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Major Thrombotic and Nonthrombotic Complications

Loss of Patency

Abstract

Patency of the vascular access device and the vein that houses the device is critical for the successful delivery of infusion therapy. Loss of catheter patency comes from decisions made during device insertion and from methods used for infusion, flushing, dressing, and removal. Loss of vein patency comes from insertion techniques, patient activity, anatomic and physiologic reasons, and the primary disease or underlying chronic diseases. This review provides the latest information on causes, reported incidences, management, and prevention of catheter and vein patency problems frequently encountered in all clinical settings.

Patency is defined by *Dorland's Medical Dictionary* as "the condition of being widely open (p. 1243)."[1] In considering vascular access devices (VADs), it must be kept in mind that both the vein and the catheter must remain open to allow free flow through and around the device. Loss of patency results from causes as simple as the patient's position to causes as involved as combinations of complex clotting processes juxtaposed on the disease process. Clinical outcomes range from successful resolution of the problem to replacement of the catheter and permanent damage to the vasculature with lifelong discomfort.

Loss of catheter patency comes from decisions made during device insertion and from methods used for infusion, flushing, dressing, and removal. Loss of vein patency comes from insertion techniques, patient activity, anatomic and physiologic reasons, and the primary disease or underlying chronic diseases. This review provides the latest information on causes, reported incidences, management, and prevention of catheter and vein patency problems frequently encountered in all clinical settings.

• LOSS OF CATHETER PATENCY

Mechanical problems affecting catheter patency include anatomic forces involving the vein wall, muscles, bones,

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TABLE 1

Loss of Catheter Patency

Outside catheter	Catheter tip position in relationship to vein wall or valve
	Pinch-off syndrome
	Catheter fracture, partial or complete
	Catheter emboli, fragment or entire catheter
	Catheter dislodgement, into and out of vein
	Catheter migration
Inside catheter lumen	Chemical interactions
	Drug precipitate
	Mineral precipitate
	Lipid sludge
	Thrombosis

ligaments, and thoracic pressure; catheter insertion and removal techniques; catheter flushing techniques; and patient activities. Inside the catheter lumen, patency depends on prevention of chemical interactions and the clotting process (Table 1).

Mechanical Forces (Table 2)

Catheter tip position should be parallel to the vein wall[2] and free-floating inside the bloodstream. The superior vena cava is the best vein for accomplishing this tip position. Midclavicular tip location can result in catheter contact with the vein wall because the distal subclavian vein arches up and slightly backward over the first rib. Also, the last venous valve is found at the junction of the subclavian vein and the internal jugular vein. Catheter tip location distal to this junction can result in flow obstruction if the catheter lodges under a venous valve.

The clavicle and first rib form a narrow triangle as they join the sternum. On the medial edge, the costoclavicular ligament joins these bones together with the anterior scalene muscle behind the bones. The subclavian vein and artery as well as the brachial nerve plexus pass through this small space. When venipuncture is made close to the small triangle or medially, the catheter may pass under the clavicle before it enters the subclavian vein. The patient usually is in the Trendenlenburg position during the procedure with a rolled towel or sheet between the shoulder blades. This position causes the angle of the clavicle and first rib to be at its widest. However, when the procedure is completed and the patient returned to an upright position, the weight of the shoulder closes the angle and compresses the catheter. Known as the pinch-off syndrome, this problem is well documented with tunneled catheters and implanted ports.[3-12]

Two studies have documented the same incidence rate of 1.1% for the pinch-off syndrome: 11 of 987 catheters[13] and 16 of 1457 catheters, respectively.[6] Catheters used frequently, especially those with high-volume continuous infusion, required a median of 5 days (range, 1 to 138 days) from placement to diagnosis.[6] Hinke[13] reported that 73% were diagnosed within 3 weeks of catheter insertion. When pinch-off syndrome is confirmed by radiography, recommendations for catheter replacement range from immediately[3,5,6,10] to evaluation by chest x-ray every 4 weeks and removal within 6 months after insertion.[12]

Catheter fracture is a partial or complete breaking of the catheter. Pinch-off syndrome is the most common cause when subclavian venipuncture is used. Over time, movement of the clavicle against the first rib causes a scissors-like action with the catheter caught in the middle. Partial fracture at this point results in fluid leaking into the subcutaneous area. Complete fracture causes catheter emboli of the distal segment. Although breakaway needles are available, through-the-needle insertion has been replaced by through-the-introducer insertion using a peel-away sheath.

Catheter fracture can result from the method used for insertion, especially from peripheral insertion of central catheters. In 1954, the first report of a catheter emboli was published. This occurred with a polyethylene catheter inserted through a needle from an antecubital vein. Formally recognized as a health hazard by British physicians, through-the-needle procedures gave way to the Seldinger insertion methods in the mid-1950s.[14,15]

When the catheter is partially withdrawn through the needle, the damage can range from a small nick in the catheter wall to complete severing of the distal tip. Although this damage may be known immediately during the insertion procedure, it may not be evident until a latter point. Catheters with any weakened point may completely fracture and embolize during difficult removal or under any force, as when they are caught in clothing or subjected to high pressures during injection through the catheter.[16]

Pressure inside the catheter lumen is another cause of fracture. Flow of fluid through any tube is related to the difference in pressure between the two ends of the tube and to the factors that create resistance or impediments to the flow.[17] The pressure difference between the two ends of the tube causes the flow. Normal venous pressure in the hand is approximately 35 mm Hg, in the axillary vein approximately 8 mm Hg, and in the superior vena cava 0 mm Hg.[17] Infusion pressure must be great enough to overcome normal venous pressure in addition to any resistance along the way (Figure 1).

