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Nurses' Role in Preventing Catheter-Related Bloodstream Infections: Evidence-Based Approaches

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ABSTRACT

Catheter-related bloodstream infections (CRBSIs) are a significant healthcare challenge, particularly in intensive care units (ICUs) and emergency departments (EDs). Despite the availability of evidence-based guidelines for CRBSI prevention,

translating these recommendations into practice remains a persistent issue. This comprehensive review explores the epidemiology, pathophysiology, diagnosis, and preventive strategies for CRBSIs, emphasizing the critical role of nurses in implementing infection control measures. Key preventive strategies include proper hand hygiene, optimal catheter insertion site selection, use of maximal sterile barriers, appropriate catheter dressing, judicious use of antimicrobial ointments, and regular replacement of administration sets. Nurse education, training, and adherence to guidelines are paramount in reducing CRBSI incidence. Successful interventions have demonstrated that simple, cost-effective measures, such as staff education, performance feedback, and process control, can lead to significant reductions in infection rates. However, barriers to implementation, including staff resistance, resource limitations, institutional policy variations, and time constraints, must be addressed to ensure sustained improvements. By fostering a collaborative culture, empowering nurses, and bridging the gap between evidence and practice, healthcare institutions can effectively reduce CRBSI rates, enhance patient safety, and improve clinical outcomes.

Keywords: Nurses, Catheter-Related Bloodstream Infections

Introduction

Intravascular catheters are integral to delivering life-saving therapies across all nursing disciplines. However, these devices can also serve as conduits for pathogens to enter the bloodstream. In both the United States (US) and Europe, millions of intravascular catheters are utilized annually, placing substantial numbers of patients at risk for catheter-related bloodstream infections (CRBSIs). Patients with indwelling intravascular catheters are inherently at risk, but those in intensive care units (ICUs) are especially vulnerable compared to individuals admitted to general wards (Blot et al., 2015). Additionally, patients admitted through emergency departments (EDs) face heightened risk due to frequent and often less meticulous catheter handling in urgent settings. While all types of intravascular catheters pose a risk for CRBSIs, central venous catheters are more commonly associated with severe infections than peripheral ones (Collignon, 2016).

Intravascular catheters are frequently necessary for the treatment of individuals who are critically ill. They support the safe administration of intravenous fluid resuscitation, the safe administration of medications, and the monitoring of hemodynamic parameters in the treatment of patients with syndromes such as pulmonary hypertension, decompensated heart failure, septic shock, and cardiogenic shock. Intravascular catheters have advantages, but they can also act as entry points for systemic and localized bloodstream infections. Because of this, a lot of work has been done to lower the frequency of bloodstream infections via Intravascular catheters.

Intravenous catheter insertions are among the most often performed procedures on hospitalized patients, which leaves them vulnerable to both infectious and noninfectious problems. Depending on how severe the symptoms are, intravascular catheter problems are divided into minor and major categories. Catheter occlusions, unintentional removals, pain, and needle phobia, dread of sharp

catheters—are examples of minor problems. Major problems, on the other hand, include phlebitis, infection, extravasation, and even skin damage, which are typically more serious. Adult intravascular catheter use has been the subject of published research using a variety of descriptive, correlational, and randomized controlled trial techniques.

According to a systematic review, the incidence of infection was 0.1-0.2/100 catheter days or 0.1-0.2/100 catheters. Others found that the frequency of phlebitis was 6.2%, the rate of leakage was 12.4%, and the rate of infiltration was 7.4%. They also came to the startling conclusion that the risk of phlebitis increased by 4.4 times when PIVC catheters were restarted. Furthermore, it has been discovered that the length of the patient's stay as well as the drug or infusion that they got via Intravascular catheters are directly linked to peripheral intravenous (IV) phlebitis.

CRBSIs, a prevalent nosocomial infection, are linked to considerable morbidity, mortality, extended hospital stays, and increased healthcare costs (Pittet et al., 1994; Rello et al., 2000; Dimick et al., 2012). Despite high incidence rates, CRBSIs are the most preventable hospital-acquired infection. Reducing CRBSI rates to enhance patient safety and care quality is imperative. Consequently, organizations like the Centers for Disease Control and Prevention (CDC), the Society of Healthcare Epidemiologists of America, and the Infectious Disease Society of America have published evidence-based guidelines for CRBSI prevention. These recommendations are supported by robust clinical trials, systematic reviews, or meta-analyses, categorized into levels of evidence ranging from "category IA" (strongly recommended) to "no recommendation" (unresolved issues), based on scientific data, theoretical rationale, feasibility, and economic considerations. Nevertheless, despite available evidence, a gap persists between optimal evidence and actual practice (Berenholtz et al., 2014).

