ASSESSMENT OF THE INFANT WITH A PERIPHERAL INTRAVENOUS DEVICE

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ABSTRACT

Inserting, monitoring, and maintaining peripheral venous access is an integral component of neonatal nursing care. Although complications associated with peripheral vascular devices are typically minor, some infants may experience life-threatening sequelae or serious and prolonged alterations in function. This article provides a review of the relevant anatomy and physiology of the peripheral venous system, techniques for maintaining catheter security, and guidelines for conducting a systematic physical assessment. The most commonly occurring complications, such as infiltration, phlebitis, and occlusion, are described. The etiology of the complications, signs and symptoms, and key evidence-based prevention strategies are outlined.

KEY WORDS: peripheral IV, peripheral intravenous catheter/cannula, newborn, complications, physical assessment, phlebitis, infiltration, extravasation, infection.

Peripheral venous access devices, commonly known as peripheral IVs (PIVs), were introduced more than 40 years ago to deliver dextrose, parenteral nutrition solutions, and medications to infants.[1,2] The PIV is currently the most commonly used vascular access device and remains an indispensable tool in neonatal care.[3]

Early PIVs were placed using the steel butterfly-style needle. The introduction of the plastic catheter was associated with improved outcomes related to the ease of insertion, enhanced catheter dwell times, and an overall lower risk of complications.[2] In infants, the average dwell time of a PIV ranges from 15 hours for a steel needle to 54 hours for a catheter-style device.[2,4-11]

A clinical quality improvement audit, conducted in a large tertiary care center, evaluated the safety and efficacy of PIVs in 145 admissions. A PIV was placed in 33% of the infants admitted to the neonatal intensive care unit (NICU).[2] These infants underwent 1 to 19 (median, 4.63) insertions requiring 1 to 12 (median, 2.2) attempts during their hospitalization. Despite the frequent use of PIV therapy, evidence supporting preferred cannulation sites, optimal care techniques, and strategies to minimize complications is lacking.[2]

UNDERSTANDING PERIPHERAL VENOUS ANATOMY AND PHYSIOLOGY

The three layers of the vein are the tunica adventitia, the tunica media, and the tunica intima (Fig 1).[12] The outermost layer, the tunica adventitia, is primarily loose connective tissue with a network of collagen and elastic fibers.[13] This configuration allows the vein to roll away from external trauma and protect its structure.[12] The middle layer of the vein, the tunica media, is a thick layer of connective tissue composed of elastic and smooth muscle fibers.[12] The elastic ability of the muscle fibers allows the vein to elongate and to tolerate changes in blood volume and pressure.[12] Vasoconstriction, in response to temperature (cooling), pressure, and trauma, is also mediated by this venous layer.[12]

The timing and duration of tourniquet placement are critical for successful PIV insertion and requires a clear understanding of the response of the tunica media. Placement of a tourniquet causes the vein to dilate from an increase in blood volume.[12] Within seconds, the pressure within the vein falls, regardless of the increase in volume.[12] After the tourniquet is removed, pressure and volume are quickly re-established. Apply the tourniquet immediately before cannulating the vein; prolonged use can lead to excessive stretching of

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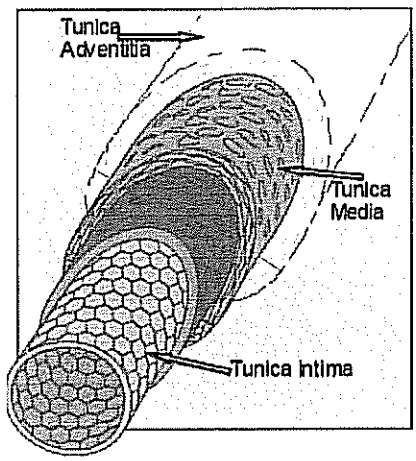


Figure 1. Anatomy of the peripheral vein highlighting the 3 distinct tissue layers. Reprinted with permission. LifeArt image copyright 2003 Lippincott Williams & Wilkins. All rights reserved.

the smooth muscle and may obscure one's ability to see and feel the vein.[12]

The innermost layer of the vein, the tunica intima, is composed of a single layer of tightly configured endothelial cells.[12] The occlusive design of this cell layer prevents fluid from escaping the vasculature into the tissue.[12] Substances released from these endothelial cells, such as prostacyclin and nitric oxide, alter vascular tone and regulate blood flow.[12,13] The smooth design of the vein surface prevents cell accumulation and clotting.[12] Injury to these exquisitely sensitive endothelial cells exposes the subendothelial layer and initiates the inflammatory and coagulation processes leading to phlebitis and thrombosis (Table 1).[13]

Identifying Appropriate Infusates for Peripheral Vein Infusion

Assessing the potential impact of a specific solution or medication on the tunica intima of the vein is a critical step that should be completed before beginning any infusion.[14] Infusate-induced chemical irritation of the tunica intima results in inflammation, infiltration, edema, thrombosis, and cell loss.[15] This constellation of events is commonly known as chemical phlebitis. Infusate-induced vessel damage may occur proximal or distal to the catheter tip.

