Complications of Peripheral Venous Access Devices: Prevention, Detection, and Recovery Strategies

Elizabeth A. Mattox, RN, MSN, MS, ACNPC, ACNP-BC, CPPS

Most hospitalized patients have placement of a peripheral venous access device, either a short peripheral catheter or a peripherally inserted central catheter. Compared with central venous catheters that are not peripherally inserted, the other 2 types are generally perceived by health care providers as safer and less complicated to manage, and less emphasis is placed on the prevention and management of complications. Expertise of nurses in inserting, managing, and removing these devices may reduce the likelihood of complications, and increased recognition of complications associated with use of the devices is important to ensure continued improvements in the safety, quality, and efficiency of health care. Complications associated with short peripheral catheters and peripherally inserted central catheters include tourniquet retention, tubing and catheter misconnections, phlebitis, air embolism, device fragment embolization, and inadvertent discharge with a retained peripheral venous access device. Integration of prevention, detection, and recovery strategies into personal nursing practice promotes the quality and safety of health care delivery. (Critical Care Nurse. 2017;37[2]:e1-e14)

Use of venous access devices (VADs) is ubiquitous in health care. Experts estimate that at least 85% of patients hospitalized in the United States receive intravenous therapy.1-3 Most hospitalized patients have insertion of a peripheral VAD (PVAD), either a short peripheral catheter (SPC) or, less commonly, a peripherally inserted central catheter (PICC). Compared with non-PICC central venous catheters (CVCs), SPCs and PICCs are generally perceived as safer and easier to manage,4 and less emphasis is placed on the prevention and management of complications.5,6 The expertise of nurses who insert, manage, and remove these devices may affect the likelihood of complications,1 and increased recognition of PVAD complications is important to ensure continued improvements in the safety, quality, and efficiency of health care.5,7,8

In this article, I focus on strategies for prevention, detection, and recovery for selected complications of SPCs and PICCs relevant to acute and critical care nurses. The emphasis is on strategies most easily integrated into personal nursing practice. Complications reviewed include tourniquet retention, tubing and catheter misconnections, phlebitis, air embolism, embolization of device fragments, and inadvertent
Several important PVAD complications are not reviewed: catheter-associated venous thrombosis, infiltration and extravasation, and infection; these are briefly described in Table 1. Guidance in addressing prevention and management of PICC-related infection discharge of patients before removal of a PVAD. Table 1 provides basic definitions and signs and symptoms of these complications.9-18

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Table 1

<table>
<thead>
<tr>
<th>Complication</th>
<th>Definition</th>
<th>Potential signs and symptoms</th>
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<tbody>
<tr>
<td>Tourniquet retention</td>
<td>Tourniquet intended to temporarily promote venous distention for PVAD placement (or phlebotomy) is inadvertently left applied for an extended time</td>
<td>Transient pain, edema, and/or paresthesia of involved extremity and/or leaking at puncture or catheter insertion site(s)</td>
</tr>
<tr>
<td>Tubing and catheter misconnections</td>
<td>Event wherein components of a medical device are attached to the connector or port of another device that performs a fundamentally different function (eg, attachment of enteral feeding tube to a PICC)10,11</td>
<td>May include back pain, fever, chest pain, dyspnea, anaphylaxis, cardiopulmonary arrest, seizures, altered mental status, sepsis, and/or coagulopathies11,15 Signs and symptoms vary widely, may be subtle or catastrophic, and onset varies widely, from insidious to abrupt</td>
</tr>
<tr>
<td>Phlebitis</td>
<td>Inflammation of vein wall due to chemical, mechanical, and/or particulate-induced irritation3</td>
<td>Local pain, swelling, tenderness, and local and/or streaking erythema</td>
</tr>
<tr>
<td>Air embolism</td>
<td>Inadvertent venous administration of air via intravenous access device or insertion site</td>
<td>Sudden dyspnea, cough, wheezing, chest and/or shoulder pain, agitation, sense of impending doom, tachypnea, tachycardia, hypotension, and/or neurological findings consistent with cerebrovascular accident16 A harsh systolic murmur may be present</td>
</tr>
<tr>
<td>Device fragment embolization</td>
<td>Migration of part of a damaged vascular device (a fragment) through the vascular system3</td>
<td>Palpitations, arrhythmias, chest pain, shortness of breath, cough, localized swelling and/or pain, confusion/altered mental status, and/or hypotension3,17,18 Catheter dysfunction (eg, inability to flush or aspirate blood) may signal catheter damage or imminent embolization3,18</td>
</tr>
<tr>
<td>Retained PVAD at discharge</td>
<td>Situation in which a patient inadvertently leaves the health care setting with a PVAD in place despite the intention to remove the device before departure</td>
<td>No specific signs and symptoms beyond the presence of the device; secondary signs and symptoms may occur because of complications (eg, phlebitis or infection)</td>
</tr>
<tr>
<td>Catheter-associated venous thrombosis</td>
<td>Venous thrombosis due to the presence of a venous access device3</td>
<td>Majority of patients are asymptomatic; when present, signs and symptoms include pain, edema, venous engorgement, and/or difficulty with motion of the affected extremity or shoulder, neck, or chest3 If thromboembolism occurs, patients may show signs and symptoms of pulmonary embolism3</td>
</tr>
<tr>
<td>Infiltration</td>
<td>Inadvertent administration of a nonvesicant solution into subcutaneous tissue instead of the intended vascular route3</td>
<td>Persistent pain and burning at insertion site or along vascular pathway, edema, coolness or blanching of local tissue, leaking at the insertion site, and/or local parasthesias5</td>
</tr>
<tr>
<td>Extravasation</td>
<td>Infiltration of a vesicant (an agent “capable of causing blistering, tissue sloughing, or necrosis”) into subcutaneous tissue, instead of the intended vascular route3</td>
<td>Signs may include erythema, which may progress to blistering and/or tissue necrosis</td>
</tr>
<tr>
<td>Infection associated with vascular access device</td>
<td>Infection (local or systemic) due to placement of a vascular access device</td>
<td>Local induration, erythema, tenderness, and/or site drainage (may be purulent); patients with more severe infections may show signs of systemic infection (eg, fever)5</td>
</tr>
</tbody>
</table>

