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Overview about Complications of Central Venous Catheters of Hemodialysis and Their Prevention in Adults: Review Article

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ABSTRACT

Background: Nontunneled hemodialysis catheters and tunneled hemodialysis catheters, often known as tunneled dialysis catheters, are the two catheter types utilised for vascular access during hemodialysis. Short-term (1 week) consequences include catheter malfunction, central vein stenosis or thrombosis, and catheter-related infection. Long-term (>1 week) complications include those occurring during catheter placement and immediate access-related injuries.
Objective: Review of literature about complications of central venous catheters of hemodialysis and their prevention in adults. **Methods:** Central venous catheters and complications were searched for on Science Direct, Google Scholar, and PubMed. The authors also reviewed the relevant literature. Nonetheless, only the most recent or exhaustive analysis was included, covering the time span from January 2005 to December 2022.There are no translation resources available, thus non-English documents are out. Unpublished articles, oral presentations, conference abstracts, and dissertations were not included because they were not considered to be part of major scientific projects.
Conclusion: Infection in the bloodstream is a potentially fatal consequence of a central venous catheter (CVC). The best methods for preserving a catheter have been the subject of numerous scientific investigations. This included delaying replacement, exchanging catheters via a wire, or preserving a new catheter with antibiotic locks and systemic antibiotic therapy, but it was clear that removing the contaminated catheter was the best approach to get rid of the organism.
Keywords: Central venous catheters, Hemodialysis, Complications.

INTRODUCTION

Nontunneled hemodialysis catheters and tunneled hemodialysis catheters, often known as tunneled dialysis catheters, are the two catheter types utilised for vascular access during hemodialysis. The doctor can choose the most suitable catheter from among many different models. Polyurethane, poly (carbonate) urethane, and silicone are the materials used to make hemodialysis catheters. Both tunneled and non-tunneled catheters are formed from polyurethane, while the latter is made to be softer in chronic hemodialysis catheters due to the longer dwell durations, while the former is made to be slightly stiffer at the time of insertion but softens when exposed to normal temperature of the body **(1)**.

Nontunneled hemodialysis catheters: Catheters that aren't tunneled feature a conical point at the end and often have two or three lumens **(2)**.

Tunneled hemodialysis catheters:

A tunnel is constructed subcutaneously through the chest wall in the case of the internal jugular site, and through the thigh in the case of the femoral site, before the catheter is placed into the vein. The catheter is secured and infection risk is decreased with the help of an ingrowing tissue point created by the polyester cuff inside the ensuing subcutaneous tunnel. It is possible to create a fixation point that aids in prevention by sealing the cuff into the intravascular section of the catheter from the skin. Infection rates can be lowered by ting migration or unintentional dislodging **(2)**.

Catheter design:

The dialysis circuit consists of two lumens and two ports, one blue and one red. Conventionally, blood is withdrawn from the patient through the red port, which indicates the "arterial lumen," and returned to the patient through the blue port after being processed by the dialysis machine. Dialysis requires a higher blood flow rate than normal central venous access catheters can handle (300-375 mL/min). Hemodialysis catheters come in sizes ranging from 8 to 14 Fr for those that aren't tunneled, and from 10 to 16 Fr for those that are tunneled.

Catheters come in a wide range of shapes and styles, with a number of different configurations and tip designs to choose from. Catheter tip separation can be achieved via a staggered tip design, a septum that protrudes beyond the perforations, or lumens that separate distally. The catheter tip can be pushed away from the vessel wall by built-in curvature in another version for self-centering. The goal of these layouts is improved circulation and, for some patients, less recirculation **(3)**.

Surface-coated catheters:

Silver, chlorhexidine, rifampin, and minocycline are only some of the antimicrobials that have been tried and tested as surface coatings forwarding against infection. Antimicrobial-coated hemodialysis catheters were found to be useful in avoiding intravascular catheter infections in early research. Heparin-coated catheters reduce the risk of blood clots caused by the device **(4)**.

Indications:

Nontunneled hemodialysis catheters: Acute kidney injury, hemodialysis AV fistula thrombosis, and poisoning all call for the immediate insertion of a catheter that does not require tunneling. Critically ill individuals who are bedridden can have femoral catheters placed

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without tunneling the artery. Ambulatory patients should not use nontunneled femoral catheters because of their increased risk of kinking and femoral vein thrombosis. In order to prevent bacteremia, non-tunneled catheters should be removed after no more than two weeks of use. They are not intended for non-hospital settings [5].

Tunneled hemodialysis catheters:

To prevent catheter-related infections in patients whose hemodialysis treatments are expected to last longer than two weeks (even in the intensive care unit context), tunneled hemodialysis catheters are used when establishing acute vascular access for hemodialysis used in the outpatient situation. Some patients, such as those who have had multiple AV accesses fail with no available lines, or who have anatomical abnormalities that prevent ideal combinations of inflow artery and outflow veins, or who do not yet have an AV access created and prefer cuffed catheter-based hemodialysis, may have a tunneled central venous catheter inserted indefinitely [5].