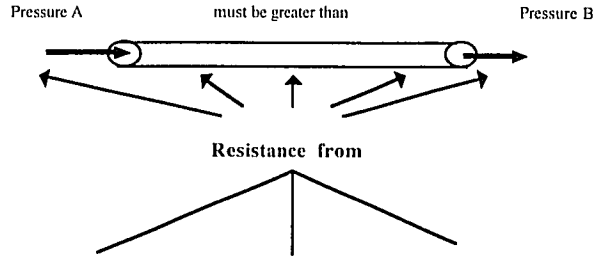
Three methods are used to create a higher pressure on the external side of the catheter: 1) gravity or height of the fluid container, 2) electronic or mechanical flow-controlling devices, and 3) pressure applied to a syringe plunger. Fluid container heights of 36 to 48 inches usually are sufficient to overcome venous pressure and other

TABLE 2

Mechanical Forces Acting upon the VAD

Clinical Problem	Signs and Symptoms	Management	Prevention
Catheter tip impinging on vein wall, bent under or abutting a venous valve	Ability to flush but not aspirate Inability to infuse	Reposition patient Coughing Valsalva maneuver Reposition catheter, if possible	Tip location in the superior vena cava at the level of 3rd intercostal space
Pinch-off syndrome	Resistance to flushing, infusion, or aspiration Points on the external catheter that "balloon out" during flushing	Roll shoulder or raise arm on the ipsilateral side Immediate relief of problem is a definite indicator Confirmed by observing catheter narrowing under fluoroscopy	Venipuncture in axillary vein at or lateral to the middle of the clavicle Avoid subclavian venipuncture medial to the middle of the clavicle Other approaches include cephalic vein cutdown, internal or external jugular puncture, and tunneled over the clavicle Use of PICC
Catheter fracture, partial	Fluid leaking from the puncture site Unusual pockets of swelling or other signs of inflammation along the catheter pathway	Radiograph of chest, shoulder, and upper arm Catheterogram or injecting a contrast media through the catheter to determine fluid pathway (avoid contrast media with the potential for tissue necrosis) Removal under fluoroscopy For PICC, have tourniquet under the arm during removal to "trap" fragment in the periphery For external fractures, clamp between the patient and the fracture	Avoid use of clamps or other sharp instruments on catheter *Never* use excessive pressure during flushing regardless of the syringe size *Always* stop flushing and investigate the cause of resistance during flushing regardless of the syringe size
Catheter emboli, fragment or entire catheter	Shortness of breath Confusion Pallor Lightheadedness Tachypnea Tachycardia Hypotension Anxiety Unresponsiveness	For PICC have tourniquet under the arm during removal to "trap" fragment in the periphery Immediately place patient on the left side in the Trendelenburg position Monitor vital signs and pulses in tourniqueted arm Obtain radiographic confirmation of fragment location Radiologic snare techniques to remove fragment	Observe for pinch-off signs Confirm "pinch-off syndrome" and replace catheter Never use forceful injection Maintain firm grasp on external portion of catheter during any repair or exchange procedure involving hub amputation
Catheter dislodgement into and out of venipuncture site	Changes in external catheter length Clinical signs of local catheter infection Inability to flush or infuse	Assess the changes in external catheter length Confirm tip location with chest x-ray Assess the current tip location with the type of solutions being infused Exchange the catheter with over-wire or through the introducer technique, if possible Insert catheter at new site	Adequately secure the external catheter with taping, sutures, and intact dressing Instruct the patient about the type of physical activities to avoid Assess understanding of and compliance with instructions during the entire catheter dwell
Catheter migration	May be free of any signs and symptoms Pain, swelling, redness, discomfort in the shoulder, arm, or neck Inability to flush, infuse, or aspirate Complaints of "ear-gurgling" or hearing a running stream Headache	Chest x-ray to confirm tip location Repositioning with radiologic techniques if no thrombosis is present Removal of the catheter	Assure correct tip location in the lower portion of the superior vena cava at the time of insertion Periodic reassessment of tip location

PICC = peripherally inserted central catheter.



External hub	Inside lumen	Internal tip
Syringe size	Drug/mineral precipitate	Venous pressure
Pressure applied to plunger	Fibrin	Position of catheter tip
Height of fluid container	Thrombosis	Fibrin sheath
Tubing diameter	Compression from clavicle	Thrombosis
Pump pressure	and first rib	Venous spasm
In-line filters	Compression from muscle	
Kinked tubing	contractions	
Fluid viscosity	Fluid viscosity	
Fluid temperature	Fluid temperature	
	Catheter lumen diameter	

FIGURE **1.**
Vascular access device in-line pressure comes from multiple sources.

resistance from the tubing and catheter. The occlusion pressure of most large-volume infusion-controlling devices usually falls between 5 and 10 pounds per square inch (psi), and the normal pumping pressure is less than the occlusion pressure. Ambulatory infusion-controlling devices may have occlusion pressures as great as 20 to 25 psi. Measurements of psi are easily converted to mm Hg: 1 psi equals 50 mm Hg.

In administering any medication or flush solution with a syringe, there is no way to know how much pressure is being exerted inside the catheter lumen. Syringe pressure is a combination of the syringe size and the amount of pressure applied to the plunger. Higher pressures can be generated with smaller syringes, whereas larger syringes generate lower amounts of pressure. Other variables include the size and strength of the operator's hand and the attention given to the amount of pressure applied. A 3-pound weight force on an empty 10-ml syringe generates less than 10 psi, whereas an empty 3-ml syringe generates pressures greater than 25 psi.[18] One study demonstrated that hand injection of contrast media with a 12-ml syringe generates 35 to 91 psi, pressures well beyond that recommended by most catheter manufacturers.[19]

Vascular access device (VAD) manufacturers provide information regarding the maximum amount of pressure tolerated by their brand of catheter. Some list specific syringe sizes, usually 10 ml or greater, for use with their catheters because of the potential for catheter rupture or fracture when applied pressures exceed the recommended limits.

As discussed, syringe size is an important factor in the generation of in-line pressure, but it is not the only factor (see Figure 1). Exclusive use of 10-ml syringes for flushing without an understanding of the principles of pressure, flow, and resistance could create a false sense of security. When resistance is felt, if more pressure is applied to overcome it, catheter fracture could result, regardless of the syringe size. Any resistance encountered during delivery of any solution from a syringe to a catheter should be investigated.

Syringe sizes are important for medication delivery through a catheter, not just for flushing. Restricting the size could present additional challenges. Intravenous medications given by the push method require accuracy. Measuring fractions of a milliliter is difficult with a large syringe. Pediatric and neonatal dosages are usually in small volumes, and catheters used in these patient populations have the lowest tolerance for pressure.[19]

Another concern for medication administration through catheters involves the use of power injectors for computed tomography (CT). Uniform delivery of the contrast, optimal timing of delivery, and decreased radiation and needle exposure to healthcare workers are the primary reasons for use of these injectors. Ruess et al.[19] studied the in-line pressures in five small-bore catheters during in vitro injection of contrast media. All study catheters were made of silicone by two manufacturers including 3- and 4-Fr peripherally inserted central catheters (PICCs) as well as single- and double-lumen tunneled catheters. The PICCs were tested with a 180° curve that did not change the amount of pressure generated.