To determine the appropriateness of a specific infusate for peripheral use, evaluate 3 critical variables[16]:

- Osmolality
- pH
- Chemical properties of the solution or medication

Infusate Osmolality

Osmolality and tonicity are terms used interchangeably to describe the number of particles suspended in a solution.[14] Normal serum osmolality is 280 to 295 mOsm/kg.[17] Ideally, to prevent vessel damage, all substances infused into the peripheral vein should have a physiologic osmolality.[14] Substances with an osmolality higher than serum are termed hyperosmolar or hypertonic. Conversely, when the osmolality is less than the serum, the solution is hypotonic or hypoosmolar.[18] A hypertonic solution draws fluid from the endothelial cells to the serum, causing the cells to shrink.[18] Hypotonic solutions cause a net influx of fluid into the cell, resulting in cell distention and possible rupture.[18]

The precise osmolality at which damage to the venous endothelium and subsequent phlebitis occurs is unknown.[18] Trials in adults reduced the risk of chemical phlebitis by limiting the infusate osmolality to 450 mOsm/kg.[19] A moderate risk of chemical phlebitis was found with osmolalities between 450 and 600 mOsm/kg, and with an osmolality >600 the risk was 100%. Based on this data, the Infusion Nurses Society (INS) recommends limiting the osmolality of peripherally infused substances to 500 mOsm/kg.[20] The American Academy of Pediatrics Committee on Nutrition recommends a range of 300 to 900 mOsm/kg for PIV infusates, but fails to offer evidence to support the safety of this recommendation.[22]

Venous tolerance to a particular solution may be related to the duration of exposure. Experimental an-

Table 1. Factors Leading to Damage of the Endothelial Cells of the Tunica Intima of the Vein[12,13]

Catheter Placement
- Contamination of the catheter during insertion
- Rapid catheter advancement
- Mismatch between the size of the catheter and vein (disproportionately large) resulting in restricted blood flow around the device, venous stasis, and limited dilution of infusates
- Catheter placed in area of flexion allowing catheter contact with the vein wall during extremity movement
- Catheter tip adjacent to vein wall or valve

Catheter Maintenance
- Excessive catheter movement due to insecure taping

Catheter Infusates
- Infusion of hyperosmolar or hypoosmolar solutions or medications
- Infusion of highly acidic or alkaline solutions or medications
- Infusion of particulate material
- Infusion too rapid for the tolerance of the vein

Table 2. Chemical Composition of IV Solutions[66]

Solution	Osmolality (mOsm/kg)
Isotonic Solutions	
• D5W	260
• Normal saline	308
Hypotonic Solutions	
• 0.45% normal saline	154
Hypertonic Solutions	
• D10W	505
• D12.5W	625
• D15W	757
• D20W	1,010
Other	
Amino acid solutions: each 1%	100

imal studies suggest tolerance of higher osmolalities with shortened infusion times.[21] For example, a solution with a tonicity of 550 mOsm/kg was tolerated over a 24-hour infusion, whereas a tonicity of 820 mOsm/kg was tolerated over an 8-hour infusion.[21]

Altering the osmolality of medications to mimic serum osmolality is accomplished by using specific diluents.[18] The resulting osmolality of a medication is a function of the dose, the amount of solution prepared, and the type of diluent used.[18] Tables 2 and 3 reflect sample osmolalities of solutions and medications commonly used in the NICU. Note the varying osmolality of ampicillin when reconstituted with normal saline versus with water. The most physiologic preparation results from reconstituting the ampicillin with sterile water to a concentration of 50 mg/mL.

Infusate pH

The pH of a substance is based on the concentration of hydrogen ions.[18] A neutral pH is 7 with a normal range of 7.35 to 7.45.[18] When the blood is exposed to a pH outside normal, the blood buffers (eg, bicarbonate) attempt to neutralize this variation in pH.[18] Maintaining the pH of infusates close to neutral minimizes phlebitis.[23] Restricting the pH of repeated peripheral infusates from 5 to 9 minimizes damage to the vein.[18] Many medications are unstable at a neutral pH.[18] Altering the pH of a solution or medication is often difficult to accomplish without sacrificing the nature or stability of the infusate and becoming labor-intensive for the pharmacy.[18,23] Consider central administration for infusates with a pH outside of this range.