Complications:

Short-term (1 week) consequences include catheter malfunction, central vein stenosis or thrombosis, and catheter-related infection, longer-term (>1 week) complications include those occurring during catheter placement and immediate access-related injuries. The larger the catheter, the more times it must be punctured, and the longer it must be in place, the greater the risk of problems [6].

The placement of a central venous catheter is not without risk. Most mechanical difficulties occur at the time a catheter is inserted, depending on the skill of the practitioner, but infectious and thrombotic complications tend to show up later. When adopting dynamic ultrasound-guided venous entry, the risk of mechanical problems is drastically cut down. The venous access location is selected after careful thought and deliberation. Trial insertions in the subclavian vein are associated with a higher rate of mechanical problems compared to the internal jugular access and the femoral vein, respectively [7].

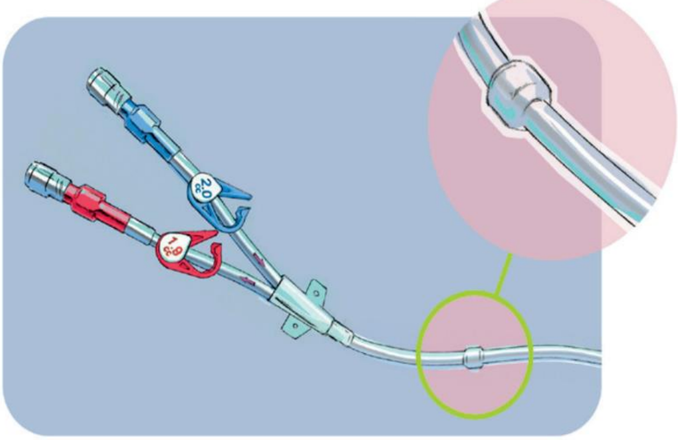

Figure (1): Catheter design circuit lumens [3]

Pneumothorax:

Harmful complications include pneumothorax. Central catheterization of subclavian veins is associated with an increased risk of iatrogenic pneumothorax. Pneumothorax rates during insertion vary according to access site, predisposing conditions (such as lung disease), the success or failure of the initial access attempt, and operator lack of experience [8].

Venous air embolism:

Central venous access is connected with the risk of air embolism, a potentially deadly consequence. Modern dialysis catheter kits are made with air embolism prevention built into the design of the peel-away sheaths. An air embolism in the veins can occur before, during, or after a central venous catheter is inserted. If possible, the Trendelenburg position should be used during catheter insertion to lessen the chance of an air embolism [9].

Arterial injury:

One potential risk of central venous access is that the needle will be inserted into an adjacent artery rather than the intended vein. Between 3.7% and 12.0% of all cva procedures involve arterial puncture. Vascular damage can be mitigated, but not prevented, when ultrasonography is consistently used during central catheter insertion. Compression of the airway due to a hematoma that may follow a carotid artery injury poses a life-threatening hazard to the patient [10].

If the artery is cannulated and dilated with a large bore catheter, a vascular surgeon will need to be consulted immediately so that the catheter may be removed and the damaged artery can be repaired. Because arterial tamponade might occur if a catheter is removed without surgical supervision [11].

Bleeding:

The puncture sites, the catheter tunnel, and the veins themselves are all potential sources of bleeding during central venous catheterization [12].

External bleeding:

Arterial and venous injuries both cause quick bleeding on the outside. This may occur during the initial insertion process, during vascular dilation, or when inserting a device. First, direct pressure should be applied at the point of access or on the tube for any external bleeding. Suture implantation can improve the prevention of bleeding in cases of local hematomas, for which the same principles apply [13].

Internal bleeding:

Hemorrhage can form locally, in the retroperitoneum in the event of femoral access, or in the thorax in the event of jugular or subclavian access.

Hemothorax:

Hemothoraces are a complication of venous access through the subclavian or jugular veins. The gold standard treatment for these individuals is thoracostomy with a 32 or 36 Fr chest tube to drain the chest cavity. Rarely, surgical intervention is required [14].

Cardiac injury and pericardial effusion:

Very few people can handle these kinds of injuries. The symptoms may be attributed to persistent erosion from the indwelling device or to how the guidewire, dilator, or catheter was inserted. Bradycardia, hypotension, poor oxygen saturation, and increased venous pressures are all symptoms of pericardial effusion. Perforation of the right atrium by a tunneled hemodialysis catheter can cause severe bleeding and hypotension, perforation of the myocardium during hemodialysis might cause immediate pericardial tamponade, requiring thoracotomy or sternotomy for evacuation of the pericardial effusion [15].