In-line pressure was compared with flow rates. Both lumens of a 7-Fr double-lumen catheter were able to deliver clinically useful flow rates up to 3 ml per second and to remain under the pressure limit set by the manufacturer. The two PICCs and the 6.6-Fr catheter required limited flow rates to keep the pressure below that recommended by the manufacturer. The 3-Fr PICC required flow rates of 0.2 to 0.4 ml per second and the 4-Fr PICC needed flow rates of 0.8 to 1.2 ml per second to remain within the manufacturer's pressure limits.

The range of flow rates is related to the viscosity of the contrast media tested, with the most viscose achieving the lower rate. Shorter catheter length also was tested, and the results showed an increase in achievable flow rate that stayed within recommended pressure limits. This study also measured pressure from hand injection, with 20-ml syringes yielding pressure ranges of 22 to 70 psi and 12-ml syringes affording ranges of 35 to 91 psi. Therefore, hand injection can create a higher risk than a mechanically controlled power injector. These researchers did not intend to establish clinical practice recommendations, but after documenting clinically acceptable flow rates through some small-bore catheters, they suggested that manufacturers provide information about flow rates achievable at certain pressures.[19]

Catheter fracture also has been documented during the physical activities of golfing[5] and carrying a backpack.[12] High levels of physical activity in the shoulder or excessive weight on the shoulder area contributes to compression and ultimately fracture of the catheter.

Catheter emboli can involve the entire catheter or segments of varying lengths. A review of English-language literature since the first report in 1954 shows 402 cases of catheter emboli, with 313 cases involving the central venous system. Causes were listed as severing by the needle, broken or separated, torn off, disappeared, compression, material fatigue or defect and operator error.[20] The most common sites at which fragments lodge are the right side of the heart and the pulmonary artery.

Catheter emboli allowed to remain have a 49% complication rate, and 96% of all those in the right side of the heart cause complications. Infection, arrhythmia, thrombosis, and vessel perforation account for the largest majority of complications, most of which occur within the first month.

A French study of 3916 silicone catheters found four incidences of catheter emboli. Pinch-off syndrome was not reported because 90% were jugular insertions. The causes of emboli were inappropriate use of syringe pressure to open obstructed catheters, complete catheter emboli during insertion, and a 4-cm distal catheter segment found to be lacking.[21]

Fragments located in a peripheral vein can be found by exploration under local anesthesia. Centrally located fragments are found on chest x-ray and retrieved using transvenous loop snares, ureteric stone extractors, or catheter-grasping forceps. When interventional radiologic techniques are unsuccessful, the risk of surgical removal must be compared with the risk of allowing the fragment to remain in situ. Antibiotic prophylaxis and low-dose warfarin (1 mg/day) are recommended when retrieval is not possible.[20]

Catheter dislodgement can result in several patency problems. Movement of the catheter into and out of the insertion site is related to inappropriate methods of securing the catheter or to motion of the extremity, neck, or shoulder. The muscle pump, sometimes called the venous pump, moves blood back to the heart by muscle contractions placing pressure on each vein.[22] The length and flexibility of PICCs lead to movement of the catheter in or out of the vein due to this muscle pump. Dislodgement, abruptly or slowly, increases the likelihood of phlebitis and infection. Changes in the original catheter tip location results from any mechanism of dislodgement and compromises the infusion.

Catheter migration occurs when the tip of an undislodged catheter is displaced from a documented satisfactory position in the superior vena cava to another position in a neighboring vein.[23] Changes in intrathoracic pressure, coughing, sneezing, Valsalva maneuver such as during heavy lifting, vigorous extremity use, forceful flushing, or congestive heart failure could lead to migration of the tip. Catheter tips migrate to the internal jugular vein, axillary vein, or contralateral subclavian vein. Because the hub portion of the catheter is securely fixed in a tunnel, in a port pocket, or by external sutures, the catheter does not become dislodged from the vein. One report suggests that short segments of the catheter herniate into the internal jugular with progressive movement of the tip toward the cranium.[23] Another case study reported one PICC that spontaneously migrated several times.[24]

The frequency of catheter migration is difficult to determine. However one study reported this problem in 4 out of 61 (6.7%) tunneled catheters.[25] Recommendations from the Central Venous Catheter Working Group included periodic assessment of tip location, although optimum intervals were not specified.[26] Due to the spontaneous nature of the problem, the best strategies for detection are vigilance in assessing catheter function.

Inside the Catheter Lumen

Catheter lumen occlusions are caused by two problems: incompatibility of the solutions being infused and accumulation of blood products. *Incompatibility* is defined by Trissel as a "physiochemical phenomena," with the end products seen as a change in the physical state such as precipitation, haziness, color or viscosity change, or gas formation.[27] Precipitation is the primary concern related to catheter lumen patency (Table 3).

Precipitation can occur because of the drug's concentration in solution. Supersaturated solutions, although initially stable, can precipitate unpredictably over time. Another problem is associated with drugs not easily dissolved in water. These drugs require a cosolvent or "vehicle" such as ethanol, propylene glycol, or polyethylene glycol that allows them to mix with water.[27] Additional dilution, usually recommended for IV administration, may produce precipitation. For example, digoxin should be diluted with only a fourfold volume of solution to avoid this problem.

The pH of many drugs (Figure 2) is directly related to their degree of solubility. Barbiturates, phenytoin, and methorexate are examples of weak acidic drugs formulated with a pH high enough to cause solubility. When the pH is lowered by contact with other medications or flush solutions, a precipitate occurs. The same action occurs with low-pH drugs: Contact with other medications or flush solutions can increase the pH, causing a precipitate. Reversing the precipitate requires choosing the correct solution to instill inside the catheter lumen. When the precipitated drug is one formulated with a high pH, sodium bicarbonate is used to return the precipitate to solution. When the precipitated drug is one formulated with a low pH, hydrochloric acid is used to return the precipitate to solution.[28–33]

Precipitation can occur due to the formation of insoluble salts. Calcium and phosphate combinations are well-documented causes of precipitates in parenteral nu-

TABLE 3

Factors Influencing Precipitate Formation

Factor	Examples
Concentrations exceeding the point of saturation solubility	Trimethoprim-sulfamethoxazole Etoposide Teniposide
Cosolvents or vehicles used to improve the drug's water solubility	Diazepam Digoxin Phenytoin Trimethoprim-sulfamethoxazole Etoposide Teniposide
Alteration in pH of drug	Barbiturates Phenytoin Methotrexate Mercaptopurine
Formation of insoluble salts	Calcium and phosphate combinations
Combination of organic anions and cations	Heparin and high concentrations of aminoglycosides such as amikacin, gentamicin, and tobramycin
Lipid infusion	3-in-1 or total nutrient admixture for parenteral nutrition

trition solutions. The factors involved in this process include the concentration of calcium, phosphate, amino acids, and dextrose; the type of calcium salt (calcium chloride has greater potential); the composition of the amino acid solution; the temperature of the solution; the pH of the solution; the presence of other additives; and the order of mixing.[27] Hydrochloric acid has been successfully used to clear catheter occlusions of this type.[29–31]