Infusate Chemical Composition

Occasionally, an infusate may be isotonic with a physiologic pH, yet be toxic to the vein because of its inherent chemical composition.[24] Amphotericin B is an example of such a medication. Repeated administration of chemical irritants warrants central venous access to limit peripheral venous damage.[24]

Bedside caregivers need rapid access to resources that quantify and describe the properties, such as osmolality, pH, and chemical composition, of IV solutions and medications to assure correct administration and decrease the risk of preventable complications.[25]

Table 3. Chemical Characteristics of Selected Medications[66]

Medication	Concentration	Diluent	Osmolality mOsm/kg	pH	Irritant/ Vesicant
Amphotericin B	0.1 mg in 1 mL	D5W	256	5.7	X
Aminophylline	10 mg in 1 mL	NS	318	8.6 to 9	
Aminophylline	10 mg in 1 mL	SW	43	8.6 to 9	
Ampicillin	100 mg in 1 mL	NS	664 to 763	8 to 10	X
Ampicillin	100 mg in 1 mL	SW	486 to 602	8 to 10	X
Ampicillin	50 mg in 1 mL	NS	493 to 520	8 to 10	X
Ampicillin	50 mg in 1 mL	SW	243	8 to 10	X
Calcium gluconate	100 mg in 1 mL		276	6 to 8.2	X
Cefotaxime	100 mg in 1 mL	NS	654	4.5 to 6.5	
Cefotaxime	100 mg in 1 mL	SW	377	4.5 to 6.5	
Cefotaxime	50 mg in 1 mL	NS	333	4.5 to 6.5	
Dopamine	0.8 mg in 1 mL	D5W	269	3.3	X
Gentamicin	1 mg in 1 mL	NS	278	3 to 5.5	
Phenobarbital	65 mg in 1 mL		9,285 to 15,570	9.2 to 10.2	
Phenytoin	50 mg in 1 mL		6,175 to 9,740	10 to 12.3	
Potassium chloride	2 mEq in 1 mL		3,440 to 4,355	4 to 8	X
Sodium bicarbonate	0.5 mEq/mL (4.2%)		815 to 1,000	7 to 8.5	X
Vancomycin	5 mg in 1 mL	NS	291	2.5 to 4.5	X

NOTE. Significant variation in osmolalities may be attributed to differences in manufacturer and methods of calculating values. Check with your clinical pharmacist for product specific osmolalities in your institution.

PERFORM A FOCUSED PHYSICAL ASSESSMENT

The early detection of complications, through systematic hourly IV site assessments, is essential to prevent or limit further damage to the vein and surrounding tissues.[26] More frequent assessments are necessary when using high-risk solutions and medications or when the routine assessment identifies suggestive, but inconclusive findings.[27]

Verifications

The first assessment of the shift should begin with a verification process. Verify that the following are true:

- Solution(s) hanging match with the solution(s) ordered
- Pump rates are set as ordered
- Ordered solutions are appropriate for their respective line locations
- Hang dates and times are appropriate for solution and tubing
- Solution is free from particulate material, discoloration, or cloudiness
- Solution and tubing are intact and free from leaks (evaluate systematically from the patient catheter to the fluid source)
- Leur-locks and connections are secure, and clamps are appropriately positioned

Check the infusion pump's occlusion alarm limit setting. The alarm should be set at the lowest available limit to prevent false occlusion alarms while detecting

SIDEBAR 1. STABILIZATION TECHNIQUES FOR PERIPHERAL INTRAVENOUS DEVICES

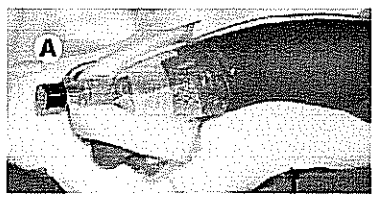
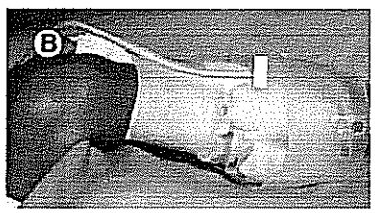


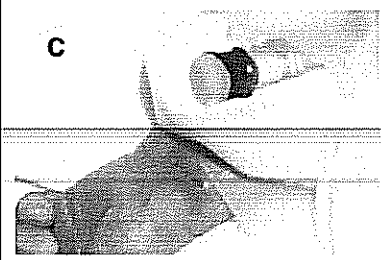
Figure 2. (A) Proper PIV stabilization. The IV catheter is well secured to the skin to minimize movement of the device and enhance visualization of the surrounding tissue.

The method of securing the peripheral IV at the time of insertion is critical to allow visualization of the insertion site and surrounding skin, therefore preventing complications.[65] Minimizing catheter movement reduces the risk of kinking, phlebitis, infiltration, infection, and migration.[41,65] Figure 2A-C show an effective method to stabilize a PIV, using a sterile transparent semipermeable membrane dressing (eg, Tegaderm, OpSite) placed aseptically over the catheter.[53] If desired, place sterile tape over the hub and wings of the device before placing the transparent dressing.



(B) Improper PIV stabilization. The application of tape has obscured visualization of the PIV site and surrounding tissue.