Pseudoaneurysm:

After arterial puncture during central venous access, pseudoaneurysm might also develop [16].

Arrhythmia:

Limiting the depth to which the guidewire penetrates the heart can prevent ventricular dysrhythmias and bundle branch block. Cardiac perforation is uncommon but can occur when a nontunneled central venous catheter is placed too deeply in the right atrium or with its tip in the right ventricle [17].

Tunneled hemodialysis catheter-related bloodstream infection (CRBSI):

CVC-related bloodstream infections can potentially be fatal. Each case of catheter-related bloodstream infection (CRBSI) in the United States costs between $25,000 and $45,000 yearly. In as many as 44% of bacteremic episodes, serious consequences arise, highlighting the importance of providing the best care possible. Epidural abscess, septic arthritis, endocarditis, osteomyelitis, thromboembolism, and mortality are all possible outcomes [5].

Many dialysis patients rely on CVCs, making it crucial for nephrologists to effectively manage infected catheters. There has been a movement in the recent decade to expedite the fistula placement process for individuals with chronic renal disease. The US Renal Data System (USRDS) inspired this since it indicated that catheter users had four times the risk of infection as transplant users and eight times the risk of fistula users [18].

Risk factors for infection:

Risk factors that have been found to increase the rate of an infection must be suspected before a diagnosis of infection can be made. Poor hygiene, a history of catheter-related infection, ineffective dialysis, low albumin levels, diabetes, hypertension, and extended catheter use are all risk factors**.** Most infections that arise from using a hemodialysis catheter are caused by gram-positive bacteria. Most studies find that 40–80% of cases are caused by coagulase-negative staphylococci and S. aureus together. Twenty percent to forty percent of catheter-related bloodstream infections (CRBSIs) are caused by Gram-negative organisms, while ten to twenty percent are caused by polymicrobial infections. Infection with S. aureus is a leading cause of serious illness and death. Tunneled catheters in hemodialysis patients have shown an increase in methicillin-resistant S. aureus (MRSA) infections [19].

Enterococcal and gram-negative bacteremias associated with hemodialysis catheters are more common than those caused by staphylococci. Polymicrobial infections, as well as infections caused by gram-negative bacteria and fungi, are more common in hemodialysis patients who are positive for the human immunodeficiency virus (HIV) [16].

Infection was most often predicted by the presence of fever, rigors, abnormal mentation, a noticeable alteration in the look of the exit site, and/or inexplicable hypotension. Among patients with bacterial infections caused by catheters, only 47% experienced fever. Fever alone, fever with rigors, and rigors alone were all equally represented among the symptoms, although up to 20% of people showed no signs of illness at all [15].

Since several different symptoms can suggest a catheter-related illness, a high temperature may not be necessary. A thorough examination is required anytime the appearance of the exit site changes, as it is one of the entry points that lead to catheter-related bacteremia. Daily use and manipulation of the catheter can lead to erythema, but any pain, bruising, or fever should be closely monitored [19].

Diagnosis of Suspected Catheter-Related Bloodstream Infection (CRBSI):

At the first sign of infection, blood cultures should be drawn from both the catheter and a peripheral location. The catheter tip should be cultured if it can be removed right away. Two separate cultures are taken to determine if the infection is originating from the catheter or somewhere else in the body. A CRBSI can be definitively diagnosed if the same organism is found in both a peripheral culture and the catheter tip. Another diagnostic tool is a quantitative blood culture taken from the catheter axis, which typically reveals three times the bacterial load of a culture taken from a peripheral vein [19].

Management of Confirmed Infections:

Catheter Management:

Antibiotic treatment alone has a poor success rate. Thus, catheter lock, removal, or guidewire exchange must be incorporated into the treatment regimen [20].

Because of the skin trauma and shorter time for endothelialization and fibrosis of the catheter tunnel, bacteremia-causing exit-site infections are more common in recently inserted tunneled lines [21].

Abscess formation in the tunnel and the natural building of a biofilm, which can host organisms, both reduce antibiotic penetration. When a patient has an infection at the point of exit but no fever, a topical antibiotic can be given. When this therapy failure happens, systemic antibiotics can be started, and the catheter can be removed, in the event that the infection is not quickly cleared [21].

After collecting blood cultures, empirical treatment for hemodialysis patients suspected of having a CRBSI begins with intravenous vancomycin and ceftazidime at doses of 20 mg/kg and 1 gm, respectively. A greater starting vancomycin dose (35 mg/kg) has been recommended by certain specialists [22].

Preventing complications:

Vascular access should be put by a competent operator or vascular access team for the best possible patient outcome. Complications from catheter insertion can be minimised by using a skilled operator, ultrasound guidance, and nurse assistance. A comprehensive preventative plan can lower the rate of problems even in the absence of a professional vascular access team [23].