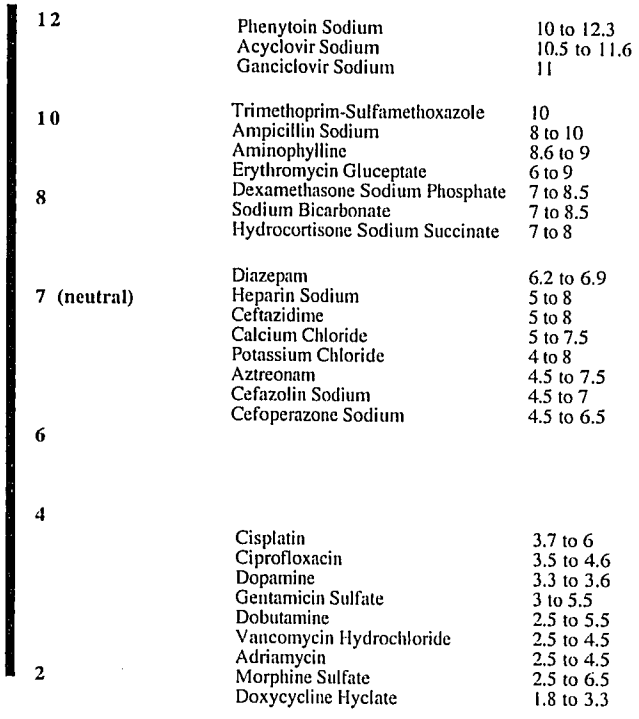


FIGURE **2.**
The pH of common IV medications. Trissel LA. Handbook on injectable drugs, 9th ed. Bethesda, MD: American Society of Health-System Pharmacists, 1996.

Finally, precipitation has been documented with combinations of large organic anions and cations. The mixture of heparin (the anion) with aminoglycoside antibiotics (the cation) leads to the formation of insoluble complexes. This precipitate forms in the presence of high drug concentrations.[27]

The infusion of lipid emulsions, associated with occlusion of catheter lumens, is described as "waxy lipid material," a "lipid precipitate," and a "lipid-protein layer."[28,34–36] Whereas some authors associate this problem primarily with total nutrient admixture or a 3-in-1 infusion, others do not limit the problem to this type of fluid admixture. The exact mechanism of this problem has not been identified, contributing factors include the use of total parenteral nutrition (TPN) catheters for the infusion of other medications and for blood sampling, the composition of the parenteral nutrition, continuous or intermittent administration, the catheter material, and the shape of the portal body.[37] Ethanol and sodium hydroxide have been used successfully to clear these occlusions.[34,35,37]

Last, but certainly of major importance, is catheter lumen occlusion by fibrin or thrombus. Inappropriate flushing solutions, procedures, and timing exacerbate the problem. Catheters must be flushed by means of positive pressure flushing techniques as soon as the infusion is completed. Needleless injection systems can add to the "dead space" in the cannula cap that remains empty

TABLE 4

Reported Solutions Used for Catheter Clearance

Solution	Dosage	Administration Techniques	Time
Hydrochloric acid	0.1 N	1 ml or amount equal to lumen internal volume	Up to 60 minutes
Sodium bicarbonate	8.4% (1 mEq/ml)	1 ml or amount equal to lumen internal volume	Up to 60 minutes
Ethanol	70% in water	Up to 3 ml instilled	60 minutes
Sodium hydroxide	0.1 N	Infusion of 10 ml, followed "lock"	>1 hour for 2 hours
Urokinase	5000 U/ml	1 ml or amount equal to lumen internal	15–60 minutes

when all the flush solution is injected. When the syringe is withdrawn from the injection cap, this space is filled by reflux of the injected solution into the dead space followed by reflux of blood into the internal catheter tip. This blood does not mix well with the flush solution and begins slowly to occlude the catheter lumen.

Positive pressure flushing techniques include withdrawing the syringe tip from the injection cap during the flush of the last 0.5 ml of flush solution, or closing a clamp while maintaining pressure on the syringe plunger. Administration of blood or blood components, extremely slow infusion rates, small lumen catheters, and frequent blood sampling add additional factors to exacerbate the problem.

Thrombolytic agents such as urokinase, streptokinase, and tissue plasminogen activator have been used to restore lumen patency. Urokinase is the only medication the FDA has cleared for the market, with catheter clearance as a labeled indication.

Before the use of any solution for catheter clearance, it is necessary to make a careful assessment of events preceding the problem. Important details to know include the exact formulation of any solution being infused, all medications given through the lumen in the past 24 hours, the amount and timing of flushing procedures, alterations to resistance from position changes, length of time the catheter has been in place, any patient activity, and details about the onset of occlusion problems. Armed with this information, healthcare personnel can choose the most appropriate solution to dissolve the precipitate causing the problem (Table 4).

Most authors report a second solution instillation if the first attempt is unsuccessful. Some even report leaving the solution in a capped catheter overnight. Before the agent is instilled, the catheter lumen should be aspirated to remove as much fluid as possible between the precipitate or clot and the catheter hub, increasing the contact between the agent and the obstructing material. This can be accomplished with negative pressure from a syringe aspiration followed by clamping of the catheter, or by use of syringes attached to a three-way stopcock.

The size of syringe that should be used to instill the pharmacologic agent is quite controversial. Originally, small 1-ml tuberculin syringes were used, but these can generate excessively high pressure in the catheter lumen, leading to catheter fracture. Measuring small quantities of solution in larger syringes is difficult. However larger syringes generate less pressure in the catheter lumen.

Preventing precipitate or clot formation in the catheter lumen is much more appropriate than trying to dissolve these substances. Preventive strategies include careful attention to the solutions being flushed or infused through each catheter lumen. It is important to know what pharmacists mean by expiration time, shelf life, and utility time. Typically, expiration time is applied by the manufacturer, whereas utility time is applied by the pharmacy after constitution and admixture. Shelf life could be applied to either factor. Infusion must be accomplished within the appropriate time after admixture.