Abbreviations: PICC, peripherally inserted central catheter; PVAD, peripheral venous or vascular access device.
and thrombosis\textsuperscript{14-23} and PVAD infiltration and extravasation\textsuperscript{1,24-26} is widely available. A review is provided in the sidebar Bloodstream Infection Associated With Short Peripheral Catheters.

**Peripheral VADs**

**Short Peripheral Catheters**

According to the Infusion Nurses Society,\textsuperscript{8} approximately 330 million SPCs are sold annually in the United States, and experts estimate that 80% of hospitalized patients have insertion of at least 1 SPC.\textsuperscript{6} SPCs are often described as the most commonly used VAD in health care.\textsuperscript{6,8,32}

**Peripherally Inserted Central Catheters**

PICCs are venous catheters 30 to 40 cm long that are inserted in an upper extremity and terminate in the vena cava.\textsuperscript{3} Compared with SPCs, PICCs permit prolonged duration of therapy, allow central infusion of vesicants and irritants, and (when fully operational) reduce the need for repeated phlebotomy. According to market research cited by the Agency for Healthcare Research and Quality,\textsuperscript{33} more than 2.5 million PICCs were inserted in acute care settings in the United States in 2010. The popularity of PICCs is due to multiple factors, including implementation of nurse-led insertion teams, improved patient satisfaction, and the perception that PICCs are safer than...
are non-PICCs. Experts report that PICC use has steadily increased since the early 2000s.

**PVAD Complications: General Considerations**

Recognition of complications of SPC and PICC use is important for many reasons. The sheer pervasiveness of use of PVADs demands attention to prevention of complications and reduction of harm. Unfortunately, many experts suspect that PVAD complications are underrecognized among health care providers, partly because of persistent overestimation of the safety of these devices.

SPCs and PICCs have unique characteristics: the complication profile, prevention, detection, and recovery strategies differ between SPCs and PICCs. Whenever possible, I have covered the specific considerations for PICC versus SPC management. When information about complications associated with a specific device is limited (eg, PICC-related tourniquet retention and embolization of fragments of an SPC device), I have noted the deficiencies.

The Infusion Nurses Society describes multiple factors contributing to the general risk for SPC complications, including lack of standardization of technique, variations in practice, communication breakdowns, and insufficient knowledge and skills among providers. These factors contribute to inappropriate selection of site or device or both and suboptimal device placement, use, management, and removal, situations that ultimately may lead to complications. These factors certainly also contribute to PICC-related complications.

Selection of an appropriate device and insertion site is the first critical step in minimizing PVAD complications and harm. The patient’s condition, as well as the anticipated duration and type of intravenous therapy, are considered during selection of the device and site.

The Infusion Nurses Society provides practice criteria for site selection; however (with the exception of the recommendation to avoid insertion of SPCs in lower extremities), evidence supporting the criteria is of low quality (ie, recommendations from professional organizations or a generally accepted standard of practice without a research basis). PICCs are indicated for short- or long-term infusion of vesicants and known irritants; the convenience of the patient or the provider is not an appropriate indication for PICC placement. Selection of an infusion device should include an evaluation of the risks and benefits of specific devices as indicated by available evidence. For example, PICCs and CVCs are associated with similar rates of infection and with a high risk for deep vein thrombosis.

PVAD complications can interrupt or delay critical treatments; provoke pain and discomfort; reduce patient satisfaction; and result in suboptimal health care outcomes, injury, permanent disability, and death. Complications may also necessitate more invasive and costly vascular access or require additional patient monitoring and therapies, contributing to additional avoidable costs in health care.

