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Nursing Care and Pharmacists Management of Central Venous Catheters: Evidence-Based Practices for Safety and Infection Prevention

Shaden Abdullah Alharbi [(1)] , Yousef Tala Almutairi [(1)] , Sheddi Raffaa Alshammari [(1)] , Ranya Salem Baabbad [(1)] , Ibrahim Suliman Alaboudi [(1)] , Rawdah Mohammed Omar Alsomali [(1)] , Amna Mohammed Ali Wahishi [(1)] , Nahlah Abdulrahman Alfaraj [(1)]

(1) Medical Supply Department , Ministry of Health, Saudi Arabia

Abstract

Background: Central Venous Catheters (CVCs) are indispensable for administering critical therapies in settings like intensive care, oncology, and hemodialysis. However, their use carries significant risks, with Central Line-Associated Bloodstream Infections (CLABSIs) being a foremost concern. CLABSIs contribute substantially to patient morbidity, mortality, and healthcare costs, underscoring the vital importance of evidence-based catheter management.

Aim: This article aims to provide a comprehensive review of evidence-based practices for the nursing care and management of CVCs, with a primary focus on strategies to prevent infections and enhance patient safety throughout the catheter lifecycle.

Methods: The review synthesizes established guidelines and best practices, covering CVC anatomy, indications, and contraindications. It details the essential equipment, personnel competencies, and meticulous techniques required for insertion, daily maintenance, and monitoring. The critical roles of sterile protocols, skin antisepsis with chlorhexidine, appropriate dressing selection, and securement devices are emphasized.

Results: Adherence to structured care bundles significantly reduces complications. Key results highlight that meticulous hand hygiene, maximal sterile barriers during insertion, daily chlorhexidine bathing, and the use of dedicated vascular access teams are proven to lower CLABSI rates. Furthermore, daily review of catheter necessity and prompt removal when no longer indicated are crucial for minimizing infection risk and healthcare costs.

Conclusion: Effective CVC management is a fundamental nursing responsibility that directly impacts patient outcomes. A consistent, multidisciplinary approach grounded in evidence-based protocols is essential for preventing complications and ensuring patient safety.

Keywords: Central Venous Catheter, CLABSI, Infection Prevention, Nursing Care, Aseptic Technique, Patient Safety, Vascular Access.

Introduction

Central venous catheters (CVCs) are indispensable devices widely utilized in critical care, hemodialysis, and oncology settings, serving as essential tools for the delivery of life-sustaining treatments. Their clinical utility includes the administration of intravenous fluids, electrolyte replacements, blood products, parenteral nutrition, chemotherapeutic agents, vasoactive medications, and antibiotics. In addition, CVCs provide reliable access for hemodialysis and enable continuous hemodynamic monitoring, which is crucial for managing critically ill patients. Despite their significant therapeutic advantages, the insertion and maintenance of indwelling CVCs carry substantial risks that surpass those associated with peripheral intravenous catheters. The propensity for thrombus formation, embolization, and local or systemic infections increases by more than 200% in patients with CVCs, demonstrating the magnitude of the clinical hazards that accompany their use [1][2]. Among these risks, central line-associated bloodstream infections (CLABSIs) represent one of the most serious and frequent complications. Central line infections occur more often than any other type of healthcare-associated infection and are responsible for an estimated 33,000 deaths annually in the United States alone. The consequences of CLABSIs extend beyond mortality, contributing significantly to patient suffering, clinical deterioration, and prolonged recovery. Infected patients frequently require intensified antimicrobial therapy, additional diagnostic evaluations such as blood cultures or imaging studies, and repeated line replacements. As a result, CLABSIs are associated with substantial increases in morbidity, mortality, and hospital length of stay. Literature indicates that a single CLABSI episode can extend hospitalization by up to three weeks, adding an average of $33,000 in healthcare costs due to prolonged treatment, diagnostic testing, and the need for advanced interventions [3][4][1].

*Corresponding author e-mail: shdn.2010@hotmail.com (Shaden Abdullah Alharbi).

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The high burden of CLABSIs emphasizes the necessity for health care professionals, particularly nurses who provide frontline vascular access care, to be highly competent in evidence-based central line maintenance. To address the risks and reduce infection rates, authoritative bodies such as the Healthcare Infection Control Practices Advisory Committee (HICPAC) and the Centers for Disease Control and Prevention (CDC) have established comprehensive guidelines. These recommendations are designed to standardize practice, promote the safest possible techniques, and reduce variability in clinical care. Guidelines include meticulous hand hygiene, the use of maximal sterile barriers during insertion, appropriate catheter site selection, strict aseptic technique during line access, and routine assessment of the necessity of the catheter to ensure timely removal [3][4]. Adhering to these evidence-based strategies has been shown to significantly reduce the incidence of CLABSIs and improve patient outcomes. For nursing professionals, mastery of central line care is not only a technical skill but a critical responsibility in safeguarding patient safety and improving overall healthcare quality [3][4].