Flushing each lumen with 3 to 10 ml of preservative-free sodium chloride after each medication is critical. The volume of solution depends on lumen size, catheter length, and the medication infused. In 1983, benzyl alcohol, the antimicrobial agent used in bacteriostatic sodium chloride was prohibited for use in neonates. In 1995, use of the same preservative was prohibited in inhalants. Case reports of hypersensitivity reactions in adults can be found.[38] Larger volumes of saline flushes can mechanically remove drugs and blood products from the catheter lumen. However, preservative-free saline will decrease the possible reactions from the benzyl alcohol.

Due to concern about clinical problems associated with heparin use and its costs, many authors now recommend the elimination of heparin as a strategy for maintaining catheter patency. Two recent studies demonstrated the continued need for heparin in some patient populations. A randomized, prospective clinical trial of saline-only versus saline and heparin flush for peripherally inserted central catheters showed a significantly higher incidence of catheter lumen clotting when only saline was used (39.5% compared with 1.9% in saline and heparin group).[39]

Another study of heparin versus saline for flushing peripheral catheters in obstetric patients supported the use of heparin. At 72 hours, 68% of the catheters flushed with heparin remained patent, but only 27% of the catheters flushed with saline remained so. Due to the physiologic changes of pregnancy resulting in a hyperco-

aguable state, the authors concluded that heparin was needed to maintain peripheral catheter patency.[40]

Drug compatibility is a complex subject requiring communication between nurses and pharmacists with up-to-date information resources. Specific compatibility must be ascertained before drugs are admixed in the same bag or given simultaneously through the same tubing. When no information can be found, it must be assumed that the two drugs are incompatible. Safe intravenous administration mandates that contact between the two drugs be prevented by adequate flushing between drugs.

• LOSS OF VEIN PATENCY

Whereas loss of catheter patency may mean the loss of the catheter requiring subsequent reinsertion, loss of vein patency can have more devastating clinical outcomes. Restriction or complete loss of extremity function, systemic illness, and death are the dire clinical outcomes that can result from catheter-related phlebitis, thrombosis, and infection.

Phlebitis

Phlebitis, by basic definition, is an inflammation of the vein. The inflammatory process involves the release of biochemical mediators and occurs only in vascularized tissue, with most of the necessary components found in the circulation.

The process of inflammation begins with cellular injury. Insertion of all VADs causes cellular injury to the skin, subcutaneous tissue, and all three layers of the vein wall. Multiple attempts to enter the vein, rapid or forceful catheter advancement, excessive physical activity after catheter insertion, pH and osmolality extremes of infused solution, and particulate matter are examples of factors that increase the injury and inflammation to the tunica intima.

Cellular injury causes:

- mast cell degranulation releasing histamine, leukotrienes and prostaglandins
- activation of complement, clotting, and kinin plasma proteins
- release of other components such as granulocytes and platelets.

Clinical results of cellular injury are seen as redness and heat (vasodilation), swelling caused by leakage of fluid from the capillary wall (vascular permeability), pain from the stimulation of nerve endings, formation of a platelet plug that progresses to a clot, and destruction of bacteria or foreign particles resulting in pus formation (phagocytosis).

Phlebitis is associated with three causes: chemical, mechanical, and bacterial. For short peripheral catheters, it is difficult, if not impossible, to see a specific clinical picture associated with each of the three causes. However, with peripherally inserted central catheters (PICCs) and peripherally implanted ports, it is possible to observe a difference. Because a longer portion of vein houses the catheter, signs and symptoms can be observed at the insertion site, mid-upper arm, and catheter tip. Since the first PICC studies were published, incidences of phlebitis have been included showing a wide variety of results (Table 5).

The challenges in assessing the literature include the following:

- *Lack of standard definitions for phlebitis.* Some studies described the signs and symptoms, whereas others combined data on phlebitis and thrombophlebitis. Still others used nonstandard terms, but the explanation could be interpreted as phlebitis.
- *Combination of data on varying tip locations including superior vena cava, midclavicular, and midline.* Peripheral phlebitis associated with mechanical causes and thrombophlebitis associated with vein wall/catheter tip contact and the pH and osmolality of solutions are difficult to separate.
- *Multiple methods of reporting data on clinical decisions.* Some considered phlebitis to be a indication for immediate catheter removal, whereas others attempted treatments.

Phlebitis associated with all types of catheters inserted from the veins of the antecubital fossa requires more study. How should all signs and symptoms be classified? When should treatment be attempted, and when should the catheter be removed? What should the treatment plan include: continuous or intermittent heat? moist or dry heat? What benefit, if any, is derived from the use of nonsteroidal anti-inflammatory drugs such as ibuprofen? What long-term effects do these episodes have on vein patency?

The first published studies of PICCs reported a phlebitis rate of 20%, which compared favorably with that of previous studies.[41,42] Phlebitis rates have decreased since the first study, possibly because of improvements in insertion methods, better catheter materials and design, and a greater body of knowledge. The author proposes use of the term "early-stage mechanical phlebitis" (ESMP) and defines it as redness, tenderness, and swelling along the venous pathway in the upper arm appearing within the first week after catheter insertion. Several subsequent studies[43–45] support the original work of Lawson et al.,[41] with the majority of cases responding to treatment in 24 to 72 hours.

TABLE 5

Reported Phlebitis with Peripherally Inserted Central Catheters (PICCs) and Peripherally Implanted Ports