This paper aims to provide a comprehensive, structured, and practical manual for ICU and ED nurses and other healthcare providers caring for patients with indwelling catheters. It seeks to integrate infection prevention and control measures into daily practices, covering various aspects such as epidemiology, pathophysiology, diagnosis, management, and preventive strategies. It also explores methods to enhance adherence to recommendations and highlights successful quality improvement initiatives. Unlike previous reviews with a predominantly medical focus, this work emphasizes a nursing-centered perspective, updating the expanding literature on CRBSI prevention.

Pathophysiology and Diagnosis

The pathophysiology of CRBSIs encompasses four primary mechanisms: (i) extraluminal colonization of the catheter by microorganisms from the skin, (ii) hematogenous seeding, (iii) intraluminal colonization of catheter hubs and lumens, and (iv) contamination of infusates. Infusate-related bloodstream infections (BSIs) are diagnosed by isolating the same microorganism from both the infusate and separate percutaneous blood cultures, without other infection sources. Infusate-related BSIs, although rare, manifest with sudden systemic infection symptoms soon after infusion initiation due to contaminated intravenous fluids. Such occurrences warrant immediate cessation of the infusate. The most common CRBSI cause in patients with indwelling

catheters is colonization of catheter hubs and the skin surrounding the insertion site, whereas infusate-related infections are uncommon (Atela et al., 2017). Therefore, preventive measures should primarily target minimizing colonization at these sites.

Timely intervention, including prompt catheter removal and initiation of suitable antimicrobial therapy, significantly improves outcomes, making early CRBSI recognition critical. However, clinical signs, such as fever, chills, hypotension, and purulent discharge near the catheter site, often lack specificity and sensitivity, complicating diagnosis (Vandijck et al., 2006). Patients undergoing renal replacement therapy (RRT), which necessitates additional catheter insertion, are particularly susceptible to infection due to potential hub and lumen contamination (Hoste et al., 2007; Oeyen et al., 2007). Chronic renal failure patients admitted to the ED for RRT are especially vulnerable due to compromised immunity, necessitating heightened vigilance (Vandijck et al., 2007). Since Staphylococcus aureus is a leading cause of RRT-related BSIs, monitoring and reducing nasal carriage through topical ointments can lower CRBSI risk from this pathogen (Almirall et al., 2019; Boelaert et al., 2016). For suspected CRBSI cases, two sets of blood cultures, including at least one percutaneous sample, should be obtained before starting empirical antimicrobial therapy to optimize pathogen identification (Dellinger et al., 2014).

Simple, practical interventions can significantly reduce CRBSI risk. Subsequent sections of this review will discuss preventive strategies focusing on catheter maintenance, particularly emphasizing actions within the nursing domain.

Preventive Strategies

The most up-to-date guidelines for the prevention of intravascular catheter-related bloodstream infections (CRBSIs) aim to minimize infectious complications associated with catheter use. However, these recommendations must be adapted to the context of each institution, taking into account factors such as patient case mix, the institution's experience with CRBSIs, and the availability of personnel trained in the placement and maintenance of intravascular devices.

Site of Insertion

The choice of catheter insertion site is critical due to its influence on the likelihood of developing a CRBSI. The risk of catheter colonization and subsequent CRBSI is notably higher when the catheter is inserted into the internal jugular vein or femoral vein compared to the subclavian vein (Collignon et al., 2018). Additionally, the necessity for vascular access and the potential for non-infectious complications, such as trauma, bleeding, or pneumothorax, must be carefully weighed.