Anatomy and Physiology

The placement of a central venous catheter (CVC) requires a thorough understanding of the anatomy and physiology of the major central veins commonly used for vascular access. The three primary sites for CVC insertion are the internal jugular vein, the subclavian vein, and the femoral vein. Each site offers unique anatomical characteristics, physiological considerations, and clinical implications, which influence the choice of insertion site based on patient condition, risk factors, and the clinical purpose of the catheter. The internal jugular vein (IJV) is frequently selected because of its predictable anatomical location and relatively superficial course in the neck. Situated lateral to the carotid artery within the carotid sheath, the IJV provides straight access into the superior vena cava (SVC). Ultrasound-guided cannulation is considered the standard of care for this site due to the ability to visualize vascular structures, identify anatomical variations, reduce the risk of arterial puncture, and improve overall success rates. The IJV is physiologically advantageous because of its high blood flow, which reduces the risk of thrombosis and facilitates rapid infusion of medications or fluids. The subclavian vein, located beneath the clavicle and anterior to the apex of the lung, offers another common route for central line placement. It provides a direct path into the brachiocephalic vein and subsequently the SVC. The subclavian vein is often preferred for long-term access due to lower infection rates compared to other sites, likely because it is distant from areas with high bacterial colonization such as the groin and neck folds. However, its deeper and less compressible location presents greater technical challenges, and complications such as pneumothorax or hemothorax may occur if the pleura or subclavian artery is inadvertently punctured.

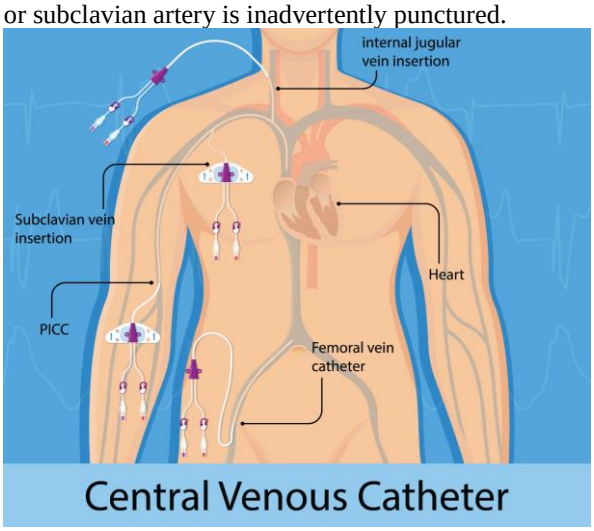

Fig. 1: Central Line Catheter.

The femoral vein, accessed in the groin region medial to the femoral artery, is typically used when upper-body access is contraindicated or in emergency situations where rapid cannulation is required. Although cannulation is often easier due to its superficial location and large diameter, femoral access carries significantly higher infection rates compared to the IJV and subclavian sites [5]. This increased risk is attributed to proximity to the perineal area, higher bacterial colonization, and challenges maintaining sterile dressings in the groin. Additionally, patients requiring prolonged bed rest or those with obesity may experience further complications related to femoral catheter placement. Despite anatomical differences, all CVC insertions share common procedural elements: puncture of the skin and underlying tissues, dilation of a tract through subcutaneous and muscle layers, cannulation of a proximal central vein, and advancement of the catheter tip into the vena cava. Understanding the surface anatomy, vascular landmarks, and ultrasound visualization of these sites is essential for safe and effective catheter placement. Infection rates, thrombosis risk, and mechanical complications vary significantly by anatomical site, emphasizing the importance of thoughtful site selection to minimize patient harm and optimize vascular access outcomes [5].

Indications

Central venous catheter (CVC) placement is a critical procedure in modern clinical practice, serving multiple purposes across a wide range of medical specialties, including critical care, oncology, nephrology, and emergency medicine. The indications for CVC placement reflect both therapeutic and diagnostic needs, particularly in patients whose conditions require reliable, high-capacity vascular access. Understanding these indications is essential for ensuring appropriate use of

central lines and optimizing patient outcomes while minimizing complications. One of the foremost indications for central line placement is drug administration, particularly when medications cannot be safely administered through peripheral veins. Certain drugs—such as vasopressors, chemotherapy agents, and hypertonic solutions—are caustic to peripheral vessels and carry significant risks of extravasation injury, tissue necrosis, or vascular irritation if administered through standard peripheral intravenous lines. CVCs provide a stable and large-bore access route capable of handling these potent medications safely. Vasopressors, for example, require continuous infusion and precise dosing that central access facilitates, while chemotherapeutic agents often demand stringent safety measures that only central venous access can provide [5].

Another important indication is the need for prolonged intravenous therapy. Treatments such as total parenteral nutrition (TPN) or long-term intravenous antibiotics rely on sustained, uninterrupted venous access. Because peripheral lines are prone to early failure, phlebitis, and infiltration, they are unsuitable for extended-duration therapy. A central line ensures that patients receiving multi-week intravenous treatments can do so safely and comfortably, reducing the risk of repeated venipuncture and preserving peripheral veins. Difficult peripheral venous access represents a common and practical indication for central line placement. In patients with obesity, edema, severe dehydration, chronic illness, or those with sclerosed or scarred veins from prior cannulations, peripheral venous access can become exceedingly challenging. Similarly, agitated or combative patients may not tolerate repeated attempts at cannulation. In such situations, a CVC offers a reliable alternative and allows clinicians to proceed with essential diagnostic or therapeutic interventions without delay. Central lines are also essential for hemodynamic monitoring. They provide access for measurement of central venous pressure (CVP), central venous oxygen saturation ($ScvO_2$), and guidance in fluid resuscitation, especially in critically ill patients with shock, sepsis, trauma, or cardiac dysfunction. Although the interpretation of CVP has evolved, central venous monitoring remains invaluable in specific clinical contexts, including perioperative care for major surgeries and unstable medical conditions requiring continuous evaluation of intravascular volume status.