Reference	Total Number of PICCs	Total Number with Phlebitis	Number Removed due to Phlebitis	Comments from Article
Hoshal[80]	36	NR	6	Reactions labeled as Venous (thrombophlebitis, tenderness, induration, streaking) Nonvenous (swelling, pain in area of puncture site) No treatment attempts reported
Prian and Van Way[81]	22	8	2	6 with venous inflammation resolved with hot soaks without necessitating catheter removal
Bottino et al[42]	87	20	6	14 transient episodes of basilic and cephalic phlebitis Warm soaks applied within 24 hours and completely resolved with 72 hours All but 1 episode started within 10 days after insertion
Mills et al[82]	68	NR	7	Thrombophlebitis, not responding to local care, necessitated removal No further explanation given
Morris et al[83]	22	1	NR	No treatment attempts reported
Graham et al[76]	76	11	NR	No treatment attempts reported
Markel and Reynem[84]	130	NR	5	No treatment attempts reported
Salem et al[85]	47	3	0	Self-limiting phlebitis requiring elevation alone
Abi-Nader[86]	92	5	3	2 cases resolved with continuous heat Of the 3 removed 1 was resolving 1 was not treated 1 resulted from 15% glucose infusing into cephalic vein
Goodwin and Carlson[16]	858	40	40	All incidences occurred during the first week after insertion and were unresponsive to heat application
James et al[43]	78	19	1	Average of 4 days from insertion to diagnosis of phlebitis 18 with documented complete resolution within 3 days Treatment included Applying continuous heat at 105°F with electronically controlled pad Rest with minimal daily activities Elevation Began immediately when the first symptoms were observed
Loughran and Borzatta[87]	322	28	17	4 were treated with local therapy and went on to complete IV therapy 7 were removed for other reasons Identified 2 clusters of patients 11 developed phlebitis at an average of 18.27 days 17 developed phlebitis at an average of 3.7 days
Tice et al[44]	137	14	3	11 resolved with heat and ibuprofen 3 removed due to persistent or progressive phlebitis; all improved with line removal
Merrell et al[45]	393	32	12	Swelling, erythema, tenderness along the tract of the catheter appearing during the first 24–72 hours after insertion 20 resolved with moist heat 12 removed due to persistent phlebitis
Lam et al[88]	135	3	3	No treatment attempts reported
Schuman[89]	70	4	0	All successfully treated with warm packs, elevation, and ibuprofen
Frey[90]	269	6	3	3 resolved with moist heat for 24–48 hours, applied 20 minutes every 4 hours while awake 3 removed without treatment attempt complained of pain or discomfort without visible signs Tip cultures were negative Tips on 2 of 3 were in axillary vein
Alhimyary et al[91]	135	3	3	No treatment attempts reported but made a referral to treatment discussed by others

NR = not reported.

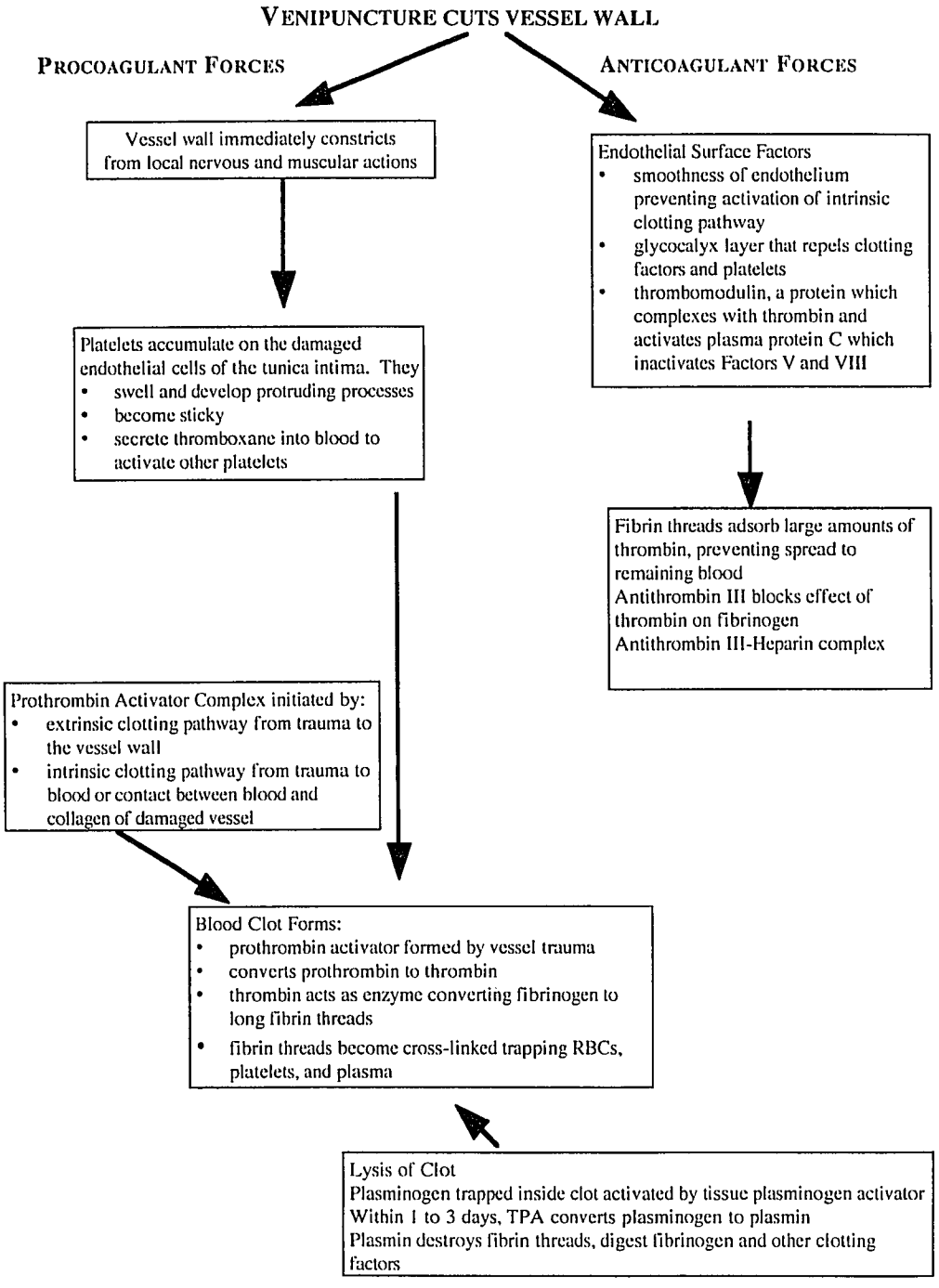


FIGURE **3.**
Clotting process.

Questions remain about the cases that do not respond to treatment. In an attempt to explain the cause of intractable phlebitis episodes with PICCs, Geiss and Friedman[46] used computerized axial tomography (CAT) scans to study vein diameter and catheter location in the upper arm. Their work showed significant areas of narrowing along the vein from the elbow to shoulder in 4 of 10 patients, 3 of whom developed midarm phlebitis. Others[16,44,45] have reported small numbers of patients that did not respond to treatment (see Table 5). More research is needed to answer these and other questions about phlebitis associated with all antecubitally inserted catheters.

The goal is to minimize the degree of cellular injury and thus decrease the inflammatory response. To achieve that goal, we must develop carefully crafted venipuncture techniques, use slow and gentle catheter advancement techniques, and choose tip locations based on a thorough assessment of the patient, therapy, and clinical environment.

Thrombosis

Blood clotting is essentially a delicate balance between factors called procoagulants that promote coagulation and factors called anticoagulants that inhibit coagulation. At the time of vessel damage, procoagulants are activated, causing them to override the anticoagulants that usually are in control (Figure 3).

