

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

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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.^{4,7,8}

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

Table 1 Selected complications of peripheral venous access devices: definitions, signs, and symptoms

Complication	Definition	Potential signs and symptoms
Tourniquet retention	Tourniquet intended to temporarily promote venous distention for PVAD placement (or phlebotomy) is inadvertently left applied for an extended time	Transient pain, edema, and/or paresthesia of involved extremity and/or leaking at puncture or catheter insertion site(s) ⁹ Infusion may infiltrate or flow slowly ⁹
Tubing and catheter misconnections	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}	May include back pain, fever, chest pain, dyspnea, anaphylaxis, cardiopulmonary arrest, seizures, altered mental status, sepsis, and/or coagulopathies ¹¹⁻¹⁵ Signs and symptoms vary widely, may be subtle or catastrophic, and onset varies widely, from insidious to abrupt
Phlebitis	Inflammation of vein wall due to chemical, mechanical, and/or particulate-induced irritation ³	Local pain, swelling, tenderness, and local and/or streaking erythema Venous cording (rigidity and firmness) may be palpable in severe cases ³
Air embolism	Inadvertent venous administration of air via intravenous access device or insertion site	Sudden dyspnea, cough, wheezing, chest and/or shoulder pain, agitation, sense of impending doom, tachypnea, tachycardia, hypotension, and/or neurological findings consistent with cerebrovascular accident ¹⁶ A harsh systolic murmur may be present
Device fragment embolization	Migration of part of a damaged vascular device (a fragment) through the vascular system ³	Palpitations, arrhythmias, chest pain, shortness of breath, cough, localized swelling and/or pain, confusion/altered mental status, and/or hypotension ^{3,17,18} Catheter dysfunction (eg, inability to flush or aspirate blood) may signal catheter damage or imminent embolization ^{3,18}
Retained PVAD at discharge	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	No specific signs and symptoms beyond the presence of the device; secondary signs and symptoms may occur because of complications (eg, phlebitis or infection)
Catheter-associated venous thrombosis	Venous thrombosis due to the presence of a venous access device ³	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 chest ³ If thromboembolism occurs, patients may show signs and symptoms of pulmonary embolism ³
Infiltration	Inadvertent administration of a nonvesicant solution into subcutaneous tissue instead of the intended vascular route ³	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 paresthesias ³
Extravasation	Infiltration of a vesicant (an agent "capable of causing blistering, tissue sloughing, or necrosis") into subcutaneous tissue, instead of the intended vascular route ³	Signs may include erythema, which may progress to blistering and/or tissue necrosis
Infection associated with vascular access device	Infection (local or systemic) due to placement of a vascular access device	Local induration, erythema, tenderness, and/or site drainage (may be purulent); patients with more severe infections may show signs of systemic infection (eg, fever) ³

Abbreviations: PICC, peripherally inserted central catheter; PVAD, peripheral venous or vascular access device.

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discharge of patients before removal of a PVAD. Table 1 provides basic definitions and signs and symptoms of these complications.⁹⁻¹⁸

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

Bloodstream Infection Associated With Short Peripheral Catheters

Monitoring for catheter-associated bloodstream infection, system-level prevention efforts, and research and published guidelines overwhelmingly focus on central venous access devices.^{5,6} However, as Hadaway⁵ notes, the Centers for Medicare and Medicaid Services disallows payment for any “vascular catheter-associated infections,” including infections associated with short peripheral catheters (SPCs), both local and systemic.

The incidence of local soft tissue infection related to SPC placement is not well defined,²⁷ and discussions about SPC-associated infection are complicated by overlapping and conflicting definitions of phlebitis and local soft tissue infection. SPC-associated bloodstream infection is rare: 0.1% of SPCs placed, or 0.5 per 1000 catheter days.²⁸ By comparison, the rate of bloodstream infection associated with peripherally inserted central catheters among hospitalized patients is estimated to be 6%, or 2.16 per 1000 catheter days (similar to the reported rates for central venous catheters).²⁹

Bloodstream infection associated with an SPC is a potentially life-threatening complication. In one case,³⁰ a patient died after an SPC inserted in the emergency department “went unnoticed for 5 days.” Phlebitis and infection developed, directly resulting in the patient’s death. In another case,² a patient had a well-functioning SPC that had been placed 96 hours earlier. He had no signs or symptoms of inflammation. Discharge was (at that time) anticipated for the next day, and placement of a new SPC was likely to be difficult, so the interdisciplinary team opted to keep the first SPC in place. During the next 24 to 48 hours, the site became erythemic. The SPC was promptly removed, but bacteremia due to methicillin-resistant *Staphylococcus aureus* developed followed by an epidural abscess that required 6 weeks of intravenous antibiotics. The infections were directly attributed to phlebitis at the SPC site.