Do not apply nonsterile tape under the transparent dressing. Do not obscure the ability to visualize the IV site and surrounding tissue with tape. Minimize the use of tape, and avoid direct application on the skin to prevent the skin damage associated with removal.[65] Anchor the T-connector and/or IV tubing to the skin to prevent catheter movement and dislodgement.[53]



(C) Improper PIV stabilization. Tape damage to an extremity resulted from arm motion because of improper securement and ineffective ongoing monitoring.

When the insertion site is near a joint, place the cannulized extremity on a padded arm board to adequately immobilize the joint and minimize the risk of venous damage resulting from flexion.[42] Evaluate the extremity position for comfort; be alert for the potential for nerve compression, pressure sores, and contracture formation.[42,53] To prevent venous stasis and entrapment of infiltrated fluid do not completely encircle the extremity with tape.[44] Covering the catheter with a plastic shield prevents catheter movement and protects the catheter from impact and tissue damage, dislodgement, and infiltration.[41,44,65]

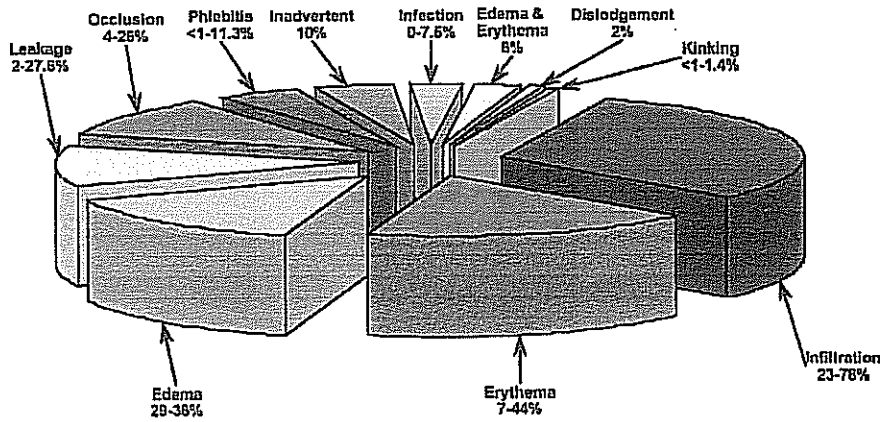


Figure 3. Reported ranges of complications associated with PIVs compiled from literature reports.[2,4-11]

infiltration. Evaluate the pump's resistance or pressure over time indicator, if present, to detect an evolving occlusion or infiltration.

Inspection

Begin the assessment by visualizing the catheter insertion site. Compare findings with those on the opposing extremity or opposite side of the scalp. Evaluate the integrity of the dressing and replace soiled or nonadherent dressings. Observe the insertion site and surrounding tissue for drainage, moisture, edema, erythema, blanching, and bleeding. Follow the course of the vein past the end of the catheter observing for edema, erythema, pallor, and blanching. Sidebar 1 presents pragmatic techniques to maintain catheter stability while enhancing ongoing assessment of the site.

Palpation

Palpate the area surrounding the catheter noting swelling, induration, fluid leaking from the catheter or insertion site, and temperature. Investigate dependent areas for the presence of concealed edema. Avoid touching the catheter tip to prevent trauma to the venous endothelium. Observe for pain cues while palpating or infusing solutions or medications; these may indicate infiltration or phlebitis. Carefully evaluate any extremity secured to an arm board for pressure points, restrictive edema, moisture, and drainage.

Documentation

At least hourly, record the appearance of the catheter insertion site and surrounding tissue, integrity of the dressing, and quantity of fluid infused. Document the presence of any atypical findings or complications and any interventions undertaken.

Complications Associated With PIVs

Although the PIV is a commonly used life-sustaining device, modern catheter style devices are associated with complication rates ranging from 0% to 78% (Fig 3). The incidence has remained relatively constant over the past 20 years.[2,4-11,28,29] In general, complications including infiltration, leaking, and occlusion account for the removal of 95% of the devices.[2]

Precise complication rates are difficult to determine because of significant interfacility variation in reporting,[2,4-11] a lack of consistent definitions for complications, and reports focused on select complications. The overlap of symptoms further confuses the incidence figures for infiltration and phlebitis.

