Review

COMPLICATIONS RELATED TO CENTRAL VENOUS CATHETERS : A SPECIAL FOCUS ON INFECTIONS

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Abstract

The central venous catheter (CVC) is essential for various diagnostic and therapeutic procedures and was first reported to have been used in a patient in 1969. Over time, the indications for its use have become increasingly numerous. Its application involves placing the catheter into a large-lumen venous system—most commonly the internal jugular, subclavian, or femoral vein—for the administration of parenteral nutrition and fluids, certain medications, hemodialysis (HD), blood sampling, and central venous pressure (CVP) measurement. Complications related to CVC placement occur in 2–26% of cases and may be mechanical, infectious, or thrombotic. Although CVC insertion can be beneficial for patient recovery, it is not always essential for treatment. Therefore, the decision to place a CVC must be carefully considered. During catheter insertion, it is crucial to ensure thorough preparation, adherence to sterile technique, and appropriate post-procedural care to minimize the risk of potentially life-threatening complications. Among these, infections are the most frequently reported and will be discussed in detail in this paper.The aim of our study was to present the advantages and disadvantages of different approaches to central venous access, as well as the potential complications associated with CVCs, with a particular focus on infections. This review is based on a search of scientific and professional literature, especially original research articles published within the last five years, in the following scientific databases: PubMed, SCOPUS, MEDLINE, the Science Citation Index (SCI), and digital academic archives and repositories such as Dabar and Heart.

Keywords: catheters, veins, infections, intensive care

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Introduction

Central venous access is a “lifeline” that is indispensable in clinical practice and patient care within hospital settings.[1] During the 1960s and 1970s, the use of central venous catheters (CVCs) became routine in intensive care units, oncology, neonatology, hemodialysis, parenteral nutrition, and palliative care. With the introduction of new materials and techniques, CVCs have become safer and more effective, reducing the risk of infections and other complications.[2]

Although CVCs are relatively safe and beneficial for patient care and treatment, their use can lead to numerous complications during both insertion and post-catheterization. The literature suggests that complications related to CVCs occur in 2–26% of cases and may be mechanical, infectious, or thrombotic. While CVCs insertion can significantly aid in patient recovery, it is not always an essential procedure; therefore, the decision to place a CVC is of critical importance.[3]

When inserting a catheter, careful preparation, strict adherence to sterile technique, and diligent post-insertion care are vital to minimizing the risk of potentially fatal complications—among which infections are the most common. These will be the primary focus of our paper. The aim of our study was to present the advantages and disadvantages of different approaches to central venous access and to explore potential complications in patients with CVCs, with particular emphasis on infections.

Central Venous Catheters

Globally, nearly three-quarters of patients treated in intensive care units require central venous catheterization.[4–6] Catheters can be either tunneled or non-tunneled and are primarily classified as short-term or long-term devices.[7] Their use is essential for various diagnostic and therapeutic procedures. It is reported that the first CVC was used in a patient in 1969.

The indications for CVCs use have expanded significantly. Placement typically involves inserting the catheter into a large-lumen venous system—most commonly the internal jugular, subclavian, or femoral vein—for the administration of parenteral nutrition and fluids, specific medications, hemodialysis (HD), blood sampling, and central venous pressure (CVP) monitoring. The choice of vein depends on several factors, including the patient's clinical condition, body habitus, local anatomical findings, vascular status, physician experience, and other endogenous and exogenous factors.[1]

Dialysis catheters, for example, are used when urgent HD is required, when all other vascular access sites are exhausted, or when waiting for the maturation of an arteriovenous fistula (AVF) is not feasible. However, CVCs use carries the risk of numerous complications, including systemic infections, thrombophlebitis, endocarditis, bleeding, and pneumothorax.

For HD, the preferred sites for CVC placement are the right internal jugular vein or the right or left subclavian vein. The left internal jugular vein is used less frequently due to its proximity to the thoracic duct, while the femoral vein is generally avoided because of its proximity to the anogenital region, which increases the risk of infection at the catheter site. [8–10]

For non-HD indications, the most commonly used sites are again the right internal jugular vein and the right or left subclavian vein.[2,3] Literature suggests that the most frequent complications associated

with CVCs include hematoma, infection, and pneumothorax.[11,12]Rarer complications include generalized venous system weakness.[11,12] Additionally, studies indicate that the use of ultrasound significantly improves the success rate of cannulation and reduces early complications during insertion, while proper aseptic maintenance is essential in preventing late complications.[11–13]

Complications Associated with CVC

Given that central venous catheters (CVCs) are widely used for administering medications, fluid replacement, and parenteral nutrition, earlier studies estimated that approximately 5 million CVCs are inserted annually in the United States, while more recent global estimates suggest that around 27 million CVCs are inserted each year. Despite their widespread use, CVC placement is associated with significant risks, including immediate complications such as pneumothorax and arterial cannulation, as well as catheter-related bloodstream infections (CRBSIs), deep bloodstream infections, venous thrombosis, and others.[14]

