CONTINUING EDUCATION

EDUCATIONAL OBJECTIVES

After participating in this activity, clinicians should be better able to

- Describe the most common complications encountered with vascular access device use
- Identify the diagnostic criteria for catheter-related infections and occlusions
- Explain how to manage catheter-related infections and occlusions

Troubleshooting complications of vascular access devices

Dawn Camp-Sorrell, MSN, FNP, AOCN

STATEMENT OF NEED/PROGRAM OVERVIEW

Long-term use of VADs is a necessity for treating many types of cancer. The difficulty of maintaining vascular access during treatment continues to be a challenge. The most common complications associated with VADs are catheter-related infections and occlusions. Diagnosis and management of these complications, however, are not standardized and remain a challenge to nurses.

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Troubleshooting complications of vascular access devices

VADs enable long-term intravenous therapy; however, the devices and their use pose a unique set of challenges for oncology nurses.

A peripherally inserted central catheter line is inserted into a peripheral vein.

BY DAWN CAMP-SORRELL, MSN, FNP, AOCN

The use of intravascular (IV) drugs and fluids has increased significantly in the past three decades due to their proven effectiveness in treating a wide array of diseases. This treatment modality necessitates long-term use of vascular access devices (VADs); however, maintaining vascular access throughout the course of treatment can be a challenge. Serious complications may develop or treatment delayed if vascular access cannot be maintained. Phlebitis and extravasation are other potential complications when smaller, more fragile blood vessels are used. Treatment often becomes a painful, dreaded ordeal especially for patients with limited or damaged blood vessels.

Selecting the appropriate device, providing continuous maintenance care, and troubleshooting complications requires specialized knowledge. A wide array of vascular access devices is available, and every device incurs a risk of complication. Although insertion complications can be life threatening, they occur less frequently[1-4] (Table 1). Catheter-related infections

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and occlusions are the most serious complications, as well as the most frequently reported.[5] Therefore, this article will focus on catheter-related infections and occlusions.

AN OVERVIEW OF VASCULAR ACCESS DEVICES

Peripherally inserted central catheters (PICCs), tunnel catheters, and implantable ports are the types of long-term VADs used.[6-7] They are referred to as long-term because the catheter tip lies in the distal third of the superior vena cava, and the device can be maintained for months to years.[3] Despite the unique design of each VAD, all types can be used to administer fluids, medication, blood products, and hyperalimentation or to obtain blood samples. VADs are available in single or double lumen design, with an open or one-way valve catheter distal tip. Newer, technologically advanced devices have systems that allow for power injection of contrast material.[7]

Peripherally inserted central catheters were initially developed in the 1980s. They were used mainly for venous access in patients receiving home care. A PICC insertion site is peripheral with the exit site at or above the antecubital area of the arm.

Tunnel catheters, available since the mid-1970s, are used for long-term administration of hyperalimentation and bone marrow transplant patients.[7] This type of catheter is tunneled through subcutaneous tissue and anchored within the tunnel by one or two cuffs located on the catheter. Tunnel catheters exit on the anterior chest and are the only device available in a triple lumen design.

Implantable ports were introduced in 1982 in an effort to reduce VAD infection rates.[8] Ports differ from other VADs in that the portal body is in a pocket created completely under the subcutaneous tissue and accessed using a noncoring needle. Care and maintenance of implantable ports and monitoring for complications must be emphasized with increased use of these devices.

CATHETER-RELATED INFECTIONS

The reported infection rate of VADs ranges from 0.8% to 27%.[3,4] The true incidence of VAD infection is difficult to measure because the definitions of infections are not standardized. Adherence to strict hand-washing and aseptic techniques and patient/caregiver education are effective preventive measures.[9] Surveillance of infection rates help monitor the occurrence of VAD infections, the type of infections that develop, use of antibiotics, hospital stay, and the need for VAD removal. Dressings protect the VAD exit or insertion site from infective organisms on the caregiver's hands and the patient's skin. However, studies evaluating the effect of dressing type (gauze vs transparent) and frequency of dressing change on the incidence of infectious VAD complications involved small sample populations; therefore, the data is insufficient for establishing standard-of-care recommendations.[10,11] Cleansing the skin to remove potentially infective organisms is a vital step in infection prevention. Chlorhexidine has been found to be the most effective agent for pre- and postinsertion cleansing. The solution should be applied with friction without contaminating the site and allowed to air dry for approximately 30 seconds.[7,11]