Certain specialized treatments necessitate central venous access due to their unique technical demands. Hemodialysis, for instance, requires high-flow access that peripheral veins cannot support, making CVCs essential for patients requiring urgent or temporary dialysis. Plasmapheresis, a therapy used in autoimmune and hematologic disorders, likewise relies on central access for rapid blood exchange. Additionally, transvenous cardiac pacing, often required in emergencies such as complete heart block, depends on central venous access for the insertion of pacing wires [5]. Given these wide-ranging indications, any patient who requires such interventions during hospitalization will also require comprehensive care aimed at maintaining the safety and functionality of the central line. This includes meticulous adherence to clinical governance standards, careful documentation, and routine monitoring. Daily CVC care focuses on maintaining a clean, dry, and uncontaminated insertion site to minimize infection risks—the most serious complication associated with CVC use [5]. Regular assessment of the dressing, evaluation for signs of infection, verification of line necessity, and prompt removal when no longer indicated are all essential components of high-quality central line management. CVC placement thus plays a vital role in the care of complex patients, and its indications must be understood within the broader context of patient safety, clinical efficacy, and long-term vascular access preservation [5].

Contraindications

The insertion of a central venous catheter (CVC) is a common and often life-saving procedure, yet it is not without significant risk. Consequently, careful consideration of contraindications is fundamental to safe clinical practice. Contraindications may be absolute or relative and can be present at the time of insertion or arise later during the course of treatment. A comprehensive risk–benefit assessment must therefore be undertaken prior to cannulation and repeated throughout the period of catheter use, as patient factors, disease processes, and treatment regimens can evolve over time. Embolic phenomena constitute an important category of contraindications. The presence of pre-existing central venous thrombi represents a significant hazard, as guidewire or catheter manipulation can destabilize these clots and precipitate embolic events such as pulmonary embolism or cerebrovascular infarction. A similar risk profile is seen in the context of endocardial or valvular vegetations, particularly in infective endocarditis, where friable bacterial aggregates can be dislodged and embolize to the cerebral, coronary, or systemic circulation. In addition, intracardiac or myocardial tumors, including atrial myxomas or metastatic deposits, may provide a highly thrombogenic surface, predisposing to further clot formation which may become mobilized during catheter insertion or adjustment. In such settings, alternative access strategies or imaging-guided planning are strongly advised to minimize the risk of catastrophic embolic complications [5].

Bleeding risk represents another critical area of concern when considering CVC placement. Patients with hematologic disorders such as thrombocytopenia, coagulopathies, or qualitative platelet dysfunction are at increased risk of

hemorrhagic complications at both the insertion site and deeper vascular or mediastinal planes. This risk is compounded in individuals who are anticoagulated or receive antiplatelet agents as part of their pharmacologic treatment. Prior trauma or surgery at the intended insertion site can distort normal anatomy, increase vascular fragility, and elevate the risk of inadvertent arterial puncture or uncontrolled bleeding. In such cases, correction of coagulopathy when feasible, use of ultrasound guidance, and selection of an alternative site may be required to mitigate risk. Infection remains one of the most important contraindications and complications in central venous access. Active infection at the proposed insertion site is an absolute contraindication, as cannulation through contaminated or inflamed tissue greatly increases the risk of local extension, catheter colonization, and systemic dissemination. Even when a line is already in place, new-onset erythema, tenderness, purulent discharge, or other signs of local infection at the catheter entry site mandate urgent evaluation and, in most cases, removal of the device. Bloodstream infections, particularly catheter-related bloodstream infections, are generally regarded as a relative contraindication to continued use of the same catheter. The intravascular surface of the CVC can support biofilm formation and bacterial persistence, making eradication of infection more difficult and often necessitating more frequent catheter changes and strict adherence to aseptic technique in any subsequent cannulations [6]. Skin integrity at and around the insertion site is another important determinant of suitability for CVC placement. Prior radiation therapy can cause chronic skin and soft-tissue changes, including fibrosis, atrophy, and impaired microvascular perfusion, all of which compromise wound healing and increase the risk of infection or dehiscence. Pressure-related ulceration or local tissue damage can also occur as a result of the CVC itself, especially in situations of poor catheter stabilization or prolonged use. Direct trauma to the region, whether recent or remote, may further alter local anatomy and impair the ability to create a safe and stable subcutaneous tunnel. These factors should be carefully evaluated before reusing a previously traumatized or irradiated site for further cannulation.

Historically, the presence of an existing catheter at a given site was often viewed as a relative contraindication to further cannulation of the ipsilateral vein, particularly for high-demand therapies such as hemodialysis. Concerns centered around the risk of venous stenosis, thrombosis, or mechanical interference between catheters. However, more recent evidence suggests that previous or current central venous catheterization does not categorically preclude reuse of the same vein for hemodialysis catheter placement, especially when the original insertion was uncomplicated and there is no evidence of stenosis or obstruction [7]. This evolving perspective underscores the need for individualized decision-making, supported by imaging when necessary, rather than rigid adherence to historical dogma. In summary, contraindications to central venous catheter insertion are multifactorial and dynamic, encompassing embolic risk, bleeding diathesis, infection, skin and soft-tissue integrity, and the presence of pre-existing intravascular devices. Clinicians must integrate these considerations with the urgency of the indication and the availability of alternative access routes. Ongoing reassessment throughout the lifespan of the catheter is essential, as conditions that were initially acceptable may become contraindications over time, necessitating line removal or relocation to safeguard patient safety [6][7].