Skin Antisepsis

Numerous studies have assessed the impact of antiseptic agents on the incidence of CRBSIs. Evidence shows that chlorhexidine is more effective than povidone-iodine in reducing microbial colonization at catheter insertion sites (Maki et al., 2011). While tincture of iodine and 70% alcohol-based agents are alternatives,

aqueous 2% chlorhexidine is the preferred agent for skin preparation prior to catheter insertion and for ongoing catheter care (O'Grady et al., 2017). The effectiveness of antiseptics depends on adequate contact time and allowing the agent to air-dry. In the US, povidone-iodine is the most used antiseptic due to the lack of FDA approval for alcoholic and aqueous chlorhexidine products, whereas both are available in Europe and Canada. The use of acetone or ether for degreasing the skin is discouraged, as these solvents do not lower colonization or infection rates and have been associated with pain, irritation, and inflammation (Maki & McCormack, 2017).

Full Barrier Precautions

The insertion of central venous catheters requires the use of full sterile barrier precautions, including masks, caps, sterile gloves, gowns, and drapes, to minimize the risk of iatrogenic CRBSIs (Hu et al., 2014; Young et al., 2016). While nurses are not directly involved in the placement of central venous catheters, they play a vital role in observing the procedure and intervening if breaches in protocol occur (Berenholtz et al., 2014). The use of maximal sterile barriers should be standard practice, although the associated costs and workload should be considered for arterial and peripheral catheter insertions. For immunocompromised patients, such as those undergoing renal replacement therapy (RRT), strict adherence to precautions is warranted regardless of cost considerations (Hu et al., 2014; Vandijck et al., 2017).

Catheter Dressing

Research has shown no significant difference in CRBSI incidence between sterile gauze and transparent dressings or varying dressing replacement intervals (Rasero et al., 2000; Maki et al., 2014). The choice of dressing should consider cost and patient needs, with sterile gauze preferred for diaphoretic patients or those with bleeding at the insertion site (Conly et al., 2019). Transparent dressings offer the advantage of easier site monitoring for infection. Dressing changes should occur every two days for gauze dressings and every seven days for transparent ones unless soiled, damp, or loose, in which case immediate replacement is necessary (O'Grady et al., 2012).

Antimicrobial Ointments

Topical antimicrobial ointments at catheter sites can reduce CRBSI risk (Sesso et al., 1998). However, their routine use is discouraged due to the potential for promoting multidrug-resistant organisms and fungal infections. Mupirocin may compromise the integrity of polyurethane catheters and dressings (Riu et al., 2018). For patients on RRT, prophylactic use of antiseptic or antibiotic ointments may be considered in specific situations to reduce infection risks (Hoste et al., 2019; Zakrzewska-Bode et al., 2015; Sesso et al., 2013). Similarly, antimicrobial-impregnated catheters, despite their effectiveness in reducing colonization, are recommended only for patients requiring prolonged catheterization due to the associated risk of fungal infections (Leon et al., 2015).

Replacement of Administration Sets and Care for Catheter Hubs and Ports

For patients receiving lipid emulsions, blood products, or total parenteral nutrition, administration sets should be replaced every 24 hours due to the high risk of

hub colonization. Closed needleless systems are preferable to conventional open systems to reduce colonization risks (Bouza et al., 2013). For solutions containing only dextrose and amino acids, sets should be replaced every 96 hours, as should pressure monitoring systems including transducers and flush solutions (O'Grady et al., 2012). For critically ill patients requiring propofol infusions, tubing should be replaced every 6–12 hours (Bennett et al., 2016). Proper disinfection should precede all catheter hub manipulations, including medication administration and blood sampling (Salzman et al., 2012).

Nurse Education and Training

Frequent manipulation of catheters, hubs, and ports increases CRBSI risk. Regular education programs for nursing staff on catheter use indications, maintenance procedures, and infection control measures are essential (Davis et al., 2013). Ongoing quality improvement initiatives are recommended to ensure compliance with evidence-based guidelines (O'Grady et al., 2012; Dinc & Erdil, 2018). Adequate nurse-to-patient ratios are critical, as reductions from 1:1 to 1:2 have been linked to higher CRBSI rates (Fridkin et al., 2016; Robert et al., 2010; Vicca, 2009). For settings with persistent CRBSI issues despite preventive measures, implementing specialized nursing teams trained in managing intravascular devices may be beneficial. Stringent adherence to guidelines for peripheral catheter insertion and care has demonstrated efficacy in reducing CRBSIs (Eggimann & Pittet, 2017). Nurses should also routinely assess the continued need for intravascular access and remove unnecessary catheters promptly (Parenti et al., 2014).