Although some facilities require clinicians to wear a mask while changing the dressing, infections are more often associated with bacteria on the skin than with respiratory organisms. Using full aseptic technique for VAD insertion may prevent infection;[6] however, routine use of sterile drapes, masks, gowns, and gloves is not proven to lower the incidence of infection.[10] Cleansing the hub before and after connecting tubing or a syringe is also necessary because bacteria can be introduced through the catheter hub. A higher risk of infection is associated with longer device placement; therefore, the need to maintain a VAD should be routinely assessed. Removal is recommended once it will not be used.[9,11]

> VADs should have good blood return to ensure safe infusions. This is defined as the ability to draw back 3 mL of blood within 3 seconds.

Risk factors that increase the incidence of catheter-related infections include neutropenia, femoral catheterization, prolonged duration of catheter placement, hyperalimentation, and substandard maintenance care.[9,11] Organisms may adhere to and multiply on the surface of the catheter or skin, causing a catheter-related infection in the hub, tunnel, port pocket, exit site, or bloodstream (Table 2). Infection can also develop in a thrombus in which bacteria or fungi colonize. It then becomes a constant source of seeding to the bloodstream. Many bacteria excrete a polysaccharide matrix that coats the catheter.[6] The matrix bonds the organism to the catheter, rendering systemic antibiotics ineffective. The most common organisms associated with VAD infections include gram-positive bacteria, mainly *Staphylococcus aureus*, and coagulase-negative staphylococci.[4] Symptoms of a catheter-related infection are local erythema, edema, or purulent drainage. Systemic infection can also include fever, chills, hypotension, and malaise.

Diagnosis A catheter-related infection might be difficult to diagnose in the absence of local signs of infection.[6,8] If an infection is suspected, blood cultures should be drawn from each lumen and a peripheral site before initiating antibiotics to compare concentrations of organisms in the catheter

TABLE 1. Complications related to vascular access device insertion[1-4]

Complication	Symptoms	Etiology
Air embolism	• Cardiac arrest • Chest pain • Hypotension • Sudden respiratory difficulty • Tachypnea	Intrathoracic pressure becomes less than atmospheric pressure at the open needle or catheter
Cardiac tamponade	• Anxiety • Chest discomfort • Cyanosis • Face and neck vein distention • Hypotension • Light-headedness • Mild dyspnea to respiratory arrest • Restless • Tachycardia • Tachypnea	Cardiac compression of fluid accumulation within the pericardial sac caused by catheter perforation
Carotid artery puncture	• Hypotension • Internal or external bleeding at insertion site • Pallor • Rapid hematoma formation at insertion site • Stroke • Tachycardia • Weak pulse	Carotid artery punctured during percutaneous insertion into the internal jugular vein
Catheter migration	• Ear pain • Neck pain • Palpitations • Partial or total occlusion • Shoulder pain	Catheter tip no longer located in the superior vena cava
• Chylothorax • Hemithorax • Hydrothorax • Pneumothorax	• Chest pain • Cyanosis • Decreased breath sounds • Dyspnea • Shift in heart sound location • Tachypnea	Caused by air, blood, lymph, or fluid infusion into the pleural cavity after injury to the pleura, vein, or thoracic duct during catheter insertion
Exit site bleeding/hematoma	• Bleeding at exit site that persists for hours • Discoloration or bruising at exit site	• Catheter insertion is traumatic or larger introducer sheath is left in place. • Patient may have coagulopathy or thrombocytopenia.
Pinch-off syndrome	• Infusion difficulties • Partial or total occlusion	• Catheter lies in the costoclavicular space next to the subclavian vein instead of inside the vein, may lead to catheter fracture. • Compression of catheter as it passes between the clavicle and first rib at the costoclavicular space.
Subclavian artery damage	• Bleeding at insertion site • Hypotension • Pallor • Rapid hematoma formation • Tachycardia • Weak pulse	Subclavian artery punctured during insertion

versus the peripheral blood. If the culture from the VAD turns positive before the peripheral sample, a catheter-related infection is diagnosed.