Equipment

The safe insertion and maintenance of central venous catheters (CVCs) require meticulous adherence to sterile technique and the use of appropriate equipment designed to minimize the risk of infectious and mechanical complications. All procedures involving CVC placement or manipulation must begin with thorough hand hygiene and the application of sterile drapes, gloves, gowns, and instruments. This foundational emphasis on sterility is essential given the well-established association between catheter manipulation and the introduction of pathogens into the bloodstream. The sterile field must be maintained throughout insertion and during all subsequent care activities to reduce preventable contamination events that could result in central line–associated bloodstream infections (CLABSIs). A critical early step in catheter insertion involves rigorous skin preparation. Evidence strongly supports that the majority of CVC-related infections originate from bacterial colonization of the skin at the insertion site, with organisms migrating along the catheter tract toward the bloodstream [5]. Randomized controlled trials have demonstrated that skin cleansing with chlorhexidine significantly decreases microbial load and reduces infection rates by up to sixfold compared to other antiseptic agents [8][9]. Consequently, current guidelines recommend the routine use of 2% chlorhexidine solutions or specialized applicators for skin antisepsis. Although antiseptic ointments and antibacterial preparations may appear beneficial, their routine use after catheter insertion is not advised. While some studies have shown reductions in septic complications with topical antimicrobials, evidence also indicates increased emergence of resistant organisms and a heightened risk of Candida colonization and subsequent infection, underscoring the importance of selective rather than universal use [5].

Dressings constitute another essential component of CVC equipment. Their function is to protect the insertion site from contamination,

moisture accumulation, and mechanical disruption. Transparent polyurethane film dressings are widely used because they allow continuous visualization of the catheter site, enabling clinicians to detect early signs of infection, hematoma, or pressure injury without disturbing the dressing [5]. However, despite their advantages, transparent dressings have limitations. Some studies suggest they may promote moisture retention at the site, potentially increasing microbial colonization. In a study involving 343 patients undergoing routine catheter insertion, infection occurred in 2.3% of cases when gauze was placed beneath a transparent dressing [10]. Subsequent reviews, including a notable 2006 analysis, concluded that permeable dressings may be superior in reducing moisture pooling and bacterial colonization, recommending their use in settings where sweating, humid environments, or prolonged dressing adherence pose higher risks [9]. Beyond the dressing itself, the access hubs of the central venous catheter represent another major potential route of pathogen entry. The repeated connection and disconnection of infusion sets introduce opportunities for contamination that must be mitigated through strict aseptic non-touch technique (ANTT). Disinfection of hubs prior to access, minimization of handling, and the use of needleless connectors or mechanical valves all contribute to reducing infection risk. Innovative strategies—such as povidone-iodine–impregnated gauze wraps or specialized antiseptic hub devices developed in European trials—have demonstrated statistically significant reductions in catheter-related infections, yet widespread adoption has been limited due to cost, policy variations, and the need for further validation across diverse patient populations [5].

Another integral component of CVC equipment involves the use of intravenous fluids, particularly crystalloids, which are commonly infused continuously in intensive care settings. These infusions serve to maintain catheter patency by reducing the risk of intraluminal clot formation and to ensure that pressure transducers connected to the line receive consistent fluid flow for accurate central venous pressure (CVP) monitoring. CVP measurement remains valuable both for assessing intravascular volume status and for detecting line migration or malposition, as abrupt changes in waveform characteristics may indicate catheter displacement or obstruction. In summary, the equipment used for central venous catheter insertion and maintenance—sterile barriers, chlorhexidine antiseptics, dressings, hub protection devices, and continuous infusions—plays a pivotal role in preventing complications. Optimal outcomes require not only the correct selection of these materials but also strict adherence to evidence-based protocols governing their use. These measures collectively form the backbone of safe CVC management and remain crucial in reducing the incidence of CLABSI and other adverse events [5][8][9][10].

Personnel

The safe insertion, management, and maintenance of central venous catheters (CVCs) depends heavily on the knowledge, skill, and vigilance of the healthcare personnel involved. This guidance applies to a broad range of professionals, including medical and nursing staff working in intensive care units (ICUs), operating rooms (ORs), renal dialysis units, and chemotherapy units—areas in which frequent handling of CVCs is routine and central access is integral to patient care. These environments require staff to be proficient in sterile technique, catheter manipulation, and early recognition of complications, as even minor lapses can lead to serious bloodstream infections or mechanical injury. In settings where patients remain for prolonged periods, or where outpatient management with long-term indwelling catheters is common, such as oncology or home infusion services, maintaining high standards of catheter care becomes even more critical. Patients receiving long-term therapies rely on consistent best practices to prevent infection, catheter occlusion, and device-related complications. The UK National Institute for Clinical Excellence (NICE) underscores the importance of competency in this domain, recommending that "healthcare workers caring for a patient with a vascular access device should be trained, and assessed as competent, in using and consistently adhering to the infection prevention practices described in this guideline." This statement emphasizes that proper CVC care is not merely procedural but requires formal training, periodic reassessment, and adherence to evidence-based protocols. It further highlights that competence is dynamic, requiring ongoing education in response to emerging research, updated guidelines, and advancements in catheter technology. Ensuring that all personnel involved in CVC care possess the necessary expertise is fundamental to reducing infection rates, safeguarding patient outcomes, and promoting a culture of safety across clinical environments.

Preparation

Adequate preparation is a fundamental component of safe and effective central venous catheter (CVC) care, significantly reducing the risk of infection and procedural complications. A critical first step is the thorough cleansing of the skin using an appropriate antiseptic agent, as emphasized in prior recommendations [9]. Proper skin preparation minimizes microbial colonization at the insertion site, which is a key contributor to central line–associated bloodstream infections. All necessary materials for routine care—such as sterile gloves, antiseptic solutions, dressings, and catheter stabilization devices—should be gathered in advance to ensure smooth workflow and prevent contamination

resulting from interruptions during the procedure. The chosen environment should support strict aseptic technique; therefore, care is ideally performed in a controlled setting such as an intensive care unit (ICU) or operating theatre, where sterile fields and infection control practices can be consistently maintained. Once the equipment and environment are prepared, attention must be directed toward patient involvement. If the patient is awake, clear communication about the purpose of the procedure, steps involved, and any associated risks is essential to obtain informed consent and promote cooperation. This dialogue helps reduce anxiety and ensures patient understanding, both of which contribute to safer procedural outcomes. During the actual dressing change or catheter care, an aseptic non-touch technique (ANTT) must be employed, avoiding unnecessary contact with key sterile sites and ensuring that materials remain uncontaminated. Minimizing delays is equally important, as prolonged exposure of the insertion site increases vulnerability to infection. By systematically organizing materials, optimizing the sterile environment, and maintaining meticulous technique, clinicians can uphold the highest standards of CVC preparation and significantly reduce the likelihood of adverse events.