In hemodialysis (HD) patients, CVCs are associated with poorer clinical outcomes compared to arteriovenous fistulas (AVFs) and kidney transplants, largely due to more frequent complications and a reduced quality of life.[15] Various authors report that CVC placement can lead to serious complications, including infection, bleeding, pneumothorax, hemothorax, nerve damage, perforation of the right atrium or ventricle, air embolism, and more.[16]

Literature indicates that up to 90% of infections associated with intravascular catheters are linked to CVCs, underscoring

the severity of these complications. Such infections not only pose a significant threat to patient safety but also contribute to increased hospitalization duration and treatment costs [17]. The advantages and disadvantages of various approaches to central venous access are outlined in Table 1.[18]

Several studies identify malposition, infections, and thrombosis as the most common complications associated with central venous catheter (CVC) placement and maintenance.[18] Thrombosis, in particular, occurs in up to 28% of adults and 12% of children with CVCs.[19–21] To prevent thrombotic CVC occlusions, most healthcare institutions implement standardized protocols for catheter flushing, typically involving either 10 U/mL or 100 U/mL heparin solutions compared to normal saline.[22]

Pneumothorax and catheter malposition are also frequently reported adverse events during CVC placement that require close attention.[23] In a study by Ablordeppey EA and colleagues involving 2,045 patients who underwent CVC insertion, pneumothorax occurred in 14% of cases, while catheter malposition was observed in 13.4%. Notably, 57% of pneumothorax cases required thoracostomy tube placement. Additionally, venous thrombosis was found in 7.8% of cases involving incorrectly positioned catheters.[23]

Research by Cui Y and colleagues, based on 11 trials and 2,097 patients, found that catheter kinking and malposition were significantly less common in patients who underwent ultrasound-guided CVC placement compared to the control group. However, no statistically significant difference was observed between the two groups in the rates of hematoma or venous

thrombosis. Other complications such as pneumothorax, hemothorax, phlebitis, and cardiac tamponade were reported to be rare.[11]

Table 1. Advantages and disadvantages of different approaches to central vein access during the application of central venous catheters (CVCs)

CVCs insertion site	Advantages	Disadvantages
V. cephalica V. basilica	Easy catheter insertion due to clearly visible veins. Greater comfort and convenience for the patient. No risk of contact with vital organs.	Risk of catheter malposition or failure to achieve a central position. Increased risk of thrombosis. Low flow rate or limited maximum infusion rate.
V. jugularis interna	Lower risk of pneumothorax. Direct access to central veins. Low risk of thrombosis. High flow rate. Relatively easy placement.	Risk of carotid artery puncture. Uncomfortable for the patient. Not recommended for long-term venous access. Difficult to place in obese patients. Vein prone to collapse in hypovolemic states. Challenging to access during emergencies when airway management is prioritized. Higher rate of late complications.

V. jugularis externa	No risk of pneumothorax. Any bleeding that occurs is easy to control. Provides rapid venous access.	Catheter placement into the vein lumen is difficult. Not preferred for long-term venous access. Challenging to place in obese patients. High incidence of catheter malposition.
V. subclavia	More comfortable for the patient. Large diameter (about 20 mm). Resistant to collapse. Accessible puncture site, especially useful when establishing an airway. Easier placement in obese patients. Lower risk of long-term complications.	Increased risk of pneumothorax (incidence 1–2%) and hemothorax (incidence less than 1%). Difficulties during insertion related to operator inexperience. Risk of catheter misplacement. Potential interference with chest compressions. Curved anatomical pathway complicating catheter navigation.
V. femoralis	Easiest vein to puncture. No risk of pneumothorax. Capable of handling high flow rates. Easy to place. Does not interfere with intubation or CPR.	Increased risk for occurrence of thrombosis (10%). Possibility of puncture femoral artery (5%). Reduced mobility legs at the hip joint. Difficult placement in obese patients. Heavy maintenance puncture sites sterile.

Taken from: Kranjčić L. Central Venous Catheters [Thesis]. Pula: University of Juraj Dobrila in Pula; 2023 [accessed on 12.03.2025]. Available at: https://urn.nsk.hr/urn:nbn:hr:137:911055.

CVC related Infection Complications

In the literature, infection associated with central venous catheters (CVCs) is classified as the most severe complication, with its incidence increasing linearly with the

duration of catheter use. Given the widespread use of CVCs and their direct association with catheter-related bloodstream infections (CRBSIs), which negatively impact morbidity and mortality rates among patients in intensive care, oncology, and hemodialysis (HD) settings, this complication remains a major clinical concern.[24]

CVC-associated infections occur when pathogenic microorganisms enter the bloodstream via extraluminal or intraluminal routes.[25–29] Extraluminal contamination is most common in short-term (non-tunneled) catheters, where microorganisms from the skin at the insertion site migrate directly into the vein. Intraluminal contamination, on the other hand, is typically seen in long-term subcutaneous tunneled CVCs and arises from inadequate aseptic handling by healthcare providers during catheter placement, maintenance, and manipulation for therapy administration.[30–32]