Treatment Initially the drug of choice is vancomycin intravenously, which usually eradicates coagulase-negative staphylococci.[7,9,11] Antibiotic therapy must be modified after the organisms are identified according to susceptibility. The antibiotic lock technique delivers high antibiotic concentrations directly into the catheter lumen.[6,9] The technique is used alone or in conjunction with systemic antibiotics. Antibiotic solution is instilled into the lumen, and it is clamped for a specified period of time, then the solution is removed. The antibiotic solution can be rotated and infused through each catheter lumen, if needed. If the source of infection is a thrombus at the distal tip, fibrinolytic therapy combined with antimicrobial therapy may be beneficial.[4,7,11]

Routine device removal cannot be recommended for every catheter-related infection. However, if blood cultures remain positive or infectious symptoms do not subside in 1 to 3 days, the device should be removed.[11] In general, VADs should be removed from patients with severe sepsis; endocarditis; infections due to *Pseudomonas*, *Staphylococcus aureus*, or fungi; or port pocket/tunnel infections.[6,8,9]

TABLE 2. Types of VAD-related infection[4,6,9,11]

Type	Location	Symptoms	Treatment
Blood-stream	Systemic	• Chills • Edema • Erythema • Induration • Fever • Hypotension • Malaise • Purulent drainage	• IV antibiotics • Remove device when symptoms persist after initiating antibiotics
Local	Insertion or exit site	• Edema • Erythema • Induration • Local tenderness	Oral or IV antibiotics
Port pocket	Subcutaneous pocket	• Edema • Erythema • Induration • Purulent drainage	• IV antibiotics • Pack port pocket with antibiotic gauze • Port removal
Tunnel	Subcutaneous tunnel	• Edema • Erythema • Induration • Purulent drainage	• Catheter removal • IV antibiotics • Pack subcutaneous tunnel with antibiotic gauze

Key: VAD, vascular access device.

CATHETER-RELATED OCCLUSION

Partial or total occlusion can occur as a result of thrombus, fibrin sheath, drug or lipid precipitates, or catheter migration[4,5] (Table 3). Partial occlusion is a one-way valve effect in which fluids will infuse readily but blood does not aspirate. Neither fluid infusion nor blood aspiration is possible with a total occlusion. Approximately 20% of long-term VADs fail to yield blood samples. Persistent withdrawal occlusion is reported in up to 10% of patients with VADs. In addition to blood withdrawal or infusion difficulties, patients may exhibit clinical signs of erythema and edema, and may experience shoulder or sternal pain.[5,7]

Strict adherence to routine flushing protocols can minimize occlusion. Flushing the VAD cleans off the residue that adheres to the internal catheter lumen, thereby preventing build up of fibrin or drug precipitant deposits.[7] Most institutions have a standard protocol for flushing VADs; however, evidence to support universal guidelines is insufficient.[7] The pressure-activated safety valve (PASV) was developed to potentially reduce the incidence of occlusion complications. It reduces back flow of blood into the catheter tip and is available on all VAD devices.

Thrombus Risk factors for thrombus formation include dehydration, venous stasis, infection, adenocarcinoma or squamous cell carcinoma of the lung, head or neck cancer, and breast cancer. Thrombus formation is influenced by the characteristics of the catheter surface and catheter stiffness. A stiff catheter puts pressure on the intima of the vein, generating thrombi especially at the tip.[5,7] A flexible catheter is less damaging to vein endothelium because the tip floats freely in the bloodstream. The longer the VAD is in place, the more time a fibrin sheath or thrombus has to develop. Finally, the location of the catheter tip increases the risk of thrombus formation. A brachiocephalic or upper superior vena cava position and if the catheter tip is too deep into the atrium are associated with a higher incidence of thrombosis formation.

Fibrin sheath The VAD catheter becomes encased in a fibrin sheath within 24 hours after insertion, and the sheath can develop up to 2 weeks after placement.[5] Fibrin formation is a natural physiologic response initiated by platelets to the presence of any nonendothelial surface. Fibrin deposits build up from where the catheter enters the vein to where the tip touches the intima. Although a fibrin sheath typically does not produce clinical manifestations, a small risk of embolization of the fibrin material exists. Intraluminal clots account for up to 25% of VAD occlusions and may lead to complete obstruction. A mural thrombus is a clot that adheres to the

TABLE 3. Types of occlusions[4,5,7,10]