Technique or Treatment

The ongoing care of a central venous catheter (CVC) is a critical component of preventing complications, ensuring catheter functionality, and maintaining patient safety. This care involves a combination of routine inspection, sterile dressing changes, catheter flushing, and continuous monitoring for signs of infection or mechanical malfunction. Dressing changes serve not only as opportunities to maintain cleanliness but also as essential moments for thorough assessment of the insertion site, catheter stabilization device, and surrounding skin integrity. The optimal frequency of dressing changes continues to be debated, but evidence suggests that performing dressing changes every 48 hours, combined with chlorhexidine cleansing at each change, offers benefits over seven-day intervals. More frequent changes, however, do not confer additional protection and may, in fact, increase the risk of site irritation, unnecessary manipulation, and accidental contamination [5]. Aseptic technique is foundational to safe CVC care. Prior to dressing changes, meticulous hand hygiene must be performed using antimicrobial soap or alcohol-based hand rubs, and the provider must apply sterile gloves to minimize the risk of contaminating the catheter site. Both the healthcare provider and the patient should wear masks during dressing changes to prevent droplet contamination of the sterile field. After carefully removing the soiled dressing, providers must don a new pair of sterile gloves before touching the cleaned site or applying new materials, maintaining the integrity of aseptic technique. In cases where the facility is experiencing persistently high rates of central line-associated bloodstream infections (CLABSIs), the use of chlorhexidine-impregnated sponge dressings may be an important adjunct to reduce microbial density and improve patient outcomes.

During each care episode, clinicians should perform a detailed assessment of the catheter insertion site. This examination includes checking for signs of infection such as erythema, warmth, drainage, tenderness, or swelling, and ensuring that the sutureless securement device remains intact and properly positioned. The date of the last dressing change, typically written on the dress itself, should be reviewed to ensure compliance with recommended intervals. Additionally, patients should be encouraged to report any discomfort, swelling, or unusual sensations around the catheter site, as early recognition of complications greatly improves prognosis [11][4]. Flushing of the central line is another vital component of CVC maintenance. Each lumen must be flushed daily to prevent clot formation, maintain patency, and ensure that no blood or medication residue accumulates within the catheter. The order of flushing should remain consistent each time to maintain a predictable workflow and prevent errors. The choice between heparin and saline flushing depends on the catheter type and institutional protocols. Some catheter models, particularly those prone to thrombosis, require heparinized flushes, whereas others may be maintained with preservative-free normal saline. Regardless of the solution used, proper flushing technique must include the use of sterile syringes, appropriate pressure application to avoid catheter rupture, and thorough aspiration to confirm lumen patency before administering medications.

The technique of catheter care extends beyond the mechanical steps to include ongoing reassessment of the catheter's necessity. Daily evaluation of whether the CVC is still required is a critical strategy in reducing infection risk, as unnecessary lines pose an avoidable hazard. When the catheter is no longer clinically indicated, prompt removal is advised to eliminate exposure to potential complications. Overall, the treatment and maintenance of a central line require a disciplined approach that integrates sterile technique, evidence-based dressing practices, precise flushing methods, and vigilant monitoring. Through adherence to these principles, clinicians can significantly reduce the risk of CLABSI, maintain catheter functionality, and enhance patient safety [4][11].

Complications

Complications related to central venous catheters (CVCs) can be broadly categorized into immediate events occurring at or shortly after insertion, and delayed complications that develop over the course of catheter use. The majority of early

complications arise directly from the insertion procedure and are often mechanical in nature. Pneumothorax is one of the most recognized acute complications, particularly when the subclavian or internal jugular veins are used for access, as inadvertent puncture of the pleura can lead to air entry into the pleural space and subsequent respiratory compromise [12]. Vascular perforation is another serious immediate complication, occurring when the introducer needle, guidewire, or catheter penetrates the vessel wall, potentially causing hemorrhage, hemothorax, mediastinal bleeding, or pericardial tamponade depending on the vessel and location involved [12]. Venous air embolism, although less common, represents a potentially life-threatening event that occurs when air is unintentionally introduced into the central circulation, which may lead to cardiovascular collapse, arrhythmias, or cerebral ischemia if not promptly recognized and managed [12]. These immediate complications underscore the need for meticulous insertion technique, use of ultrasound guidance, and vigilant post-procedural monitoring. Delayed complications are often more insidious and may emerge after days, weeks, or even months of catheter use. Among these, CVC-associated infections are the most clinically significant and are a major focus of modern central line care practices. Central line-associated bloodstream infection (CLABSI) is relatively frequent, affecting approximately 5% of hospitalized patients with CVCs in the United States, although this incidence continues to decline due to improved preventive strategies [13]. Despite falling rates, CLABSIs remain serious events with reported mortality ranging between 12% and 25%, reflecting both the direct impact of sepsis and the vulnerability of patients who typically require central access [13]. These infections are associated with prolonged hospital stays, increased healthcare costs, and the need for intensive antimicrobial therapy, and may necessitate catheter removal and replacement at an alternative site. The pathogenesis of CVC-associated infection frequently involves colonization of the catheter surface by skin flora or contaminated infusates, followed by biofilm formation that protects bacteria from host defenses and antimicrobial agents.