**Tourniquet Retention**

Cases of tourniquets left applied to extremities after attempts at SPC placement (referred to as tourniquet retention) are described in articles on patient safety. Properly applied, a tourniquet generates distal venous distention, promoting successful SPC (or PICC) placement. Unfortunately, a tourniquet may be inadvertently left in place for many hours after an attempt (successful or otherwise) to secure intravenous access or after phlebotomy. The true incidence of these events (and resultant injury) is unknown. In the only published review of these events, Pennsylvania health care facilities reported 125 retained tourniquets related to either phlebotomy or “IV line” placement to the Pennsylvania Patient Safety Authority (PA-PSRS) in a single year.

Tourniquet retention can result in infiltration, extravasation, nerve damage, compartment syndrome, and thrombosis. Serious harm is thought to be rare: of 125 events reviewed by PA-PSRS, only 2 caused serious harm (as defined by PA-PSRS), specifically a transfer to a higher level of care and a marked infiltration. Although tourniquet retention associated with PICC placement has not been specifically described, the same factors that contribute to SPC-related tourniquet retention apply to PICCs (Table 2).

A key prevention strategy that can be integrated into practice is consciously and completely releasing tourniquets when any interruption occurs in the task that requires use of a tourniquet. Even seemingly inconsequential interruptions (eg, leaving the bedside to retrieve...
an item just across the room) should be considered moments of potential risk for a tourniquet retention.

Recovery and reduction of the potential for harm depends on prompt discovery of a retained tourniquet. Retained tourniquets are rarely discovered by the person who applied the tourniquet (ie, in < 1% of analyzed reports). Signs and symptoms may be subtle and nonspecific (Table 1), and patients most at risk for tourniquet retention may lack the ability to communicate their symptoms reliably. Thorough patient assessment, including inspection of all vascular access sites and distal extremities, theoretically improves the ability to detect a retained tourniquet and reduce the potential for harm.

### Tubing and Catheter Misconnections

Tubing and catheter misconnections occur when components of one medical device are attached to the connector or port of another medical device that is used for a fundamentally different function (eg, attachment of enteral feeding tube to a PICC). Misconnections occur with all types of VADs. The risk for misconnections involving PVADs is high, because of the devices’ prevalence of use. Inadvertent intravenous administration of a variety of liquids and gases (including enteral feedings, breast milk, medical gas, and air) has been reported. Although described as occurring with “significant frequency,” these events are underreported and the true incidence is unknown.

Signs and symptoms of infusion of an unintended fluid or gas vary widely; those listed in Table 1 are aggregated from published case reports. Clinical manifestations are related to many factors, including the patient’s size and health status and characteristics of the material infused (eg, volume, infusion rate, pH). Although some patients recover from misconnections, these events can result in permanent injury (eg, permanent neurological deficits, organ failure) or death or both.

The underlying cause of many misconnections is device overcompatibility. The ability to connect components of infusion systems (eg, PICC hubs, intravenous tubing) to sequential compression devices, enteral feeding sets, and blood pressure cuff tubing (among other devices) is an intrinsic risk. If connection is physically possible, inevitably the connection will occur, even when such an error seems unlikely or implausible.

Detection of misconnections is impeded because clinicians underappreciate the risk and may not consider misconnection as a cause of clinical changes and because the patient’s signs and symptoms may mimic those of more commonly suspected conditions (eg, pulmonary embolism). A selection of strategies for prevention, detection, and recovery for misconnections is outlined in Table 3.

### Table 2 Tourniquet retention

<table>
<thead>
<tr>
<th>Selected contributing factors</th>
<th>Selected strategies for reducing tourniquet retention and associated harm&lt;sup&gt;9,38&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient related</strong>&lt;br&gt;Obesity&lt;br&gt;Diminished or no perception of pain or discomfort&lt;br&gt;Impaired communication</td>
<td><strong>Prevention</strong>&lt;br&gt;Use long, brightly colored tourniquets that are readily visible and difficult to conceal&lt;br&gt;<strong>Detection</strong>&lt;br&gt;Fully visualize extremities and vascular access insertion sites during initial and subsequent patient assessments&lt;br&gt;<strong>Recovery</strong>&lt;br&gt;Upon detection, immediately remove the tourniquet&lt;br&gt;Assess for evidence of neurovascular compromise&lt;br&gt;Assess for infiltration and extravasation and manage according to published guidelines based on severity and characteristics of infused material&lt;br&gt;Promptly notify responsible provider if any evidence of injury or neurovascular compromise, infiltration, or extravasation is present&lt;br&gt;Document extent of injury or absence thereof&lt;br&gt;Report events in accordance with organizational guidelines&lt;br&gt;Disclose events to patients and patients' families in accordance with organizational guidelines and professional standards</td>
</tr>
<tr>
<td><strong>Use related</strong>&lt;br&gt;Susceptibility of providers to distractions and interruptions during critical but relatively routine “automatic” tasks (eg, placement of short peripheral catheter)</td>
<td><strong>Prevention</strong>&lt;br&gt;Integrate into personal practice a strategy of always fully disengaging tourniquets for any interruption, regardless of perceived risk&lt;br&gt;<strong>Detection</strong>&lt;br&gt;Keep applied tourniquets fully exposed and visible—do not cover with bedding or clothing&lt;br&gt;<strong>Recovery</strong>&lt;br&gt;Recognize the signs and symptoms of tourniquet retention, which may include extremity pain, numbness, tingling, edema, leaking at insertion site of short peripheral catheter or puncture sites, and/or poorly flowing intravenous infusion</td>
</tr>
<tr>
<td><strong>Device related</strong>&lt;br&gt;Short tourniquet&lt;br&gt;Tourniquet poorly visible against skin or bedding</td>
<td><strong>Prevention</strong>&lt;br&gt;Disclose events to patients and patients' families in accordance with organizational guidelines&lt;br&gt;Report events in accordance with organizational guidelines and professional standards</td>
</tr>
</tbody>
</table>
On the basis of the principle that device overcompatibility contributes to misconnection events, the International Organization of Standardization has developed new standards for medical device connections. The standards, which should be fully implemented by 2017, will result in products that are less compatible (or wholly incompatible) with functionally dissimilar devices. The anticipated result will be reduced (but not wholly eradicated) risk for misconnection events. Awareness of risk, prevention, detection, and recovery strategies will remain essential.