The existing clinical research studies evaluating factors influencing the life span of the PIV are small, and they often yield contradictory results. Most reports are retroprospective, quality improvement accounts of complications or small clinical trials.[2,4-11,28,29] Results may be confounded by the routine addition of heparin to IV solutions, which has been shown to improve catheter performance by decreasing the rate of phlebitis.[7,8,29] Controlling concentrations of solutions and medications, insertion site, catheter style and size,

Table 4. Selected Agents Administered to Neonates and Linked to Tissue Damage[30]

Solutions and Electrolytes	Antibiotics	Vasopressors
Calcium salts	Amphotericin B	Dopamine
Dextrose ≥10%	Ampicillin	Dobutamine
Parenteral nutrition	Gentamicin	Epinephrine
Potassium salts	Nafcillin	—
Radiocontrast media	Oxacillin	—
Sodium bicarbonate	Vancomycin	—

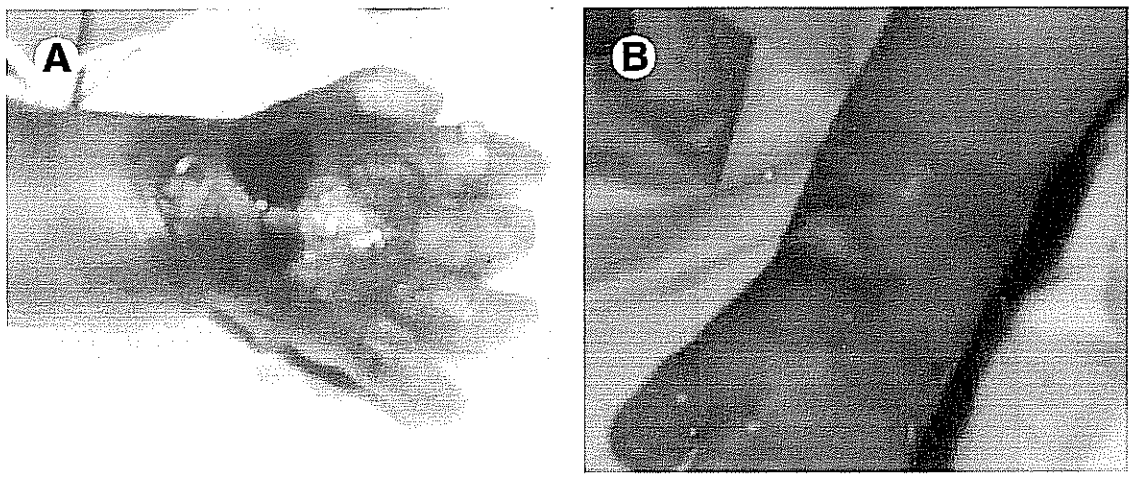


Figure 4. (A) Infiltration of this peripheral IV in the hand was noticed after the hand and fingers were grossly edematous. Blisters were evident on one finger. Tape removal resulted in skin stripping. (B) The discolored area became necrotic within several hours, resulting in tissue loss.

patient activity, and insertion and stabilization techniques would be necessary for accurate comparisons.

Incidence and Mechanism of Infiltration and Extravasation

Infiltration is the most commonly identified complication of PIV therapy. The reported incidence is 23% to 78% and carries the potential for long-term sequelae.[2,4-10,30] Infiltration describes the administration of nonvesicant solutions or medications (eg, D5W, normal saline) into the tissue surrounding the vein, whereas extravasation indicates the inadvertent delivery of a vesicant (eg, calcium, parenteral nutrition) or infusate known to cause injury into the tissue.[16] For the purposes of this article, the term infiltration will be used to refer to both phenomena.

It is commonly assumed that infiltration occurs when a catheter dislodges or punctures the vein, allowing the infusate to enter the interstitial space.[15,31] Although the precise etiology of infiltration is not well understood, 3 possible mechanisms have been identified. The first mechanism proposes that irritation of the venous endothelium from the infusate causes vasoconstriction and diminished blood flow.[32] A cycle of irritation and constriction continues as the irritating infusate becomes progressively less hemodiluted. Pressure increases within the vein, leading to rupture or exit of the fluid from the catheter insertion hole in the vein and subsequent infiltration. The second mechanism, confirmed by dye studies, shows infiltration of the infusate through the catheter insertion hole that is created with IV placement.[33] This occurs when the flow proximal to the catheter tip becomes obstructed as previously described. The increased venous pressure expands the point of entry in the vein. The third mechanism suggests that significant irritation of the venous endothelium from the osmolality, pH, or chemical composition of the infusate damages the tunica intima and allows diffusion of the infusate into the tissue, without creating a puncture in the vein.[27]

When infiltrated into tissue, a variety of agents cause injury (Table 4). Hypertonic solutions, such as parenteral nutrition, promote tissue injury from osmotic imbalance with disruption of cellular transport, leading to impaired cell function.[30,34-36] Tissue damage because of vasoactive medications, such as dopamine, results from intense vasoconstriction of the vascular smooth muscle with ischemia and necrosis.[30,34,37,38] Antibiotic-induced tissue injury may be caused by intrinsic properties of the medications and the hypertonicity of the solution.[10,30,39] The duration of exposure rather than the concentration of the infiltrated medication contributes to the tissue damage.[30,34,37,38]

Isotonic tissue infiltrations are associated with less pain and discomfort than hypotonic or hypertonic solutions.[15] Hypertonic solutions take longer than isotonic or hypotonic solutions to be reabsorbed because of concurrent fluid shifts into the tissue.[40] Pressure from fluid trapped in the tissue creates local ischemia, initiating a cycle of metabolic acidosis, loss of capillary wall integrity, and cell death.[41]