Line dysfunction represents another important delayed complication of CVC use. Dysfunction may present as difficulty aspirating blood, sluggish infusion rates, or complete occlusion of one or more lumens. The causes of such dysfunction are multifactorial and may include mechanical kinking, catheter malposition, external compression, or development of fibrin sheaths that form around the catheter tip and act as a one-way valve [12]. Fibrin sheath formation is particularly problematic, as it can allow infusion while impeding aspiration, potentially leading to misinterpretation of catheter position or patency. Positioning-related dysfunction, where changes in patient posture alter the catheter tip orientation, can also impact line performance. Pharmacologic management of catheter occlusion may involve the instillation of thrombolytic agents such as alteplase into the lumen to dissolve thrombotic material and restore flow, a strategy that has been shown to be effective in many cases and can reduce the need for catheter replacement [14]. Rarer but clinically significant delayed complications include structural failure of the catheter itself, such as fracture or rupture under high pressure or repeated mechanical stress [14]. Catheter fracture may lead to extravasation of infusates into surrounding tissues, vessel wall trauma, or embolization of catheter fragments into the central circulation, which may require endovascular retrieval. Central venous thrombosis is another serious complication associated with CVCs. The presence of a foreign body within the vessel, combined with endothelial disruption and altered blood flow, satisfies the elements of Virchow's triad and predisposes to thrombus formation [12]. Thrombosis can result in venous obstruction, limb swelling, pain, and, in severe cases, pulmonary embolism. Over time, chronic thrombotic changes and inflammatory responses can lead to venous stenosis, particularly in frequently cannulated vessels such as the subclavian or internal jugular veins, potentially compromising future vascular access options [14]. These complications highlight the importance of comprehensive CVC management, from careful insertion and site selection to ongoing maintenance and timely removal when no longer necessary. Preventive strategies—including strict aseptic technique, evidence-based dressing protocols, regular catheter assessment, and prompt attention to early signs of dysfunction or infection—are crucial in minimizing the risks associated with central venous catheters. Continuous education, adherence to institutional guidelines, and multidisciplinary collaboration further enhance the ability of healthcare teams to prevent, recognize, and manage these complications effectively [12][13][14].

Clinical Significance

The clinical significance of central venous catheter (CVC) care is substantial, as both immediate and delayed complications are associated with considerable morbidity, prolonged hospitalization, and delayed recovery. Central line-associated bloodstream infections (CLABSIs), catheter dysfunction, thrombosis, and mechanical complications not only affect physiological stability but also limit patients' access to critical treatments such as chemotherapy, hemodialysis, vasopressor support, or parenteral nutrition. These complications frequently necessitate additional invasive procedures, including catheter replacement, surgical drainage, or intensive antimicrobial therapy, all of which increase patient discomfort and risk. From a systems perspective, inadequate central line care contributes to bed occupancy pressures, higher acuity caseloads in intensive care units, and increased demand for

diagnostic and interventional resources. Thus, meticulous CVC care directly influences both individual patient outcomes and broader healthcare system performance. The economic impact of central line complications further underscores their clinical significance. When CVC-related infections or mechanical failures occur, the cost of treatment is considerable. Depending on the methodology and healthcare setting, the cost per complication has been estimated to range between $3,700 and $39,000 in the United States and China, and approximately 8,810 € per episode in European healthcare systems [15][16][17]. These figures encompass extended lengths of stay, additional diagnostic investigations, antimicrobial regimens, interventional radiology or surgical procedures, and follow-up care. In contrast, the relative cost of preventive interventions—including additional nursing care time, improved monitoring, and use of appropriate dressings and antiseptic agents—is modest. For example, the UK National Institute for Clinical Excellence has calculated that the use of an appropriate dressing can translate into a saving of approximately £93 per patient when weighed against the anticipated costs of infection and complications. This reinforces the concept that investment in high-quality CVC care yields both clinical and economic benefits.

The patient's perspective is equally important. Complications related to CVCs can have lasting health consequences, including chronic venous stenosis, recurrent infections, reduced cardiopulmonary reserve, and limitations in future vascular access options. These sequelae may influence eligibility for subsequent therapies such as stem cell transplantation, long-term dialysis, or complex oncologic regimens. Furthermore, repeated invasive procedures, prolonged hospitalization, and uncertainty regarding recovery can impose a significant psychological burden on patients and their families. Therefore, central line care is not merely a technical or procedural concern; it is a critical determinant of long-term quality of life, therapeutic possibilities, and patient-centered outcomes.

Enhancing Healthcare Team Outcomes

Optimizing central line care requires a coordinated, system-wide effort in which the entire healthcare team actively engages in prevention, early detection, and management of complications. One of the most effective strategies for improving performance is the implementation of hospital-specific or collaborative quality improvement initiatives focused on CVC care. These initiatives often include standardized care bundles, checklists, and protocols that embed evidence-based practices into daily workflows. Studies have demonstrated that such structured programs significantly improve adherence to guidelines on insertion technique, dressing care, hub disinfection, and line maintenance, ultimately reducing CLABSI rates and other catheter-related complications [1][2]. Regular auditing, feedback, and benchmarking against institutional or national standards further reinforce best practices and sustain improvements over time. Daily review of CVC necessity is another key component in enhancing team performance and patient outcomes. Each member of the multidisciplinary care team—physicians, nurses, pharmacists, and infection prevention specialists—plays a role in questioning whether a central line remains essential for ongoing care. Removing CVCs as soon as they are no longer clinically indicated reduces cumulative exposure time and, consequently, the risk of infection, thrombosis, and mechanical complications. This "line stewardship" approach mirrors antimicrobial stewardship in its emphasis on judicious use of an inherently high-risk intervention. By embedding necessity reviews into daily rounds and documentation, teams can systematically minimize unnecessary line days and improve safety metrics [1][18].