**Phlebitis**

Phlebitis occurs when chemical, mechanical, or particulate-induced irritation promotes local inflammation...
Phlebitis is a common complication of SPC use and a known complication of PICC use. After development of marked phlebitis, increasingly invasive strategies may be necessary to maintain vascular access (e.g., central catheter placement), culminating in increased cost, decreased patient satisfaction, or delay in therapy.

Short Peripheral Catheters

Phlebitis is the most common complication of SPC use, occurring in 7% to 75% of patients with SPCs. Reported rates of SPC-associated phlebitis vary widely among different populations of patients and are often not comparable because of variations in the definition of phlebitis. Phlebitis may develop up to 48 hours after an SPC is removed.

Peripherally Inserted Central Catheters

Phlebitis also occurs with PICCs, most commonly when the devices are inserted in the antecubital fossa. Although PICC-associated phlebitis associated with chemical irritants is described as rare because of the dilution of the infused material that occurs as a benefit of PICC use, 2 mechanisms resulting in altered flow during infusion have been described: catheter damage and development of a fibrin sheath. Catheter damage (e.g., fracture of the catheter) permits the infused material to infiltrate into tissue more peripherally than intended, where the material can induce local irritation. Alternatively, a fibrin sheath can develop around the PICC, partially occluding or disrupting flow at the tip. Depending on the characteristics of the sheath, the infused material might be directed backward toward the insertion site, resulting in local irritation where the material exits the sheath.

Special Considerations in Detection, Prevention, and Recovery

The Centers for Disease Control and Prevention and other authorities recommend routine replacement of SPCs every 72 to 96 hours; however, many experts claim that the evidence for routine replacement is suboptimal. Fang recommends placing emphasis on prevention of SPC phlebitis by ensuring skill and competency with respect to device placement, use, and routine maintenance rather than by focusing on scheduled SPC replacement. Routine use of inline filters with SPC infusions has been suggested as a strategy to reduce phlebitis by reducing particulate-induced irritation; however, a 2010 systematic review of randomized controlled trials indicated that the evidence for the benefit associated with use of inline filters is “uncertain.” To prevent phlebitis, nurses should adhere to local facility guidelines about SPC replacement (and use of inline filters) and promote evaluation of evidence on PVAD management and implementation of evidence-based policy and procedure.

Table 4 describes selected risk factors for the development of phlebitis and key strategies for prevention, detection, and recovery. Discovery of phlebitis necessitates prompt removal of the PVAD and initiation of new access, if clinically indicated. Thrombus or infection may develop in conjunction with phlebitis, although the direct pathophysiological relationship between phlebitis and subsequent infection is poorly understood.

Air Embolism

Air embolism is commonly associated with CVC placement or removal but also occurs with the insertion, use, and removal of PICCs and SPCs. Air embolism is uncommon (the true incidence is poorly defined) but highly lethal, with a mortality greater than 30%. The Centers for Medicare and Medicaid Services consider device-associated air embolism a preventable, nonreimbursable serious reportable (or “never”) event. The clinical manifestations of air embolism vary widely according to patient characteristics (e.g., body size, underlying health status, and presence of a patent foramen ovale), the rate of the infusion, the volume of air infused, and the ultimate anatomical location of the embolism. The likelihood of major injury or death is related to many of the same characteristics.