The Triad of Virchow, formulated in the 19th century, still forms the basis for current theory on thrombus formation. The three components are 1) changes in the blood vessel wall, 2) alterations in blood flow, and 3) changes in the chemical composition of blood.[47,48]

Changes in the vessel wall come from the intimal damage caused by:

- venipuncture and catheter advancement stripping the endothelial cells away
- catheter tip location in vessels where curvature and blood flow rates increase contact with the vein wall
- infusion of solutions with extremes of pH and osmolality causing osmotic shifts in endothelial cell fluid
- changes produced by diseases such as diabetes and hypertension.

Alterations in blood flow are produced by:

- the presence of foreign bodies such as catheters
- stenosis of vessel walls caused by previous damage or catheter presence
- compression of vessel walls related to extremity position
- immobility of an extremity
- vascular compression caused by tumor masses.

Changes in the composition of blood occur with:

- diseases such as cancer and diabetes
- increases in blood viscosity related to fluid volume deficits, high altitudes, or polycythemia vera
- genetic abnormalities in numerous clotting factors.

Venous thromboembolism occurs in approximately 1 in 1000 persons annually, with more than 50,000 deaths annually in the United States attributed to deep venous thrombosis (DVT) and pulmonary emboli.[49] Most research has focused on occurrence in the lower extremities. However, 4% to 13% of all DVT occurs in the upper extremities.[50] In one report of upper-extremity DVT, 30% to 40% were catheter-related, 20% to 30% were related to effort or spontaneous development, and another 30% to 40% were related to other causes such as intravenous drug use, trauma, or thoracic tumors.[51] Black et al.[52] report that 75% of upper extremity DVT is secondary to some type of trauma such as VAD, IV drug abuse, clavicular fracture, tumors, and infection. Radiographic confirmation of a subclinical clot has been reported in 30% to 60% of all central venous lines, with only 3% of these presenting as clinically significant.[53]

Conventional thought usually does not associate the occurrence of pulmonary emboli with upper-extremity DVT. However, recent studies are disproving this theory. In a prospective study by Monreal et al.,[54] venography confirmed upper-extremity DVT in 30 patients, 20 cases of which were catheter related. Lung scan detected pulmonary emboli in five patients, all of which were in the catheter-related group. Whereas chronic venous insufficiency is the most common complication of upper extremity DVT, it is reported that up to 12% develop pulmonary emboli.[51]

Increasing knowledge of coagulation pathways have led to the identification of hypercoaguable states. This may be an acquired state, a congenital or hereditary condition, or a combination of both. Congenital or inherited risk factors include antithrombin III deficiency, protein C and protein S deficiencies, and activated protein C resistance.[48,49] A study of approximately 10,000 blood donors led to estimates of 1 in 500 with protein C deficiency and 1 in 5000 with antithrombin deficiency. No large study has estimated the prevalence of protein S deficiency. Estimates of activated protein C resistance ranges from 3% to 7% in whites and is very uncommon in Asians and Africans.[55] The relation of these congenital deficiencies to the presence of catheter-related thrombosis is unknown at this writing. However, it is reasonable to expect some patients requiring IV therapy to have these underlying conditions.

Acquired hypercoagulation is seen in pregnancy, in parturition, and with the use of oral contraceptives. Studies show activated protein C resistance and antithrombin deficiency in pregnant and postpartum women with venous thrombosis.[49] Immobilization, trauma, and surgery produced hypercoaguability.[55]

Cancerous cells produce two types of procoagulants:

1. *Tissue factor:* a transmembrane protein expressed by normal human connective tissue cells and the malignant counterparts including sarcoma, adenocarcinoma, melanoma, neuroblastoma, lymphomas, and several types of leukemia.
2. *Cancer procoagulant:* a cysteine protease that directly activates factor X and is found in malignant colon, breast, lung, and kidney, as well as melanoma tissue.

Normal tissue can produce procoagulant activity in response to tumors. Monocytes, platelets, and endothelial cells can be triggered to produce thrombin, cytokines, and other clot-inducing peptide products as part of the host response to the tumor.[56] Chemotherapy and surgery increase the risk of thromboembolic disease in

TABLE 6

Signs and Symptoms of Catheter-related Fibrin and Thrombosis

	Signs and Symptoms
Fibrin sheath	Tenderness, pain on the ipsilateral side of catheter Edema of the ipsilateral side Resistance to flush or infusion Leaking of fluid from puncture site indicating retrograde flow between the sheath and catheter
Thrombosis	Pain or discomfort and edema in: Chest Neck Ear Jaw Extremity Engorged peripheral veins in: Extremity Chest wall Neck Difficulty swallowing Difficulty turning head
Superior vena cava syndrome	Progressive shortness of breath Dyspnea Cyanosis of: Face Neck Shoulder Extremities Extensive upper body edema without edema of the lower extremities Headache Visual disturbances Altered mental status

cancer patients, although no studies have conclusively identified tests that would adequately predict these events.[57]

In diabetic patients, many aspects of the coagulation pathway are activated such as increased circulating levels of von Willebrand factors and decreased levels of tissue plasminogen activator. Platelets from diabetic patients produce greater amounts of thromboxane, and these aggregate more easily than platelets from nondiabetic patients.[58] Increases in factor VII activation and thrombin and fibrin formation, and a decrease in antithrombin activity are also documented in diabetics.[59]

Most studies of catheter-related thromboses examine factors associated with the catheter design, polymers, insertion technique, and characteristics of the infused solution. These factors contribute significantly to thrombosis development, but there could be many patient-related factors, both inherited or acquired, that compound the problem of catheter-related thrombosis.

Sites of catheter-related thromboses include the axillary, subclavian, jugular, and innominate veins, as well as the superior vena cava and the right atrium.[60–63] Catheter-related subclavian vein thromboses have even propagated into the cerebral dural venous sinuses and presented clinically as pseudotumor cerebri with headache, visual, and other neurologic problems.[64]

Several studies have related the development of thrombosis to catheter tip location. A study of tunneled catheters examined cohorts of patients with different flush regimens, chemotherapy infusion volumes, and tip locations. Strong statistical differences were found in the tip location cohort, with no statistical differences observed in the others. Tip locations in the superior vena cava, right atrium, or the junction of the two were defined as optimal, and other locations were regarded as suboptimal. In 107 catheters, optimal tip locations were associated with a 16% rate of thrombosis, suboptimal catheters with a 62% rate. All thrombi were confirmed by venogram or autopsy.[65]

Kearns et al.[66] found similar rates in a study of PICCs with tips placed in the axillosubclavian-innominate vein versus the superior vena cava. Selections of tip locations were randomized, and solution osmolalities in both groups were subjected to controls of 160 to 455 mOsm/L. Venogram-detected thrombosis was 60% for the axillosubclavian-innominate group and 21% for the superior vena cava group.