Nurses should be aware that, although uncommon, SPC-associated bloodstream infection can occur. Although the connection between local inflammation and infection is poorly understood, early recognition of phlebitis, prompt removal of the related device, and ongoing monitoring of the inflamed access site after removal of the device may reduce the harm of SPC-associated bloodstream infections. These infections are preventable; selection of the optimal device and site for insertion; proper site preparation and insertion; and use, management, and removal of SPCs (evaluated and reinforced through ongoing competency verification) reduce the incidence of these serious events.³¹

and thrombosis^{4,19-23} and PVAD infiltration and extravasation^{3,24-26} 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,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.⁶ SPCs are often described as the most commonly used VAD in health care.^{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.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,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.^{4,34,35} Experts report that PICC use has steadily increased since the early 2000s.^{29,36}

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^{4,8,16,33} suspect that PVAD complications are under-recognized 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.³

Health care providers underrecognize the complications of SPCs and PICCs, partly because they overestimate the safety of these devices.

The Infusion Nurses Society³ 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 irritants³; the convenience of the patient or the provider is not an appropriate indication for PICC placement.³⁷ 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^{4,29,36} and with a high risk for deep vein thrombosis.^{4,23}

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.³ 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.^{9,38} 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^{9,38} or after phlebotomy. The true incidence of these events (and resultant injury) is unknown. In the only published review⁹ 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.⁹

Tourniquet retention can result in infiltration, extravasation, nerve damage, compartment syndrome, and thrombosis.⁹ 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.⁹ 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.^{9,38} Even seemingly inconsequential interruptions (eg, leaving the bedside to retrieve

Table 2 Tourniquet retention**Selected contributing factors****Selected strategies for reducing tourniquet retention and associated harm^{9,38}**

	Prevention	Detection	Recovery
Patient related Obesity Diminished or no perception of pain or discomfort Impaired communication	Use long, brightly colored tourniquets that are readily visible and difficult to conceal Prevent inadvertent concealment by rolling up (instead of pushing) patient's sleeves or by placing tourniquets over clothing Keep applied tourniquets fully exposed and visible—do not cover with bedding or clothing	Fully visualize extremities and vascular access insertion sites during initial and subsequent patient assessments 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	Upon detection, immediately remove the tourniquet Assess for evidence of neurovascular compromise Assess for infiltration and extravasation and manage according to published guidelines based on severity and characteristics of infused material Promptly notify responsible provider if any evidence of injury or neurovascular compromise, infiltration, or extravasation is present Document extent of injury or absence thereof
Use related Susceptibility of providers to distractions and interruptions during critical but relatively routine “automatic” tasks (eg, placement of short peripheral catheter)	Integrate into personal practice a strategy of always fully disengaging tourniquets for any interruption, regardless of perceived risk		Report events in accordance with organizational guidelines Disclose events to patients and patients' families in accordance with organizational guidelines and professional standards
Device related Short tourniquet Tourniquet poorly visible against skin or bedding			

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).^{9,38} 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).³⁹ Misconnections occur with all types of VADs. The risk for misconnections involving PVADs is high, because of the devices' prevalence of use.⁴⁰ Inadvertent intravenous administration of a variety of liquids and gases (including enteral feedings, breast milk, medical gas, and air) has been reported.^{10-12,39-41} Although described as occurring with

“significant frequency,”¹⁰ these events are underreported and the true incidence is unknown.⁴⁰

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.^{10-15,39,41}

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.^{10,11} If connection is physically possible, inevitably the connection will occur, even when such an error seems unlikely or implausible.^{10,11}

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 3 Tubing and catheter misconnections

Selected risk factors

Selected strategies for reducing tubing and catheter misconnections and associated harm^{10-12,39-41}