Inadvertent administration of small, generally inconsequential, volumes of air occurs regularly during PVAD placement, but no safe volume of venously administered air has been described. Fatal volume of air in humans is generally accepted as 50 mL (or 3-5 mL/kg), but up to 20 mL in adults can be lethal if delivered rapidly. The lungs can filter up to 0.35 mL/kg of air per minute, but higher volumes or the presence of a patent foramen ovale (occurring, often asymptomatically, in 10%-35% of adults and in neonates) permits...
Selected risk factors

<table>
<thead>
<tr>
<th>Patient related</th>
<th>Use related</th>
<th>Device related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced age</td>
<td>Suboptimal placement and device management techniques due to inexperience, lack of standardized training, and/or inadequate ongoing competency assessment and development</td>
<td>Large catheter diameter in relation to vein size</td>
</tr>
<tr>
<td>Female sex</td>
<td>Selection of patient’s lower extremities for SPC placement</td>
<td>Poorly secured device</td>
</tr>
<tr>
<td>Fragile, small, and/or poor-quality veins</td>
<td>Insertion in the antecubital fossa (PICC and SPC), lower extremities (SPC), and hands (SPC)</td>
<td>SPC in place more than 72-96 hours</td>
</tr>
<tr>
<td>Malignant neoplasms</td>
<td>Use transparent dressings over insertion sites and the proximal vascular pathway regularly</td>
<td>Infusion set and catheter composition</td>
</tr>
<tr>
<td>Immunocompromise</td>
<td>Avoid placement in the antecubital fossa (SPC and PICC), lower extremities (SPC), and hands (SPC)</td>
<td>Characteristics of the material infused (eg, osmolality, pH)</td>
</tr>
</tbody>
</table>

Selected strategies for reducing phlebitis and associated harm

<table>
<thead>
<tr>
<th>Prevention</th>
<th>Detection</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select catheter size and location on the basis of planned therapy and patients’ characteristics</td>
<td>Inspect catheter insertion sites and the proximal vascular pathway regularly</td>
<td>Promptly remove an SPC if localized warmth, erythema, tenderness, a palpable venous cord, or other signs of phlebitis develop</td>
</tr>
<tr>
<td>Use vein visualization technologies to facilitate proper site selection, catheter selection, and insertion</td>
<td>Use transparent dressings over insertion sites to facilitate visualization</td>
<td>Use standardized phlebitis assessment tools (eg, Infusion Nurses Society’s Phlebitis Scale or the Visual Infusion Phlebitis scale) to grade severity and guide treatment</td>
</tr>
<tr>
<td>Use specifically designed catheter-stabilizing devices to reduce mechanical irritation and protect device integrity: do not rely solely on tape, sutures, or transparent dressings</td>
<td>Use standardized phlebitis assessment tools (eg, Infusion Nurses Society’s Phlebitis Scale or the Visual Infusion Phlebitis scale) to grade severity and guide treatment</td>
<td>Notify responsible ordering provider and collaborate to determine appropriate interventions to reduce inflammation and discomfort (eg, thermal therapy with moist, warm compresses, analgesics, and/or anti-inflammatoriey)</td>
</tr>
<tr>
<td>Reduce limb motion by the least restrictive means possible</td>
<td>Avoid placement in the antecubital fossa (SPC and PICC), lower extremities (SPC), and hands (SPC)</td>
<td>Collaborate with interdisciplinary team in obtaining Gram stain and/or cultures of catheter tip</td>
</tr>
<tr>
<td>Avoid placement in the antecubital fossa (SPC and PICC), lower extremities (SPC), and hands (SPC)</td>
<td>Replace SPCs as directed by local organizational policy; extend SPC length of time in place beyond 72-96 hours with caution, regardless of presence of signs or symptoms of inflammation</td>
<td>Report events in accordance with organizational guidelines</td>
</tr>
<tr>
<td>Monitor vascular access sites for at least 48 hours after device removal; signs and symptoms of phlebitis can develop after device removal</td>
<td>Participate in ongoing skill reinforcement and acquisition for proper insertion, use, and maintenance technique for peripheral vascular access devices</td>
<td>Disclose events to patients and patients’ families in accordance with organizational guidelines</td>
</tr>
</tbody>
</table>

Selected resources

Infusion Nurses Society’s Infusion Nursing Standards of Practice (2011).3

Abbreviations: PICC, peripherally inserted central catheter; SPC, short peripheral catheter.

Air to enter the systemic arteries and travel to end organs where it can induce ischemia, infarction, or a thromboinflammatory response. Because of the risk, intravenous infusion of any volume of air should be considered “potentially consequential”49 and should be judiciously avoided.16,49

In a detailed review of infusion-related air embolism, Cook16 reports challenges associated with recognition and treatment of this complication. Specifically, clinicians may not readily recognize the reason for air entry, the diagnosis may not be intuitive, and even if air embolism is suspected, immediate interventions may seem ineffective. Furthermore, the signs and symptoms of air embolism are nonspecific and mimic many other conditions (Table 1). Prompt recognition and immediate response are critical to reduce harm associated with air embolism.50

Table 5 outlines specific actions to initiate in response to suspected air embolism. Providers’ awareness of specific clinical scenarios that may trigger an air embolism may potentially improve the likelihood of recognition of this complication and prompt action.16 Several scenarios relevant to acute and critical care settings are described in the sidebar Clinical Scenarios Resulting in Air Embolism.