The establishment of a dedicated vascular access team is another powerful strategy for improving outcomes related to central lines. Such teams, often composed of specially trained nurses or advanced practitioners, assume responsibility for CVC insertion, maintenance, troubleshooting, and removal. Evidence suggests that centralized expertise leads to higher first-attempt success rates, lower complication rates, and improved consistency in adherence to aseptic technique and institutional protocols [2][18]. These teams also serve as valuable educational resources, training other staff in best practices and contributing to policy development. Ultimately, enhancing healthcare team outcomes in the context of central line care depends on a culture of safety, interprofessional collaboration, and continuous learning. When clinicians at all levels are engaged in shared goals—prevention of CLABSI, reduction of complications, and early removal of unnecessary lines—patient outcomes improve, resource utilization becomes more efficient, and the overall quality of care is elevated [1][2][18].

Nursing, Allied Health, and Interprofessional Team Interventions

The role of nursing, allied health professionals, and the wider interprofessional team is central to the safe management of central venous catheters (CVCs). Because CVCs are associated with significant risks, including infection, thrombosis, and mechanical complications, the quality of daily care delivered by these teams directly influences clinical outcomes. A cornerstone of effective practice is structured and ongoing education. All healthcare professionals who work in environments where indwelling CVCs are used—such as intensive care units, operating rooms, renal dialysis units, and chemotherapy settings—should receive at least annual training on central line care, encompassing

indications for placement, maintenance principles, and infection control measures [3]. Regular updates ensure that practice remains aligned with evolving evidence and guidelines and that staff remain competent in both technical skills and aseptic technique [3]. In many institutions, the establishment of a dedicated CVC care or vascular access team has emerged as an effective strategy to enhance patient safety. These specialized teams typically consist of nurses and other practitioners with advanced competency in central line insertion, maintenance, troubleshooting, and removal. Evidence suggests that utilizing such teams reduces central line-associated bloodstream infection (CLABSI) rates by standardizing practice, reducing variability in technique, and concentrating expertise [1][2]. Additionally, organizational factors such as adequate staffing levels in intensive care units, minimizing the use of temporary or "float" nurses unfamiliar with unit protocols, and maintaining a low patient-to-nurse ratio have been associated with lower rates of catheter-related bloodstream infections, underscoring the importance of workforce stability and workload management [3].

Skin preparation is another critical nursing and interprofessional responsibility in central line care. Prior to catheter insertion, some traditional sources recommend full-body cleansing from chin to ankle using a chlorhexidine wash to reduce overall microbial burden [4]. This is followed by meticulous skin preparation at the insertion site with chlorhexidine gluconate, ensuring the antiseptic is applied thoroughly and allowed to dry completely before catheter insertion proceeds [1][2][4]. This drying period is essential, as incomplete drying can reduce antiseptic efficacy and compromise barrier function. Ongoing patient cleansing during hospitalization also plays an important role. Patients with CVCs are recommended to bathe or be washed daily using chlorhexidine-based products, which has been shown to decrease skin colonization and subsequently reduce CLABSI risk [3][2][19]. Nursing staff are typically responsible for coordinating and performing this daily hygiene, integrating infection prevention into routine care. Catheter securement is another area where nursing intervention has a direct effect on outcomes. Sutureless securement devices are recommended to reduce the risk of infection and mechanical trauma at the insertion site by minimizing skin punctures and local inflammation associated with sutures [4][2]. These devices help to stabilize the catheter without adding additional portals for microbial entry, and they may also enhance patient comfort and reduce dressing disruption. Proper securement technique must be combined with an evidence-based dressing regimen. Current recommendations advise against changing central line dressings every day unless they are visibly loose, damp, or soiled. Instead, gauze dressings should generally be changed every two days, while transparent, semi-permeable dressings may remain in place for up to seven days, provided they remain intact and clean [3][2]. In patients who are diaphoretic or who have active bleeding or oozing at the insertion site, gauze dressings are preferred until these issues have resolved.

Topical antibiotic ointments or creams at the insertion site are generally not recommended because they have not been shown to be effective in routine use and can promote resistance or local fungal overgrowth. An important exception exists for hemodialysis catheter care. In this context, povidone-iodine or other antiseptic ointments, including bacitracin/gramicidin/polymyxin B formulations, may be applied to the insertion site at the end of dialysis sessions to reduce infection risk specific to this high-risk population [3][2]. These nuanced recommendations illustrate the importance of condition- and device-specific protocols, which nursing staff must understand and implement correctly. Systemic antimicrobial prophylaxis is another area where nursing and allied health staff must align with best practice. Routine prophylactic use of systemic antibiotics in otherwise stable patients with CVCs is not recommended, as there is no convincing evidence of benefit and significant concern exists regarding the development of antimicrobial resistance [2]. Nursing staff play a crucial role by advocating judicious antibiotic use, reinforcing antimicrobial stewardship, and monitoring for signs of infection that warrant targeted therapy rather than blanket prophylaxis. Decisions regarding the replacement or removal of CVCs also rely heavily on interprofessional communication and nursing vigilance. Central lines should be removed promptly once they are no longer clinically indicated, as each additional day in situ increases the risk of infection and thrombosis [3][2]. However, routine replacement of central venous catheters, such as scheduled exchange over a guidewire, is discouraged. Evidence indicates that such practices may paradoxically increase infection risk by exposing patients to repeated invasive procedures and additional opportunities for contamination [3][2]. Furthermore, central lines should not be removed solely on the basis of pyrexia or hyperthermia; instead, the healthcare team should consider alternative causes of fever and perform a thorough clinical assessment and diagnostic workup before deciding to replace or relocate a catheter [2]. Nursing staff, who often detect early changes in vital signs or clinical status, are instrumental in initiating these evaluations.