Safe and reliable central venous access is fundamental to treatment in many clinical settings. Despite various preventive measures, the presence of a CVC still poses a significant risk for septic complications. Proper CVC care, including strict adherence to aseptic protocols when handling catheters, remains the key to infection prevention.[33,34]

A study by Zhu S and colleagues involving 5,046 intensive care patients with CVCs found that infections associated with CVCs significantly increased hospitalization costs and mortality due to nosocomial bloodstream infections.[35] While CVCs provide reliable venous access in critically ill patients, the risk of catheter-related bloodstream infections necessitates meticulous disinfection of the catheter exit site and the caps used to seal the catheter to prevent infection.[32]

Research indicates that the use of antiseptic protective caps is associated with a reduced incidence of CVC-related infections in intensive care units.[36,32] Similarly, Lai NM et al. demonstrated that antimicrobial dressings applied to CVC insertion sites effectively reduce catheter-related bloodstream infections.[37]

Interestingly, a study conducted in emergency departments revealed that peripheral venous catheters inserted in these settings accounted for the highest number of infection episodes among patients with CVCs. The study attributed this to excessive use of CVCs under poor aseptic conditions, highlighting the potential for infection prevention through strict asepsis and antisepsis measures, sterile device use, and proper skin antisepsis and technique.[38]

In HD patients, CVC-related complications primarily include thrombosis and infection. While these complications cannot be entirely avoided, minimizing them by timely creation of arteriovenous fistulas (AVFs) and employing safe catheter placement and maintenance practices is essential. This approach also reduces legal liability for healthcare workers and institutions responsible for proper patient care.[29]

Cosma V et al. examined the frequency of CVC infections and their causative microorganisms, identifying coagulase-negative Staphylococci (27.9%), Enterobacterales (27.5%), non-fermenting Gram-negative bacilli (10.4%), Candida species (16.9%), and Staphylococcus aureus (16.9%) as the most common pathogens (26). Similarly, Stango C et al. reported that coagulase-negative staphylococci and Staphylococcus aureus, typical skin flora, are frequently isolated from peripheral catheter.[39]

Prolonged CVC duration is associated with an increased risk of infections caused by Gram-negative bacteria, most commonly Acinetobacter baumannii, Klebsiella pneumoniae, and Pseudomonas aeruginosa. However, further prospective studies are needed to definitively identify the most

common pathogens responsible for CVC-related infections.[27]

Šentija I., in a master's thesis, presents guidelines and examples of procedural bundles aimed at preventing infections related to CVCs, serving as an example of good clinical practice in managing patients with CVCs (Table 2).[16]

The implementation of Clinical Pathway Protocols (PSPs) also yields secondary benefits by enhancing the work of healthcare professionals—both physicians and nurses—within a multidisciplinary framework. These protocols promote adherence to evidence-based practices in the clinical management and care of patients with central venous catheters (CVCs), thereby improving overall care quality and workflow efficiency.[16] To ensure the safe and effective use of CVCs for central venous access, it is essential to follow established protocols and adhere strictly to aseptic and antiseptic measures.[40]

Table 2. Prescribed procedure packages (PPP) for the prevention of infections associated with central venous catheters (CVC)

Type of PPP	Ingredients of PPP
Prescribed set of procedures for setting up a CVC	Hand hygiene Protective barriers when installing CVC Skin antisepsis using chlorhexidine Choosing the optimal insertion site (avoiding femoral access) Daily review of the necessity of retention CVC (early removal of CVC)
Modification of the prescribed set of procedures for setting up a CVC	Inspect the insertion site daily. Change the drape every seven days or sooner if it becomes wet at the insertion site. Document the ongoing need for the central venous catheter (CVC). Use a chlorhexidine-impregnated drape at the insertion site. Perform hand hygiene before each access to the insertion site. Disinfect the access port of the infusion system with an alcohol-based product before each intravenous (IV) administration.

Taken from: Šentija I. Prevention of Infections Using Central Venous Catheters in Intensive Care Units [Master's Thesis]. Zagreb: University of Zagreb, School of Medicine; 2015 [accessed on 31.03.2025]. Available at: https://urn.nsk.noclick_hr/urn:nbn:hr:105:698551

Conclusion

Considering that the indication for placing a central venous catheter (CVC) is most common among vulnerable patient groups—such as those in intensive care, hemodialysis, oncology, neonatology, and other departments—these patients are often significantly immunocompromised due to the nature of their illnesses. As a result, they are particularly susceptible to hospital-acquired infections. Therefore, clinical practice and patient care require heightened caution to prevent complications related to CVC-associated infections.

Our findings indicate that among all CVC-related complications, infections are the most prevalent. Importantly, this complication is largely preventable by avoiding femoral catheter placement when possible, ensuring proper handling of the CVC, and strictly adhering to aseptic and antiseptic measures.

Preventing infections associated with CVC use is a key predictor of patient recovery and survival. The nurse—being the healthcare professional with the most frequent patient contact—plays a crucial role in both the prevention and early detection of infections. Their supervision, along with a collaborative team approach to care (doctor-nurse), significantly contributes to reducing morbidity and mortality associated with CVC use in intensive care and hemodialysis patients.

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