Device Fragment Embolization

Device fragment embolization (DFE), also known as catheter embolism, is a rare complication of use of all types of VADs. When a device fragments, pieces may lodge in the peripheral venous system, right ventricle, or pulmonary vasculature.18
Selected risk factors

<table>
<thead>
<tr>
<th>Device related</th>
<th>Prevention</th>
<th>Detection</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large-bore venous catheter insertion site above the heart</td>
<td>Consider CVAD removal as a procedure distinct from insertion, with unique set of complications and considerations, and requiring competency assessment and verification.**</td>
<td>Be aware of clinical scenarios that can contribute to air embolism (see Sidebar)</td>
<td>Immediately initiate treatment if air embolism is suspected, even if signs and/or symptoms have not developed</td>
</tr>
<tr>
<td>Physical properties of infusion tubing that promote entrainment of air</td>
<td>Adhere to standards for removal of CVCs (including PICCs) and external jugular SPCs, such as those published by the Infusion Nurses Society</td>
<td>Be aware of the signs and symptoms of air embolism, which may be respiratory (acute dyspnea, tachypnea, wheezing, persistent cough, shortness of breath, gasp reflex), circulatory (abrupt collapse, shock), neuropsychological (altered mental status, irritability, agitation, acute focal neurological deficits), and/or psychological (impending sense of doom)</td>
<td>Prevent further air embolism: immediately occlude the suspected site of air entry by covering insertion site, or by clamping, pinching, or folding the catheter or tubing; concerns about sterility should not delay occlusion</td>
</tr>
<tr>
<td>Presence of air-filled, functionally dissimilar devices (eg, blood pressure tubing) that can physically connect to a vascular catheter, resulting in misconnections and air embolism</td>
<td>Prime intravenous tubing after attaching to container of material to be infused or syringe even when not immediately connecting to patient; leaving an unprimed intravenous set disconnected creates a risk of unintentional connection (by self or others) to the patient without priming</td>
<td>Remove all air from tubing, stopcocks, and syringes before use</td>
<td>Place patient in left Trendelenburg or, if not tolerated, left lateral decubitus position</td>
</tr>
<tr>
<td>Susceptibility to damage (eg, cracks to catheter hub, splitting of external part of catheter)</td>
<td>Clamp tubing when puncturing fluid bags</td>
<td>Do not use vented tubing with collapsible fluid bags</td>
<td>Deliver 100% oxygen via face mask</td>
</tr>
</tbody>
</table>

Selected strategies for prevention of air embolism and associated harm

** Selected strategies for prevention of air embolism and associated harm include:

- Consider CVAD removal as a procedure distinct from insertion, with unique set of complications and considerations, and requiring competency assessment and verification.
- Adhere to standards for removal of CVCs (including PICCs) and external jugular SPCs, such as those published by the Infusion Nurses Society.
- Prime intravenous tubing after attaching to container of material to be infused or syringe even when not immediately connecting to patient; leaving an unprimed intravenous set disconnected creates a risk of unintentional connection (by self or others) to the patient without priming.
- Clamp tubing when puncturing fluid bags.
- Do not use vented tubing with collapsible fluid bags.
- Take precautions to avoid inadvertent disconnections and misconnections of intravenous tubing.
- Do not use vascular access systems or devices that may be damaged.
- Prevent device damage related to suboptimal stabilization (eg, do not place tape on PICCs); use specifically designed stabilizers.
- Occlude CVAD lumen(s) with sanctioned clamp or cap before removal.
- Instruct patients to perform a Val-salva maneuver during catheter removal, unless contraindicated.
- Have fully occlusive dressing materials readily available at the bedside when patients have CVC or similar access devices.
- Use standardized removal kits for PICCs and other CVCs that include the correct dressing supplies.
- Use truly occlusive dressings and petroleum or gel-based ointments; semipermeable transparent dressings (as well as gauze and tape) may not provide full occlusion.
- Maintain initial occlusive dressing for 24 hours after device removal; catheter tract may persist for 24 hours.
- Do not use evacuated (vacuum) containers for therapeutic phlebotomy; use gravity-flow bags.
- Immediately initiate treatment if air embolism is suspected, even if signs and/or symptoms have not developed.
- Prevent further air embolism: immediately occlude the suspected site of air entry by covering insertion site, or by clamping, pinching, or folding the catheter or tubing; concerns about sterility should not delay occlusion.
- Deliver 100% oxygen via face mask.
- Attempt to aspirate air from the catheter (if it remains in place).
- Immediately notify responsible ordering provider.
- Consider activating facility-based rapid response team, particularly if patient is symptomatic or likelihood that an air embolism has occurred is high.
- Report events, regardless of extent of injury, in accordance with organizational guidelines.
- Disclose events to patients and patients’ families in accordance with organizational guidelines and professional standards.

Key resources

Cook and Wilkins and Unverdoven both present detailed discussions of the physics and pathophysiology of air embolism, including microbubble development and infusion.
Clinical Scenarios Resulting in Air Embolism

Air embolism associated with peripheral vascular access devices (PVADs) is a rare but potentially deadly complication. Prompt recognition and immediate action can reduce the likelihood of patient harm; however, providers may not detect an air embolism because of nonspecific signs and symptoms and an underappreciation of the clinical scenarios that may lead to this potentially life-threatening complication. Clinical scenarios relevant to acute and critical care settings include the following:

Administration Through Intravenous Access Devices
Inadvertent intravenous administration of an air bolus, often delivered through an air-containing syringe or unprimed infusion tubing, is the most common mechanism for air embolism. Both of these sources may result in an embolism large enough to cause cerebral ischemia and infarction.