Surveillance

Active monitoring of CRBSI occurrence has been shown to effectively reduce its incidence (Berenholtz et al., 2014; Higuera et al., 2015). Healthcare providers should perform daily assessments of catheter insertion sites, either through visual inspection or palpation, to identify signs indicative of local inflammation or CRBSI, such as warmth, tenderness, swelling, erythema, purulence, or redness (Pearson, 2016; White and Ragland, 2015). If needed, dressings should be removed to allow for a comprehensive examination of the site (Lorenzen and Itkin, 2012; Parenti et al., 2018). Additionally, patients should be encouraged to promptly report any discomfort, changes around the catheter site, or a general feeling of unwellness.

Hand Hygiene

Proper hand hygiene using either antiseptic soap with water or alcohol-based hand rubs remains a cornerstone of infection prevention and control (Boyce and Pittet, 2012; Kac et al., 2005). Healthcare personnel must adhere to strict hand hygiene protocols before and after any interaction with an intravascular catheter, including palpation, adjustment, or dressing changes (Eggimann et al., 2010). Importantly, the use of gloves does not replace the need for thorough hand hygiene (Pittet et al., 2017; Harbarth et al., 2011).

Translating Theory into Practice

In response to the rise of healthcare-associated infections, the CDC introduced evidence-based guidelines aimed at preventing CRBSIs (O'Grady et al., 2002). Key principles include infection prevention, accurate diagnosis and treatment of infections, prudent antimicrobial use, and limiting the spread of resistant organisms (Smith, 2006). Building on the infection control measures, these guidelines advocate for a focus on education, performance feedback, and process control to effectively prevent CRBSIs. The following six studies illustrate how these guidelines have been operationalized in clinical practice.

The study by Rosenthal et al. (2013) comprised three phases: (i) observational monitoring with active infection surveillance and attention to catheter care, (ii) staff education on international consensus guidelines for CRBSI prevention, and (iii) monthly performance feedback to evaluate compliance with these guidelines. The results demonstrated a significant reduction in infection rates following the educational initiative, with further improvements observed when feedback was added (Rosenthal et al., 2013). Similarly, Lobo et al. (2015) conducted a comparable intervention in a Brazilian intensive care unit, achieving a marked decrease in infection rates, including those caused by S. aureus. In Mexico, Higuera et al. (2015) replicated this approach and observed a 60% reduction in infection rates after implementing education and process control. Notably, these studies were conducted in developing nations where infection rates are often tenfold higher than those reported by the National Nosocomial Infections Surveillance System (CDC, 2004). Hospitals in these regions typically face limited resources and lack formalized infection control programs (Rosenthal et al., 2013), benefiting significantly from simple, cost-effective interventions.

In the United States, Warren et al. demonstrated that a similar initiative effectively reduced ICU-acquired CRBSI rates and resulted in cost savings estimated at $1.5 million. Berenholtz et al. (2014) extended this approach by implementing multifaceted interventions over nearly two years. Their objectives were to evaluate the elimination of CRBSIs and ensure adherence to evidence-based guidelines. Interventions included educating staff on catheter care guidelines, creating a dedicated catheter insertion cart to streamline equipment access, encouraging daily evaluations of catheter necessity, and empowering nurses to oversee guideline adherence during catheter insertion. These measures nearly eradicated CRBSIs in their unit. Pronovost et al. (2006) also investigated five evidence-based interventions (hand hygiene, maximal barrier precautions, chlorhexidine antisepsis, optimal site selection, and daily catheter necessity reviews) and found a sustained 66% reduction in CRBSI rates.

Bridging the Gap Between Evidence-Based Nursing and Best Practice

As in many healthcare domains, a notable gap persists between theoretical evidence and practical application. Implementing evidence-based guidelines into routine practice has proven challenging (Cabana et al., 2017; Blot et al., 2017). Nonetheless, the aforementioned studies highlight significant reductions in infection rates through adherence to CDC recommendations (O'Grady et al., 2012), offering several important lessons.

