgkh000429
13. Mishra, A., Aggarwal, A., & Khan, F. (2024). Medical Device-Associated Infections Caused by Biofilm-Forming Microbial Pathogens and Controlling Strategies. Antibiotics, 13(7), 623. https://doi.org/10.3390/antibiotics13070623
14. Mohapatra, S. (2017). Sterilization and Disinfection. Essentials of Neuroanesthesia, 929–944. https://doi.org/10.1016/B978-0-12-805299-0.00059-2
15. Paiva, R. de M., Ferreira, L. de L., Bezerril, M. D. S., Chiavone, F. T. B., Salvador, P. T. C. de O., & Santos, V. E. P. (2021). Infection factors related to nursing procedures in Intensive Care Units: A scoping review. Revista Brasileira De Enfermagem, 74(1), e20200731. https://doi.org/10.1590/0034-7167-2020-0731
16. Pérez-Baena, M. J., Torres-Gonçalves, A., & Holgado-Madruga, M. (2025). Nursing-led strategy to combat antimicrobial resistance: Multi-method design. BMC Nursing, 24(1), 1177. https://doi.org/10.1186/s12912-025-03822-2
17. Plachouras, D., Lepape, A., & Suetens, C. (2018). ECDC definitions and methods for the surveillance of healthcare-associated infections in intensive care units. Intensive Care Medicine, 44(12), 2216–2218. https://doi.org/10.1007/s00134-018-5113-0

18. Safaeinili, N., Vilendrer, S., Williamson, E., Zhao, Z., Brown-Johnson, C., Asch, S. M., & Shieh, L. (2021). Inpatient Telemedicine Implementation as an Infection Control Response to COVID-19: Qualitative Process Evaluation Study. JMIR Formative Research, 5(6), e26452. https://doi.org/10.2196/26452
19. Safdar, N., O'Horo, J. C., Ghufran, A., Bearden, A., Didier, M. E., Chateau, D., & Maki, D. G. (2014). Chlorhexidine-Impregnated Dressing for Prevention of Catheter-Related Bloodstream Infection: A Meta-Analysis*. Critical Care Medicine, 42(7), 1703. https://doi.org/10.1097/CCM.0000000000000319
20. Seidelman, J. L., Mantyh, C. R., & Anderson, D. J. (2023). Surgical Site Infection Prevention: A Review. JAMA, 329(3), 244–252. https://doi.org/10.1001/jama.2022.24075
21. Skok, K., Bele, U., Pintar, Š., Peršin, Z., Kuzmič, K., Bračič, M., Fras Zemljič, L., & Maver, U. (2025). Urinary catheters: State of the art and future perspectives – a narrative review. Materials Today Bio, 34, 102225. https://doi.org/10.1016/j.mtbio.2025.102225
22. Su, L. (2025). Effectiveness of Nurse-Driven Protocols in Reducing Catheter-Associated Urinary Tract Infections: A Systematic Review and Meta-Analysis. Journal of Nursing Care Quality, 40(1), 39–45. https://doi.org/10.1097/NCQ.0000000000000811
23. Teixeira, J., Reis, N., Chawłowska, E., Rocha, P., Czech-Szczapa, B., Godinho, A. C., Bączyk, G., Agrelos, J., Jaracz, K., Fontoura, C., Lucas, P., & Pinto, M. R. (2025). Current Approaches on Nurse-Performed Interventions to Prevent Healthcare-Acquired Infections: An Umbrella Review. Microorganisms, 13(2), 463. https://doi.org/10.3390/microorganisms13020463
24. Werneburg, G. T. (2022). Catheter-Associated Urinary Tract Infections: Current Challenges and Future Prospects. Research and Reports in Urology, 14, 109–133. https://doi.org/10.2147/RRU.S273663
25. Willson, M., Wilde, M., Webb, M.-L., Thompson, D., Parker, D., Harwood, J., Callan, L., & Gray, M. (2009). Nursing Interventions to Reduce the Risk of Catheter-Associated Urinary Tract Infection: Part 2: Staff Education, Monitoring, and Care Techniques. Journal of Wound Ostomy & Continence Nursing, 36(2), 137. https://doi.org/10.1097/01.WON.0000347655.56851.04
26. Zabaglo, M., Leslie, S. W., & Sharman, T. (2024). Postoperative Wound Infections. In StatPearls [Internet]. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK560533/
27. Zhang, L., Cao, S., Marsh, N., Ray-Barruel, G., Flynn, J., Larsen, E., & Rickard, C. M. (2016). Infection risks associated with peripheral vascular catheters. Journal of Infection Prevention, 17(5), 207–213. https://doi.org/10.1177/1757177416655472