Tubing Misconnection
Infusion of air (and other medical gases) has been reported in instances in which oxygen (or air) tubing or an air-filled enteral syringe is inadvertently attached to a VAD. Misconnection events are discussed in the text.

Catheter or Hub Damage
Compared with short peripheral catheters, peripherally inserted central catheters (PICCs) are particularly susceptible to external hub and catheter fracture. PICC barotrauma can be caused by excessive pressure generated by use of syringes smaller than 10 mL, by use of an unsanctioned power injector, or by flushing a PICC against resistance. Twisting, kinking, cutting, or clamping of catheters and hubs can result in mechanical damage. The age of a device and storage conditions can also contribute to potential for fracture. In one case, 2 consecutively placed PICCs fractured shortly after placement. The devices, although not past the expiration date for use, were “hard and brittle.” Investigation revealed that the PICCs had been exposed to ultraviolet light while in storage and had degraded before use.

Entrainment of Air Bubbles in Infused Material
Infusion of small bubbles may occur during continuous intravenous administration. Infusion devices are designed to permit no more than 1 mL of air during a 15-minute period, but according to the Food and Drug Administration, this standard “does not represent a universally safe level of air infusion,” and the clinical impact of cumulative infusions of small air bubbles is poorly defined. When entrained air is visually noticeable, continued infusion of air should be prevented, regardless of the presence or absence of alarms from the infusion device. Of note, patient positioning and attempts to aspirate the air do not ameliorate the consequences of air embolism related to the entrainment of particularly small (micro) bubbles.

After Removal of a VAD
Although occurrence of an air embolism during or after VAD removal is most commonly associated with central venous catheters, embolism can also occur in association with removal of PVADs. PICCs and large-bore short peripheral catheters inserted above the heart (eg, in the external jugular vein) provide adequate ingress for a clinically significant amount of air; and the standard techniques for removal of a central venous catheter should be used for these devices. Two primary mechanisms for air embolism related to removal of VADs are improper removal technique (eg, not placing the patient in the Trendelenburg position) and not placing (and maintaining) a truly occlusive dressing on the access site after the device is removed. After a catheter is removed, a tract providing a pathway for air can persist for up to 24 hours. This tract may provide ingress of air in response to the pressure gradient caused (or exacerbated) by reduced intrathoracic pressure (inhalation) or hypovolemia. Occluding the catheter tract during catheter removal and for at least 24 hours afterward and using appropriate dressing materials can markedly reduce the likelihood of an air embolism after device removal. Removal of central venous catheters (including PICCs and similar devices) is a procedure with potential for serious complications, and providers should have appropriate training and ongoing verification of competency in removal.
Short Peripheral Catheters

SPC-associated DFE is known to occur, but limited evidence is available on the underlying causes or frequency. One proposed mechanism for SPC fragmentation (and subsequent embolization) is catheter fracture or shearing due to needle reinsertion.

Peripherally Inserted Central Catheters

DFE is a well-documented complication of PICC use. A retrospective review of 215 central catheter DFEs in adults reported during a 20-year period indicated that at least 30 of the embolizations involved PICCs. Multiple mechanisms exist whereby a PICC fragment can develop and embolize (Table 6). DFE can be due to improper technique in placing a PICC, improper use of the device (e.g., improper flushing resulting in barotrauma), removal, or catheter exchange. Overall mortality due to embolization of fragments of central VADs, including PICCs, is thought to be less than 2%.

Special Considerations in Detection, Prevention, and Recovery

The clinical manifestations after DFE vary widely, and most literature addresses the signs and symptoms related to DFE of central catheters. Catheter dysfunction...
(eg, inability to aspirate blood or flush the device, pain or swelling during use, leakage at the insertion site) may be a precursor to DFE or may be the first sign of DFE and should be fully investigated. Once DFE occurs, patients may experience arrhythmias or may report palpitations (the most common indication). Other signs and symptoms are listed in Table 1. DFE can also be asymptomatic, and the presence of a foreign body may be found only incidentally (eg, during routine chest radiography) months to years after the embolization.

Table 6 lists selected prevention, detection, and recovery strategies for DFE. Removal of a PICC against resistance constitutes one preventable cause of PICC embolization. Transient vasospasm creates the resistance, and continued attempts to remove the catheter can result in fracture of the device. If a provider encounters tension while attempting removal, the (external) retrieved part of the PICC should be coiled under a sterile dressing, and cautious reattempts to remove the device can be made after the vasospasm has resolved. After removal of a VAD, regardless of whether or not resistance was encountered, the integrity of the device should be assessed. For all CVADs, the catheter length should be measured and compared with the documented insertion length to improve the likelihood of detection of catheter fragmentation.