Replacement and management of administration sets are also central components of nursing and allied health practice. To reduce the risk of CLABSI, intravenous administration sets are recommended to be changed no more often than every 96 hours, but at least every seven days under routine circumstances. Tubing used for transfusion of

blood or blood products, as well as fat emulsions, should be replaced within 24 hours of initiating these products, due to their propensity for supporting microbial growth. Similarly, tubing used with propofol infusions, which is lipid-based and susceptible to contamination, should be changed at least every 6 to 12 hours or with each vial change, depending on institutional policy. These time-based protocols require precise adherence and accurate documentation, typically coordinated and executed by nursing staff. Needleless intravenous catheter systems have become a standard of care in many settings to reduce needlestick injuries and CVC complications. The use of needleless connectors and components is strongly recommended, with the proviso that these connectors be changed with each new IV administration set and not more frequently than every 72 hours [11][4][2]. Prior to accessing any port, the access site must be scrubbed with an appropriate antiseptic agent such as chlorhexidine, povidone-iodine, iodophor, or 70% alcohol, and only sterile devices should be used to access the system [11][4]. All lumens should remain capped, preferably with disinfecting hub caps, which provide continuous antiseptic contact and reduce the risk of contamination between uses [11]. These measures require consistent application and monitoring by nursing and allied health personnel, who serve as the primary custodians of central line integrity in daily practice.

Nursing, Allied Health, and Interprofessional Team Monitoring

Beyond performing interventions, the healthcare team has a critical responsibility for ongoing monitoring of CVCs throughout their dwell time. This includes daily evaluation of the insertion site, line function, and continuing indication for central access. Nursing staff must be specifically trained and periodically reassessed in CVC care to ensure their practice remains safe and evidence-based. Although establishing a direct causal relationship between training and reduced complication rates is methodologically challenging, there is limited evidence from at least one study suggesting that care provided by non-permanent or temporary staff is associated with increased rates of CVC-associated infectious complications [20]. This finding underscores the importance of familiarity with unit protocols, continuity of care, and investment in permanent staff development. Monitoring includes systematic inspection of the insertion site for early signs of infection, such as erythema, tenderness, swelling, or purulent drainage, and checking the integrity of dressings and securement devices. Nursing and allied health teams must also assess catheter patency, ensuring that each lumen flushes and aspirates appropriately and that there are no signs of occlusion or malfunction. Changes in patient symptoms—such as new onset chest pain, dyspnea, or swelling of the limb or neck on the catheter side—should prompt immediate evaluation for thrombosis, catheter malposition, or mechanical complications.

Interprofessional collaboration is essential to effective monitoring. For instance, if the nursing team identifies recurrent occlusion or difficulty aspirating blood, this may warrant consultation with a vascular access specialist, interventional radiology, or the primary medical team to evaluate the need for imaging, thrombolytic therapy, or line replacement. Similarly, signs suggestive of CLABSI require coordinated evaluation involving infectious disease specialists, laboratory teams for cultures, and pharmacy staff for prompt initiation of targeted antimicrobial therapy. Importantly, monitoring is not limited to technical and clinical parameters but extends to patient education and engagement. Nurses and allied health professionals play a key role in teaching patients to recognize and report symptoms such as fever, chills, localized pain, swelling, or changes in dressing appearance. In outpatient or home-care settings, where patients may live with indwelling CVCs for extended periods, this education becomes vital to early complication detection and timely intervention. In summary, nursing, allied health, and interprofessional team interventions related to CVCs encompass a continuum of care—from education, preparation, and insertion support, through daily maintenance and monitoring, to timely removal and complication management. High-quality central line care is inherently collaborative, relying on shared responsibility, clear communication, adherence to standardized protocols, and ongoing professional development. When these elements are in place, the risks associated with central venous catheters can be substantially mitigated, and patient outcomes significantly improved [1][2][3][4][11][19][20].

Conclusion:

In conclusion, the safe management of Central Venous Catheters is a critical determinant of patient outcomes, demanding unwavering adherence to evidence-based practices. The high morbidity, mortality, and economic cost associated with complications like CLABSIs are largely preventable through a disciplined, systematic approach. This hinges on several core principles: rigorous hand hygiene and maximal sterile barriers during insertion, meticulous daily care including site assessment and aseptic dressing changes, and proper flushing techniques to maintain patency. The use of chlorhexidine for skin antisepsis and daily patient bathing has proven particularly effective in reducing microbial burden and infection rates. Ultimately, safety is a shared responsibility that extends beyond individual technique to encompass a culture of continuous quality improvement. The establishment of dedicated vascular access teams standardizes care

and concentrates expertise, while daily interprofessional rounds that question the ongoing necessity of every CVC are essential for minimizing unnecessary line days. Therefore, optimizing patient safety is not merely a technical task but a collaborative, system-wide commitment. By integrating rigorous protocols, ongoing staff education, and a proactive, multidisciplinary strategy, healthcare teams can significantly mitigate the risks of CVCs, turning a potentially hazardous intervention into a reliably safe conduit for life-saving therapies.

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