	Prevention	Detection	Recovery
Patient related High numbers of patient transitions and transfers with resultant tubing and catheter disconnections and reconNECTIONS Low recognition by patient and/or patient's family of risk of self-management of medical devices	Limit unnecessary disconnections Avoid simultaneous disconnections of functionally dissimilar devices Fully visualize, with adequate lighting, connectors when reconnecting even seemingly "low-risk" devices (eg, sequential compression device tubing) Label tubing distally and proximally Position functionally dissimilar tubings apart from one another Investigate establishing a unit or organizational standard for the routing of tubing (eg, intravenous tubing on the right, enteral system tubing on the left) Remove extraneous devices and tubing from patient's immediate vicinity Use devices only as intended (eg, do not use enteral feeding syringes for intravenous administration) Never force connections Do not redesign or alter medical devices Do not use damaged or altered devices	Maintain awareness of possibility of misconnection events as cause of acute or marked change in patient's cardiovascular, respiratory, or neurological status Reconcile connections after transfers or transport Recognize the warning signs of an imminent (or potential) misconnection, including having to force devices together or apart or having to use an adaptor to secure a connection	Immediately report suspected misconnection events to responsible ordering provider Sequester all devices and disposables (eg, intravenous tubing, infusion container) involved in suspected misconnections Collaborate with the interdisciplinary team to identify most appropriate interventions, which may include oxygen, antibiotics, anticoagulants, diagnostic imaging, dialysis, plasmapheresis, and/or exchange transfusion ³⁹ Report actual and near-miss events in accordance with organizational guidelines Disclose events to patients and patients' families in accordance with organizational guidelines and professional standards
Use related Inadequate visualization of connections due to poorly lit environments, reticence to disturb patients, etc Misguided reliance on color to identify purpose of tubing Misguided reliance on own underlying expectations with respect to purpose of tubing or connector (confirmation bias) Susceptibility to distractions, interruptions and fatigue, especially during routine "automatic" tasks related to connections	Avoid color coding or color differentiation as a stand-alone safety mechanism—use standardized labels, visible text, and physical segregation		
Device related Presence of many functionally dissimilar devices per patient, in physical proximity to one another Device overcompatibility (ability for functionally dissimilar devices to connect)	Educate patients, patients' families, and nonclinical staff about the dangers of misconnections and the importance of requesting assistance regardless of the perception of perceived risk		

Selected resources

Food and Drug Administration website. "Reducing risks associated with medical device misconnections"³⁹: includes many educational tools and visual examples based on reported events. Available online at www.fda.gov.
 ECRI guidance article "Preventing Misconnections of Lines and Cables."¹¹ Available online at <http://www.premiersafetyinstitute.org/wp-content/uploads/Preventing-Misconnections-of-Lines-and-Cables.pdf>.
 The Joint Commission sentinel event alerts #36 on tubing misconnections¹⁰ and #53 on managing risks during transition to new standards from the International Standards Organization for tubing connectors.⁴⁰

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.¹² Awareness of risk, prevention, detection, and recovery strategies will remain essential.

Phlebitis

Phlebitis occurs when chemical, mechanical, or particulate-induced irritation promotes local inflammation

of the vein wall.⁵ 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 (eg, central catheter placement), culminating in increased cost, decreased patient satisfaction, or delay in therapy.⁴²

Short Peripheral Catheters

Phlebitis is the most common complication of SPC use, occurring in 7% to 75% of patients with SPCs.^{1-3,27,32,43} 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.^{2,3,6} Phlebitis may develop up to 48 hours after an SPC is removed.³

Peripherally Inserted Central Catheters

Phlebitis also occurs with PICCs, most commonly when the devices are inserted in the antecubital fossa.¹⁷ 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.¹⁷ Catheter damage (eg, 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.¹⁷

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 sub-optimal.^{2,27,44} Fang² 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 in-line filters with SPC infusions has been suggested as a strategy to reduce phlebitis

by reducing particulate-induced irritation; however, a 2010 systematic review⁴² of randomized controlled trials indicated that the evidence for the benefit associated with use of in-line filters is “uncertain.” To prevent phlebitis, nurses should adhere to local facility guidelines about SPC replacement (and use of in-line 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,² although the direct pathophysiological relationship between phlebitis and subsequent infection is poorly understood.^{5,6}

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.^{16,45} Air embolism is uncommon (the true incidence is poorly defined)⁴¹ but highly lethal, with a mortality greater than 30%.^{46,47} The Centers for Medicare and Medicaid Services consider device-associated air embolism a preventable, nonreimbursable serious reportable (or “never”) event.⁴⁸

The clinical manifestations of air embolism vary widely according to patient characteristics (eg, 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.⁴⁹

Inadvertent administration of small, generally inconsequential, volumes of air occur regularly during PVAD placement,⁴⁹ 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 **Phlebitis, which occurs with both SPCs and PICCs, can develop up to 48 hours after a device is removed.**

delivered rapidly.⁴⁹ 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 asymptotically, in 10%-35% of adults and in neonates)^{16,49} permits