Unintentional Discharge With a Retained PVAD

Although the incidence of inadvertent discharge of a patient from a health care setting who has a PVAD remaining in situ is unknown, events involving SPCs have been reported, and no reason suggests that PICC-related events have not occurred. An inadvertently retained PVAD may increase a patient’s risk for phlebitis, bleeding, thrombosis, or infection. Patients who discover a retained PVAD may experience distress, anxiety, reduced satisfaction, distrust in health care, and additional expenses (eg, if asked to return to a health care setting for removal of the device).

Conceivable scenarios in which a PVAD is retained include patients who leave before final assessment by a nurse, patients who unintentionally conceal the PVAD during final review before discharge (eg, under clothing), and patients and/or members of the clinical team who forget that a PVAD is still in place. In other instances, patients may deliberately depart with an intravenous catheter in place. Instances that involve willful deception or concealment by patients are difficult to prevent, and I do not address them. In addition, few researchers have investigated these types of events and strategies for prevention.

No guidelines exist for management of a retained PVAD discovered after discharge, presenting an opportunity for development of checklists or standard procedures for treatment. Organizational-level contributing factors can potentially be identified and addressed through review of cases of retained PVADs. For example, hypothetically, emphasis on timely and early (morning) discharge, insistence on maintaining intravenous access for admitted patients regardless of clinical indication, and increased handovers and handoffs may contribute to the likelihood of inadvertent discharge of a patient with a retained PVAD. Proposed practice- and unit-level (or organizational-level) strategies for prevention, detection, and recovery of retained PVADs are given in Table 7; however, retained PVADs remain an area for continued nursing research and practice development.

Nursing Implications

PVADs are omnipresent in health care, yet many complications of their use are underrecognized. Nurses in acute and critical care environments, as well as nurses who are members of teams that manage intravenous devices, should strive to enhance recognition of PVAD complications, risk factors for complications, and strategies for prevention, detection, and recovery. Key elements of prevention of these complications include reevaluating basic knowledge and skills related to insertion, management, use (including device stabilization), and removal of PVADs. Nurses with expertise and experience in PVAD management have the opportunity to lead (or consult on) development of device-related competencies and strategies to improve device-related safety and quality. In addition, nurses with enhanced awareness of device-related hazards are critical members of product acquisition and review teams, evidence-based practice committees, and work groups focused on patient safety, quality improvement, and system design or redesign.

Although use of PVADs is extremely common, gaps remain in the overall understanding and evidence-based guidance concerning these devices. Additional research is warranted in multiple areas of PVAD safety, including the following:
• Ensuring ongoing competency and expertise in the selection, insertion, management, and removal of the variety of VADs available in acute and critical care
• Investigating routine replacement of SPCs and their impact on phlebitis, thrombosis, infection, and health care costs
• Understanding the consequences and circumstances associated with inadvertent discharge of a patient with a PVAD in place
• Investigating local and bloodstream infections related to SPCs, including incidence and prevention strategies

Ultimately, nurses play a vital role in the optimal insertion, management, use, and removal of PVADs. Understanding related complications and their risk factors, combined with integration of prevention, detection, and recovery strategies into practice, promotes quality and safety of health care delivery. CCN

Table 7  Unintentional discharge with a retained peripheral access device

<table>
<thead>
<tr>
<th>Selected risk factors</th>
<th>Prevention</th>
<th>Detection</th>
<th>Recovery</th>
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<tbody>
<tr>
<td>Patient related</td>
<td>Determine when, in the discharge process, PVADs should be removed</td>
<td>Proactively identify, as an organization, whether patients or patients’ families may safely remove short peripheral catheters on the basis of patients’ risk factors; available resources (eg, trained medical professional, clean dressings); PVAD type, size, and location; and ability to receive recommended follow-up care</td>
<td>Report events in accordance with organizational guidelines</td>
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<td>Unintentional concealment under personal clothes</td>
<td>Determine who specifically, among the discharge team, is responsible for removing PVADs</td>
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<td>Desire to leave health care setting</td>
<td>Promote the removal of clinically unnecessary PVADs</td>
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<tr>
<td>Use related</td>
<td>Identify strategies to prevent patients from unintentionally concealing PVADs under civilian clothes when preparing for discharge (eg, permitting early removal of PVADs with appropriate order)</td>
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<tr>
<td>Emphasis on early (morning) and prompt discharge</td>
<td>Be explicit with patients and their families about discharge process and importance of final check with nursing team member (eg, remind patients that just because another team member says &quot;You can go home!&quot;, there are still important steps to complete)</td>
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<tr>
<td>Fragmentation of final discharge responsibilities</td>
<td>Visually inspect extremities before patient is discharged</td>
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<td>among multiple members of team</td>
<td>Consider final discharge checklist or &quot;passport,&quot; completed with patient’s collaboration</td>
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<tr>
<td>Potential for unawareness on the part of providers (and patients) of the presence of 1 or more vascular access devices</td>
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<td>Maintenance of intravenous access up until physical departure from facility with the intent to enhance patient safety and/or reduce liability</td>
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</table>

Abbreviation: PVAD, peripheral vascular access device.

References

Financial Disclosures
None reported.