Remove the PIV with any suspected or proven infiltration.[41] Many infiltrations will resolve spontaneously. Additional treatment is controversial and is based on the infusate and type, location, and size of the injury.[41]

Monitor for Infiltration and Extravasation

Identifying an infiltration may be difficult, even for the experienced clinician.[30] The signs and symptoms often are nonspecific and easily confused with other complications, such as phlebitis, restrictive taping, ve-

Table 5. Strategies to Prevent Peripheral IV Complications

Infiltration and/or Extravasation
- Use a small enough catheter to avoid restriction of blood flow[16,39]
- Select the insertion site carefully and only infuse appropriate infusates
- Avoid areas of flexion or those that are difficult to immobilize areas[41-43]
- When extremity movement is inevitable, support the extremity with an arm or foot board to prevent catheter motion or dislodgement[15]
- Secure the device properly to avoid catheter movement but avoid restrictive taping[15]
- Avoid repeated use of a vein, particularly one surviving an infiltration, since healing and subsequent patency are difficult to determine[39]

Phlebitis
- Use polyurethane versus teflon devices[47]
- Choose the shortest and smallest catheter gauge to vein ratio to minimize catheter contact with the vein wall and subsequent venous damage[52]
- Stabilize the device carefully to avoid catheter manipulation and movement[52]
- Evaluate suitability of all infusates for peripheral administration by assessing their osmolality, pH, and chemical composition[16]

Leaking
- Tape the device and extension set securely to prevent dislodgement[53]
- Use Leur-lock connections to avoid accidental disconnections[16]

Occlusion
- Monitor compatibilities of solutions and medications especially when using heparin locks[15]
- Flush the device completely with normal saline to clear the catheter between infusion of potentially incompatible substances[15]
- Flush techniques to prevent occlusion

Infection
- Use meticulous hand hygiene measures during catheter insertion, manipulation, and maintenance[3]
- Choose an appropriate skin antiseptic (70% alcohol, 10% povidone iodine, or chlorhexidine gluconate) for insertion.[3,63] Povidone iodine and CHG are the two agents recommended for skin antisepsis by AWHONN and NANN in the joint Evidence-Based Clinical Practice Guideline for Neonatal Skin Care.[63]
- Thoroughly clean the catheter hub with 70% alcohol or an iodophor solution prior to entering it[3]
- Minimize the number of times the device is entered or disconnected[3]
- Limit the number of junctions, connection devices, or stopcocks[64]
- Maintain a closed system. Cap all openings when not in use.[52]
- Change tubing every 72 hours (every 24 hours when infusing TPN/lipids and with each blood product infusion)[3]
- Inspect the infusion bag and administration set for cracks, holes, clarity prior to infusion and throughout the shift

nous stasis, infection, or thrombosis.[15] Infusion pumps may detect evolving infiltrations by showing increasing resistance to flow or the requirement of greater pressure to overcome the resistance of pumping into the fluid-filled tissue.[15]

Examine the IV insertion site and surrounding tissue for skin color, swelling and tautness, and moisture or leaking of fluid.[41] Swelling, a hallmark sign of infiltration, may range from mild to gross edema.[15] Evaluate for edema in dependent areas that are often obscured by restraints or arm boards. Mild edema may be recognized by palpation or careful comparison to the opposing extremity or opposite side of the scalp. During palpation, observe for induration and signs of pain such as a facial grimace, brow furrowing, crying, withdrawal, or other guarding or protective behaviors.

Blanching of the skin appears as the amount of infiltrated fluid increases. Blistering is a hallmark sign of extravasation and results from infiltration of vesicants, which cause tissue damage.[16] Leaking of the infusate from the catheter insertion site may signal infiltration and/or catheter damage.[15]

To assess patency, gently instill 0.5 to 1 mL of normal saline into the vein and monitor for resistance, resultant swelling, and pain.[30] In neonates, blood return is not a reliable indicator for the presence or absence of infiltration because the small catheters often preclude the withdrawal of blood even when the IV is patent.[15,30,41] Conversely, blood return may be present when infiltration occurs at the venous insertion site or beyond the catheter tip.[15]

Assessing the severity of the infiltration injury at the time of discovery is problematic. The visible cutaneous damage does not reflect damage to the underlying subcutaneous fat and fascia that evolves over days.[37] Edema, often the first indication of infiltration, may resolve spontaneously or may progress to blistering and necrosis (Fig 4).[30] See Table 5 for prevention strategies to decrease the incidence of infiltration. A plastic site protector covering the catheter augments the dressing