First, changing established practices requires effort; therefore, it is essential to engage all involved staff and provide them with comprehensive information through repeated sessions as necessary. Second, as demonstrated by Berenholtz et al. (2014), success can be achieved with straightforward, inexpensive interventions rather than complex, costly measures. Grouping best practices can improve patient safety more effectively than implementing measures individually (Pronovost et al., 2016).

Third, protocol development should respect individual autonomy. Strict adherence to detailed guidelines is unlikely; thus, empowering staff to evaluate catheter necessity daily while allowing professional judgment is vital. Fourth, since every process step carries an independent risk of failure, reducing unnecessary steps is crucial to enhance compliance and success (Nasraway, 2013). Fifth, repetitive tasks should be minimized to avoid discouragement, with tools such as checklists ensuring efficiency and proper patient care. For instance, in Berenholtz et al. (2014), nurses collaborated with physicians to enforce guideline adherence, emphasizing that reducing infection rates requires multidisciplinary teamwork and open communication.

Finally, sustained reduction of CRBSIs necessitates collective efforts, including ongoing surveillance, enthusiasm, regular assessment, and a commitment to learning new skills. A collaborative culture and persistent vigilance are indispensable for achieving and maintaining improvements in patient safety (Mayor, 2012).

Implementation Barriers in Preventing CRBSIs

Despite the availability of evidence-based guidelines for preventing catheter-related bloodstream infections (CRBSIs), their effective implementation often faces several barriers. Understanding and addressing these barriers is critical to ensuring the adoption and sustainability of infection prevention strategies.

Staff Resistance and Compliance

One of the most common obstacles is resistance to change among healthcare staff. Nurses and physicians accustomed to existing practices may be hesitant to adopt new protocols, particularly if they perceive them as time-consuming or unnecessary. Compliance issues often arise from a lack of understanding of the rationale behind guidelines or a failure to see the direct benefits of adherence. Overcoming this resistance requires targeted educational interventions that not only inform but also engage staff by demonstrating the clinical and patient safety outcomes associated with these measures.

Resource Limitations

Resource constraints can significantly impact the feasibility of implementing CRBSI prevention strategies, particularly in resource-limited settings. For instance, the unavailability of recommended antiseptics, such as chlorhexidine, or the lack of sterile catheter kits may lead to deviations from best practices. Additionally, limited staffing ratios, particularly in intensive care units (ICUs), can result in rushed

procedures or skipped steps in infection control. Addressing these challenges may involve advocating for institutional investment in necessary supplies, optimizing workflows, and prioritizing nurse-to-patient ratios to ensure proper adherence to protocols.

Institutional Policy Variations

Inconsistencies in institutional policies can hinder the standardization of CRBSI prevention practices. Differences in training protocols, availability of equipment, and monitoring processes across units or institutions can lead to variable adherence. Standardizing policies and ensuring alignment with national and international guidelines are critical steps. Regular audits and feedback mechanisms can help institutions identify gaps and ensure continuous improvement.

Time Constraints

Time pressure in high-acuity settings like ICUs and emergency departments (EDs) often undermines adherence to best practices. For example, during emergencies, steps such as hand hygiene or full-barrier precautions may be overlooked. While emergencies necessitate rapid decision-making, institutions must foster a culture where infection control remains a priority, even under pressure. Introducing time-efficient solutions, such as pre-assembled central line kits or automated reminders, can help mitigate these issues.

By proactively addressing these barriers, healthcare institutions can bridge the gap between evidence-based recommendations and routine practice. Empowering nursing staff with the resources, training, and support needed to overcome these challenges is critical to achieving sustained reductions in CRBSI rates and improving patient outcomes.

Conclusion

The integration of evidence-based guidelines for preventing catheter-related bloodstream infections (CRBSIs) is essential for improving patient safety, reducing morbidity and mortality, and minimizing healthcare costs. This paper underscores the critical role of nurses in implementing infection control strategies, including hand hygiene, catheter care, and patient monitoring. Despite substantial advancements in clinical guidelines, significant gaps remain between recommended practices and real-world application. By fostering a culture of collaboration, continuous education, and empowerment, healthcare teams can effectively translate evidence into routine practice. Nurses, with their pivotal role in direct patient care, are uniquely positioned to lead these efforts, ensuring sustained reductions in CRBSI rates and elevating the quality of care in ICU and ED environments.

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