Table 4 Phlebitis

Selected risk factors

Selected strategies for reducing phlebitis and associated harm¹⁻³

	Prevention	Detection	Recovery
Patient related Advanced age Female sex Fragile, small, and/or poor-quality veins Malignant neoplasms Immunocompromise	Select catheter size and location on the basis of planned therapy and patients' characteristics Use vein visualization technologies to facilitate proper site selection, catheter selection, and insertion Use specifically designed catheter-stabilizing devices to reduce mechanical irritation and protect device integrity: do not rely solely on tape, sutures, or transparent dressings ³ Reduce limb motion by the least restrictive means possible Avoid placement in the antecubital fossae (SPC and PICC), lower extremities (SPC), and hands (SPC) 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	Inspect catheter insertion sites and the proximal vascular pathway regularly Use transparent dressings over insertion sites to facilitate visualization Monitor vascular access sites for at least 48 hours after device removal; signs and symptoms of phlebitis can develop after device removal	Promptly remove an SPC if localized warmth, erythema, tenderness, a palpable venous cord, or other signs of phlebitis develop Use standardized phlebitis assessment tools (eg, Infusion Nurses Society's Phlebitis Scale or the Visual Infusion Phlebitis scale) to grade severity and guide treatment 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-inflammatories) Collaborate with interdisciplinary team in obtaining Gram stain and/or cultures of catheter tip Report events in accordance with organizational guidelines Disclose events to patients and patients' families in accordance with organizational guidelines and professional standards
Use related Suboptimal placement and device management techniques due to inexperience, lack of standardized training, and/or inadequate ongoing competency assessment and development Selection of patient's lower extremities for SPC placement Insertion in the antecubital fossa (PICC and SPC), lower extremities (SPC), and hands (SPC)	Participate in ongoing skill reinforcement and acquisition for proper insertion, use, and maintenance technique for peripheral vascular access devices		
Device related Large catheter diameter in relation to vein size Poorly secured device SPC in place more than 72-96 hours Infusion set and catheter composition Characteristics of the material infused (eg, osmolality, pH)			

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

Table 5 Air embolism

Selected risk factors

Selected strategies for prevention of air embolism and associated harm^{3,16,17,49,50}

	Prevention	Detection	Recovery
Patient related Hypovolemia Adults with asymptomatic PFO unrecognized by patient and providers Neonates: PFO, low body mass Use related Underappreciation of air embolism as complication of vascular access Difficulty in identifying air embolism because of non-specific signs and symptoms and the unpredictable physiological response to recovery strategies Suboptimal catheter insertion and/or removal technique Misperception that infusion device “air in line” alarms will consistently detect any potentially harmful volume of air Device related Large-bore venous catheter Insertion site above the heart Physical properties of infusion tubing that promote entrainment of air 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 Susceptibility to damage (eg, cracks to catheter hub, splitting of external part of catheter)	Consider CVAD removal as a procedure distinct from insertion, with unique set of complications and considerations, and requiring competency assessment and verification ⁵⁰ 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 Remove all air from tubing, stopcocks, and syringes before use 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 Valsalva 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	Be aware of clinical scenarios that can contribute to air embolism (see Sidebar) 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), cardiac (chest or shoulder pain, tachyarrhythmias, hypotension, jugular venous distention, cardiovascular collapse), neurological (altered mental status, irritability, agitation, acute focal neurological deficits), and/or psychological (impending sense of doom)	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 Place patient in left Trendelenburg or, if not tolerated, left lateral decubitus position 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

Cook¹⁶ and Wilkins and Unverdoben⁴⁹ both present detailed discussions of the physics and pathophysiology of air embolism, including microbubble development and infusion.

Abbreviations: CVAD, central vascular access device; CVC, central venous catheter; PFO, patent foramen ovale; PICC, peripherally inserted central catheter; SPC, short peripheral catheter.