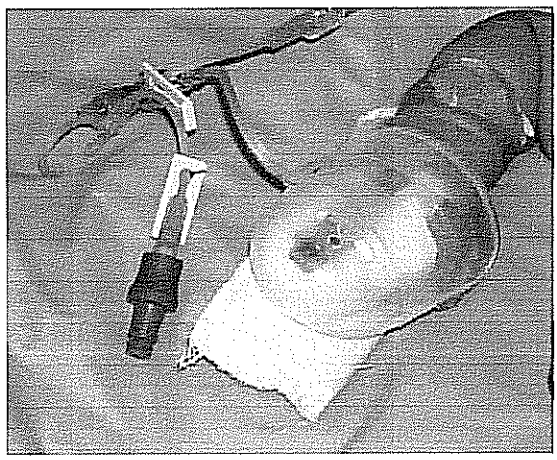


Figure 5. The PIV is protected by a plastic device, which lessens the risk of catheter motion and minimizes the risk of infiltration and dislodgement.

and protects the catheter and site from impact (Fig 5).[41,44]

Etiology of Phlebitis

Phlebitis is the inflammatory response to damage to the intimal layer of the vein caused by mechanical or physiochemical forces.[15] Activation of the immune system results in a cascade of events supporting inflammation and adherence of platelets to the damaged segment of the venous endothelium.[15,31] Vessel vasodilation causes stretching and increased capillary permeability.[45] White blood cells migrate to the site of injury.[13,45]

Although phlebitis can occur at any time with an indwelling catheter, symptoms may become evident only after device removal.[45,46] On physical examination, edema and erythema are visual clues to this occult process.[45] Formation of a clot obstructing venous blood flow results in a palpable venous cord.[45]

Mechanical events promoting the development of phlebitis begin with piercing the vein for catheter insertion and the ongoing presence of a foreign body.[31,45,46] Repeated catheter manipulation and movement within the vein, often caused by poor stabilization, increases the risk.[15] Catheters made of polyurethane (eg, Vialon; BD Medical Systems, Sandy, VT) are softer and lower the incidence of phlebitis when compared with those made of FEP-polytetrafluoroethylene (Teflon; Dupont, Wilmington, DE).[47]

Factors contributing to chemical phlebitis include the osmolality, pH, and the irritant potential of the infusate.[15,18,47,48] Obstructing blood flow through the vein with a large catheter prevents dilution and buffering of the infusate, increasing the likelihood of phlebitis.[15,49] Particulate matter in solutions and duration of exposure to the infusate are also implicated.[42]

Assess For and Treat Edema, Erythema, and Phlebitis

Observe the catheter insertion site and the surrounding tissue for edema and erythema (Fig 6). Edema or erythema may be isolated findings or occur with phlebitis. Restrictive taping, venous thrombosis, and infiltration are additional etiologies of edema.[27,42] Localized infection may be present with erythema.[42] Palpate along the course of the peripheral vein proximal to the catheter tip observing for discomfort or pain.[42] Warmth may indicate phlebitis or localized infection.

A palpable venous cord indicates an advanced stage of phlebitis.[42] When identified, remove the PIV and apply warm soaks over the affected vein 4 times per day until the phlebitis resolves.[42] This provides symptomatic relief; however, it may not alter the evolution.[49] Withdrawal of the catheter does not consistently halt the progression of the injury; delayed removal does extend the duration of symptoms.[46] Advanced stage phlebitis may require 10 to 21 days to resolve.[42] Continue to actively monitor an IV site for at least 48 hours after device removal for the presence of postinfusion phlebitis.[50,51]

Identify Leaking

The reported incidence of PIV leaks is 2% to 27.6%.[2,5-7,9,10] It is unclear whether leaking is an isolated phenomenon or symptom of phlebitis or infiltration. Dislodging the catheter from the vein, damage to the catheter or hub of the connecting tubing, or infiltration allows the infusate to escape from the body.[15,41]

To detect leaks, visualize the catheter insertion site under the dressing around the surrounding tissue and under the accessed extremity or scalp. The source of the leakage determines the appropriate remedy. If the device or insertion site is leaking, catheter removal is

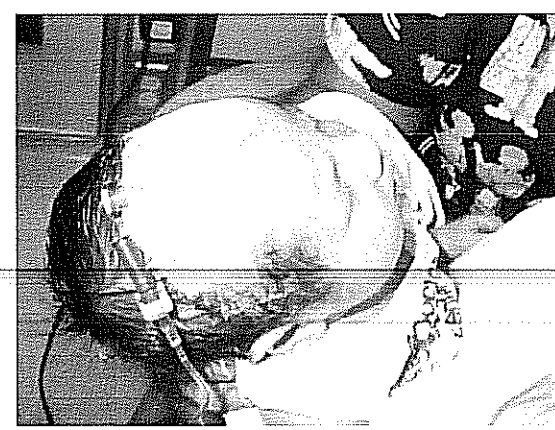


Figure 6. Phlebitis associated with a PIV. Note the circular area of erythema distal to the catheter tip. Symptoms of chemical phlebitis were seen immediately after an infusion of vancomycin.