Occlusion	Etiology	Outcome	Treatment
Drug precipitates	Drug crystallization in catheter or distal tip from infusion of incompatible solutions or inadequate flushing	Partial or total occlusion	• Infuse solution to alter precipitate pH • VAD removal may be necessary
Fibrin deposits	Sheath: Fibrin adheres to the external catheter surface, can extend total catheter length and cause fluid to backtrack	Partial or total occlusion	• Change position • Fibrinolytic therapy • Flush • VAD removal may be necessary
	Tail: Fibrin located at the catheter tip acting as a one-way valve	Partial occlusion	• Change position • Fibrinolytic therapy • Flush
Thrombus	Deep vein: Clot formation at distal tip, subclavian, axillary, or brachiocephalic vein	Total occlusion	• Anticoagulation therapy and/or fibrinolytic therapy • VAD removal may be necessary
	Intraluminal: Fibrin or clot within the catheter	Partial or total occlusion	• Anticoagulation therapy and/or fibrinolytic therapy • VAD removal may be necessary
	Mural: Fibrin forms from a vessel wall injury and binds to the fibrin covering on the catheter surface leading to thrombosis formation	Partial or total occlusion	• Anticoagulation therapy and/or fibrinolytic therapy • VAD removal may be necessary

Key: VAD, vascular access device.

vessel wall and can occlude the distal catheter tip. Deep vein thrombosis (DVT) typically occludes the vein.[4,5]

VADs should have a good blood return to ensure safe infusions. Good blood return is defined as the ability to draw back 3 mL of blood within 3 seconds. All VADs should be evaluated at the initial sign of poor blood return suggesting occlusion.[10] Initial actions to restore blood return include repositioning the patient, gently using a push-pull technique with a saline flush, and ensuring correct position of a noncoring needle in an implantable port. If an occlusion is still evident, imaging studies can be used to investigate an occluded VAD. Plain chest radiography can reveal a mispositioned catheter, pinch-off syndrome, or catheter kinkage. Venography uses contrast dye to visualize the distal tip of the catheter and backtracking of fluid along the tunnel tract. If the patient is unable to undergo venography, ultrasonography or venous Doppler examination can be used, especially if clinical symptoms suggest DVT.[2,3,5,10]

Administration of a fibrinolytic agent such as alteplase (Activase) may help to clear the occlusion caused by a fibrin sheath. Alteplase activates plasminogen conversion to the proteolytic enzyme plasmin, which has the ability to dissolve fibrin clots.[8] Current recommendations are to administer a fibrinolytic agent into the catheter lumen with a dwell time of at least 30 minutes. In 85% of cases, alteplase dissolves the clot and blood return is restored within 1 hour. If blood return is not restored, the dose is repeated. Current recommendations for DVT are to initiate anticoagulation with low molecular weight heparin followed by warfarin (Coumadin, Jantoven, generics) for at least 3 months. If the catheter remains in place after full-dose anticoagulation is complete, continuing a prophylactic dose of anticoagulant until the VAD is removed is recommended.[5]

Drug/lipid precipitates The VAD should be evaluated for possible precipitate formation if the fibrinolytic agent fails. Inappropriate concentrations or incompatible mixtures can cause medications to precipitate within the catheter lumen.[10] An infusion pH that is too alkaline or too acidotic can cause precipitation. Parenteral nutrition preparations may leave lipid residue, which can cause an occlusion. Treatment of precipitate formation is based on the pH of the infusate used.

Catheter position The catheter can migrate into the subclavian, internal jugular, or innominate vein.[3] Malposition may be caused by forceful flushing or changes in intrathoracic pressure associated with coughing or vomiting. The distal tip of a VAD does not remain stationary; it is impacted constantly by body movement. If the catheter becomes coiled, the risk for thrombosis is further increased because intravascular flow resistance becomes elevated, altering the venous flow pattern.[5] Palpitations or arrhythmias may be experienced if the tip is located too deep in the atrium. Treatment for a malpositioned catheter includes changing the patient's position or using a guide wire exchange, fluoroscopic guidance, or catheter reinsertion to reposition the catheter.[7]

CONCLUSION

An increasing number of ambulatory patients will have an IV device in place at some point during their treatment. The increased need for intravenous access has led to a greater diversity of vascular access devices. Although VADs have been used for more than three decades, numerous clinical dilemmas remain with regard to maintenance care and managing complications. VAD complications can occur during insertion or at any time after placement. Nurses must maintain their knowledge of VADs to prevent, recognize, and appropriately manage its complications. ■

Dawn Camp-Sorrell is an oncology nurse practitioner at Children's Hospital of Alabama, Birmingham, Alabama.

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