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 the nonspecific signs and symptoms and an underappreciation of the clinical scenarios that may lead to this potentially life-threatening complication.¹⁶ 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.^{16,49} 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.^{10,11,16,39-41} 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.¹⁶ 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.¹⁷ 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.⁵¹

Entrainment of Air Bubbles in Infused Material

Infusion of small bubbles may occur during continuous intravenous administration.^{16,49} 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,⁵¹ 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.⁴⁷

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.¹⁶ 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 (eg, short peripheral catheters placed in the external jugular vein) is a procedure with potential for serious complications, and providers should have appropriate training and ongoing verification of competency in removal.¹⁷

Table 6 Embolization of fragment of peripheral venous access device

Selected risk factors

Selected strategies for reducing device fragment embolization and associated harm^{3,17}

	Prevention	Detection	Recovery
Patient related Anatomical compression of PICC between the clavicle, the first rib, and the costo-clavicular ligament, or more distally at entry site due to anatomical flexion, resulting in "pinch-off syndrome"	Examine vascular access devices carefully before insertion; if damage is suspected, sequester device and packaging and report the presence of defective, damaged, or deteriorating devices Recognize precursor and early signs and symptoms of device damage, including swelling, pain, leakage, and general dysfunction Do not remove a PICC against resistance; resistance may be due to transient vasospasm, and continued attempts to remove the device against resistance can result in catheter fragmentation Ensure ongoing competency for PICC placement and removal Avoid PICC placement at antecubital fossa where compression-related damage can occur Protect all vascular access devices from twisting, bending, entanglement, acute flexion, sharp instruments and unsanctioned use of clamping or occluding devices (eg, hemostats)	Examine all removed catheters for damage or fracture Consider embolization as potential cause of palpitations or arrhythmia after removal of vascular access device	If device damage is suspected after removal, retain the device in a clean container for further examination If concerned about embolization or evidence of fractured catheter, request a chest radiograph to assess for presence of fragment (include concern for embolization of such a fragment in indication for request) If original packaging is still retrievable, secure it for investigators Report events, regardless of extent of injury, in accordance with organizational guidelines Disclose events to patients and their families in accordance with organizational guidelines and professional standards
Use related Suboptimal placement technique resulting in damage (eg, inappropriate readvancement of guidewire, stylet, or needle) Selection of a suboptimal securing strategy or inappropriate clamping or occlusion devices resulting in damage Use of undersized syringe with a PICC resulting in barotrauma Use of an unsanctioned power injector with a PICC, resulting in barotrauma	Limit use of scissors to suture removal and catheter repair; do not use to trim tape or dressings near the device Always follow manufacture guidelines on flushing (ie, syringe size, compatibility with power injectors) Repair of damaged devices (eg, PICCs) should only be undertaken by practitioners with verified competencies and by using manufacturer-endorsed repair kits		
Device related Defective device Improper storage			

Selected resource

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

Abbreviation: PICC, peripherally inserted central catheter.

Short Peripheral Catheters

SPC-associated DFE is known to occur,⁵² 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.⁵³

Peripherally Inserted Central Catheters

DFE is a well-documented complication of PICC use.^{17,18} A retrospective review¹⁸ 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 (eg, improper flushing resulting in barotrauma), removal, or catheter exchange.^{3,17,18} Overall mortality due to embolization of fragments of central VADs, including PICCs is thought to be less than 2%.¹⁸

Special Considerations in Detection, Prevention, and Recovery

The clinical manifestations after DFE vary widely,³ 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 DFE³ or may be the first sign of DFE¹⁸ and should be fully investigated. Once DFE occurs, patients may experience arrhythmias or may report palpitations (the most common indication).¹⁷ 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.¹⁸

Table 6 lists selected prevention, detection, and recovery strategies for DFE. Removal of a PICC against resistance constitutes one preventable cause of PICC embolization.¹⁷ 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.¹⁷

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,^{54,55} 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.⁴⁸

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.^{7,8} 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:

Table 7 Unintentional discharge with a retained peripheral access device

Selected risk factors

Selected strategies for reducing unintentional discharge with retained PVAD and associated harm

	Prevention	Detection	Recovery
Patient related Unintentional concealment under personal clothes Desire to leave health care setting Use related Emphasis on early (morning) and prompt discharge Fragmentation of final discharge responsibilities among multiple members of team Potential for unawareness on the part of providers (and patients) of the presence of 1 or more vascular access devices Maintenance of intravenous access up until physical departure from facility with the intent to enhance patient safety and/or reduce liability	Determine when, in the discharge process, PVADs should be removed Determine who specifically, among the discharge team, is responsible for removing PVADs Promote the removal of clinically unnecessary PVADs 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) 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 "You can go home!", there are still important steps to complete) Visually inspect extremities before patient is discharged Consider final discharge checklist or "passport," completed with patient's collaboration		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 Report events in accordance with organizational guidelines

Abbreviation: PVAD, peripheral vascular access device.

- 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**

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None reported.

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