SIDEBAR 2. EVIDENCE-BASED STRATEGIES FOR MAINTAINING INTERMITTENT INFUSIONS

Of the 6 studies addressing the efficacy of the flush solution in maintaining catheter patency, 5 support equal effectiveness between normal saline and heparin.[54-59] The optimal volume and frequency of flushing is unclear. The Infusion Nurses Society standard suggests the volume of flush equal at least twice the volume of the catheter, the extension set (if used), and the injection port.[16]

Locked catheter flushing frequencies of 4 to 6 hours have been reported; no compelling evidence to establish a standard exists.[39,48,54-56,60] One study compared continuous infusion to intermittent flushing in 238 catheters. There was not a significant difference in the overall length of catheter patency.[48] However, occlusion occurred with 25% of the catheters that were flushed intermittently (normal saline flushed every 6 hours and before and after medications) compared with a 9.1% occlusion rate with a continuous infusion of 5% or 10% dextrose at 0.5 mL to 1.0 mL/hr ($P < 0.001$). Other outcome measures that influenced loss of patency included: infiltration; phlebitis; leaking; and patients who were transferred, underwent a fluid change, or had the PIV discontinued.

The frequency of flushing and the flushing technique employed (maintaining positive pressure within the catheter), may explain the greater rate of occlusion with locked devices. Disconnecting the flush syringe allows reflux of blood into the tip of the catheter to displace the space occupied by the syringe.[16] To prevent this source of occlusion, clamp the extension set or withdraw the syringe while administering the last 0.5 mL of flush. Additionally, a positive displacement injection port (eg, CLC 2000, Posiflow, Ultrasite) may be added to the end of the catheter or extension set. Blood reflux thereby is minimized by the ejection of a drop of flush out the catheter tip on removal of the syringe.

required. Reinserting a partially dislodged catheter is contraindicated because of the risk of infection.

Monitor for Occlusion

Occlusion accounts for 4% to 26% of complications associated with the PIV.[2,5-7,11] The primary cause of catheter occlusion is the formation of a thrombus caused by fibrin or coagulated blood products.[15] When the catheter is improperly heparin- or saline-locked between infusions, blood enters the catheter tip.[15] Inadequate flushing between incompatible solutions and medications (eg, total parenteral nutrition and some antibiotics, vancomycin, and heparin) allows formation of a precipitate that ultimately plugs the device.[15]

The alarm from the infusion pump often provides the first clues to catheter occlusion.[15] When responding to an occlusion alarm, ensure that infusion tubing clamps are open. Inspect the external catheter for kinks or bends. If the device is occluded, attempts to manually flush the device may reveal resistance.[15]

Promptly remove occluded PIVs. Forcefully flushing through the catheter in an attempt to remove the occlusion is dangerous and may embolize the substance into the vascular system.[15] See Sidebar 2 for evidence-based strategies for managing intermittent infusions.

Incidence and Sources of Catheter-Related Bloodstream Infections

Although the incidence of PIV-associated bloodstream infections is typically lower than those associated with central venous catheters, the frequent use of these devices makes serious infections a significant contributor to morbidity.[3] In neonates, catheter-related infection has a reported incidence of 0% to 7.5%.[4,10] Determining the true incidence of infection is difficult because of varying definitions of catheter-related bloodstream infection and reporting methods.[3]

Infection resulting from a vascular device occurs from 4 sources.[3] Colonization of the catheter tip follows migration of microorganisms from the surrounding skin into the catheter insertion site and serves as the primary nidus for infections associated with the PIV.[3] Alternative sources of infection include hub contamination resulting from entry into the catheter, seeding from another site of infection, and contamination of the infusate.[3,61,62]

Assess for Symptoms of Infection

Inspect the catheter insertion site for erythema, edema, and purulent drainage.[15,42] Palpate for induration and warmth.[42] Infection may be localized or systemic.[3,52] Closely monitor the infant for subtle and often nonspecific signs of infection, including fever or temperature instability, apnea, feeding intolerance, and blood glucose instability. An elevation, decline, or left shift in the white blood cell count, thrombocytopenia, or an elevated C-reactive protein may be present.

When infection is suspected, remove the PIV in question. Culture purulent drainage from the site and obtain a blood culture to identify the responsible organism and target antimicrobial treatment.[52] Urine and cerebrospinal fluid cultures also may be warranted. Empiric antibiotic therapy is often initiated until culture results are available.

CONCLUSION

Maintaining peripheral venous access while minimizing complications poses many challenges for the neonatal nurse. Ongoing vigilance provides clues to catheter function and promotes early identification of complications. Although not entirely preventable, serious complications may be decreased through routine systematic physical assessment. Maintain a high

index of suspicion for complications and promptly investigate and intervene to avoid serious sequelae.

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