Appropriate operator experience: It is not known how often an operator needs practice inserting central venous catheters in order to keep their abilities up to par. Nonetheless, it's obvious that experience matters. Many hospitals now mandate a minimum number of successful central venous catheter insertions before allowing operators to put catheters unsupervised, recognising the importance of operator expertise. In addition, there is some evidence that central line placement simulation training can help reduce complications [24].

Mechanical problems: — Mechanical difficulties (such as haemorrhage, blood vessel injury, pneumothorax, and the inability to cannulate the vein) are reduced when ultrasound guidance is used, the location of insertion is chosen carefully, the patient's body habitus is taken into account, and there are fewer insertion attempts [25].

● **Limiting attempts:** – There is a correlation between the number of tries and the occurrence of a mechanical problem. Mechanical difficulties were shown to occur six times more frequently when insertion was tried more than three times than when it was accomplished on the first try, according to a prospective cohort study. Each time a hollow needle is placed into a patient's vein, or an attempt is made to widen a vein or thread a catheter over a guidewire, we count this as an attempt [25].

● **Limiting wire/catheter length:** – Normative compass arrhythmias can be prevented at both the time of catheter installation and afterwards by maintaining wire control and using a catheter of the correct length. In most cases, moving the wire away from the ventricles after a patient develops symptoms can address the problem. When placing a central venous catheter, one source suggests not inserting more than 20 centimeters of wire/catheter via the right internal jugular vein. The use of fluoroscopy for direct sight of the wire/catheter is also beneficial [25].

● **Ultrasound guidance:** – When possible, a central venous catheter insertion into the internal jugular vein should be performed using real-time, two-dimensional ultrasound guidance rather than blind, landmark-guided procedures [26].

● **Confirm catheter positioning:** – It is common practice to use a central venous catheter before verifying its location with a chest x-ray or ultrasound. Clinicians frequently utilise central lines without first confirming their insertion with imaging, especially in the operating room and during emergency settings. Failure to confirm the position can be problematic since clinician judgment does not consistently predict catheter malposition or other mechanical complications, especially with less experienced operators [27].

● **Preventing air embolism:** – Central venous catheterization carries the risk of venous air embolism, a potentially fatal complication, especially when using a large-lumen catheter. An air embolism in the veins can happen at any time during the placement or removal of a central venous catheter [28].

It is possible to prevent this complication from occurring after central venous catheter installation by using the Trendelenburg position, the Valsalva technique, immediate needle/catheter occlusion, and secure intravenous connections [28].

Patients should be positioned supine in preparation for central venous catheter removal. When exhaling, when intrathoracic pressure is higher than atmospheric pressure, the central venous catheter can be safely removed. After the object has been removed, constant, firm pressure must be administered for at least a minute. In addition, if the catheter was not tunneled, a persistent catheter tract may be sealed off by applying an occlusive petroleum-based product dressing after the nontunneled catheter is removed [28].

Infection control measures:

Some ways in which infections caused by catheters can be avoided are:

● **Maximal barrier precautions** – All operators should wear a mask, cap, sterile gown, and sterile gloves during catheter installation [29].

● **Avoid insertion into the femoral vein** – When a central venous catheter is placed in the femoral vein instead than the internal jugular or subclavian vein, there may be an increased risk of infection [29].

● **Hand hygiene** – The best way to avoid getting an infection from a catheter is to strictly stick to universal care guidelines, such as washing your hands and not touching the catheter or dressings [29].

● **Chlorhexidine skin antisepsis** – Chlorhexidine solutions are superior to povidone-iodine solutions for use in regular catheter care and handling [29].

● **Daily evaluation** – It is recommended that temporary catheters be checked every day to make sure they are still needed [29].

● **Remove unnecessary central venous catheters** – Central venous catheters should be assessed for necessity daily, and any that are deemed unnecessary should be removed immediately [29].

Patient Education for Central Venous Catheter Care:
When caring for a CVC at home, patient education is crucial. Having to deal with a catheter and regular haemodialysis treatments can be incredibly stressful for sufferers and their loved ones. Patients and their loved ones should be educated as much as possible about CVCs and how to care for them at home to lessen the likelihood of complications. At-home CVC care and management, including proper hygiene, catheter protection, and handling of complications, should be the focus of the patient education [30].

CONCLUSION

Infection in the bloodstream is a potentially fatal consequence of a central venous catheter (CVC). The best methods for preserving a catheter have been the subject of numerous scientific investigations. This included delaying replacement, exchanging catheters via a wire, or preserving a new catheter with antibiotic locks and systemic antibiotic therapy, but it was clear that removing the contaminated catheter was the best approach to get rid of the organism.

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