Superior vena cava syndrome is obstruction of blood flow through the superior vena cava. Extensive thrombosis in the vein as well as compression from tumor or enlarged lymph nodes are the causes.

Fibrin sheath or sleeve formation is another type of coagulation-dependent mechanism for loss of vein patency. In 1971, Hoshal et al.[67] was the first to report autopsy results of 55 patients with indwelling subclavian catheters. All catheters were surrounded with a coat of material confirmed microscopically to be composed of fibrin. Many were several inches long and formed from two points: the insertion site and the area where the tip contacts the tunica intima. This sheath or coat, composed of fibronectin, fibrin, laminin, collagen, and immunoglobulins, can form within 24 hours after catheter insertion.[68]

A recent study of venous catheters implanted in rats allowed histologic examination of the catheter coatings at 3, 7, and 60 days. Rats were chosen because of similarities with humans in blood clotting and thrombus organization. At 3 days, the IV portion of the catheter was covered with a red, shiny thrombus; at 7 days, the thrombus became more organized with more cellular components; and at 60 days, a white to translucent covering adhered to the catheter and surrounded the tip. This indicated the conversion of the thrombus to a covering of tough, fibrous connective tissue. Whereas thrombolytic agents will dissolve thrombus and fibrin,

TABLE 7

Definitions for Catheter-related Infection[74]

Term	Definition
Colonized catheter	Growth of ≥15 colony-forming units (semiquantitative culture) or $>10^3$ (quantitative culture) from a proximal or distal catheter segment in the absence of accompanying clinical symptoms
Exit-site infection	Erythema, tenderness, induration, or purulence within 2 cm of the skin at the exit site of the catheter
Pocket infection	Erythema and necrosis of the skin over the reservoir of a totally implantable device, or purulent exudate in the subcutaneous pocket containing the reservoir
Tunnel infection	Erythema, tenderness, and induration in the tissues overlying the catheter and >2 cm from the exit site
Catheter-related bloodstream infection (CR-BSI)	Isolation of the same organism (ie, identical species, antibiogram) from a semiquantitative or quantitative culture of a catheter segment and from the blood (preferably drawn from a peripheral vein) of a patient with accompanying clinical symptoms of BSI and no other apparent source of infection. In the absence of laboratory confirmation, defervescence after removal of an implicated catheter from a patient with BSI may be considered indirect evidence of CR-BSI.
Infusate-related bloodstream infection	Isolation of the same organism from infusate and from separate percutaneous blood cultures, with no other identifiable source of infection

connective tissue cannot be removed by these agents. The researchers suggested that humans may go through a similar window of time when this covering can be removed, but the clinical relevant time is unknown at the present.[69]

Management of catheter-related thromboses requires early recognition of signs and symptoms (Table 6). However, the majority present with minimal or no clinical signs and symptoms, and only about 3% develop a clinically significant problem.[51] Catheters that suddenly or gradually become nonfunctioning require careful assessment because this may be the only indication of a problem. Venography has long been considered the best diagnostic technique, but it can be extremely painful, producing a greater degree of venous reaction to the contrast media. Venography can provide a better understanding of the total clot size and the development of collateral circulation. Noninvasive radiographic techniques such as Doppler ultrasound scanning reportedly result in a high percentage of accurate diagnosis and thus are recommended as the first step.[51]

Treatment options involve a decision between immediate catheter removal and attempts to salvage the VAD. The patient's need for infusion therapy must include the type and purpose of therapy, the amount of time remaining for the current prescribed therapy, the number of other available venous access sites, and the future needs for infusion therapy. Conservative measures include immediate catheter removal with the application of heat, immobilization, and extremity elevation. This approach may leave many patients with postphlebitic pain and edema, limiting function of the extremity.[51]

When catheter removal is not an option, anticoagulation with heparin and warfarin are used to improve the rate of clot dissolution and lessen the degree of residual complications. The course of treatment usually involves 8 to 10 days of heparin followed by 60 to 90 days of warfarin.[51]

Thrombolytic agents such as urokinase, streptokinase, or tissue plasminogen activator may be infused through the catheter or another venipuncture site. One study allowed the problem catheter to remain in place, inserted a 4- or 5-Fr catheter with multiple sideholes directly into the clot, and infused urokinase doses of 25,000 to 120,000 units per hour. Concomitant heparin infusion was also administered. The authors salvaged 87% of the catheters in this study of 38 patients. After thrombolysis, of the 22 patients found to have vessel stenosis, successful opening was accomplished by angioplasty in 14.[70] Contraindications for use of thrombolytic agents include active internal bleeding, recent cerebrovascular accident, intracranial or intraspinal surgery or trauma, and aneurysm.[51]

Stents of many designs have been used successfully in the management of superior vena cava obstruction. These obstructions are usually unresolved by thrombolytics and angioplasty. The procedure involves systemic heparinization, cannulation of the superior vena cava with an angioplasty balloon catheter from the femoral vein, snaring of the permanent VAD with its temporary repositioning to the internal jugular vein, advancement of the stent over the guidewire to the SVC where it is deployed, and snaring of the permanent VAD and its repositioning to the SVC. Over the next few months endothelial tissue grows over the stent, and the patient remains on warfarin.[71]

Surgical intervention involves thrombectomy, venoplasty, or both. Anticoagulation with warfarin is given for a 5-month postoperative period, with a venogram to assess for residual stenosis at 2 months.[51,72]

TABLE 8

Nosocomial BSI Pathogens

Pathogen	Rate (%)
Staphylococcus epidermidis	28
Staphylococcus aureus	16
Fungi, particularly *Candida albicans*	10
Enterococci	8

BSI = blood serum iron.

Prevention of venous thrombosis includes careful attention to venipuncture and catheter advancement techniques. The goal is to minimize the trauma to the endothelial layer of the tunica intima and thus decrease the propagation of thrombus formation. Catheter tip location in the superior vena cava will greatly decrease the likelihood of thrombus. Finally, the use of prophylactic anticoagulation is now recommended.[56,57] A randomized study of 80 patients with implanted ports demonstrated a significant reduction in thrombosis when warfarin was taken in low doses, beginning 3 days before catheter insertion.[73] This study duplicated the outcomes of many other studies showing prophylaxis postoperatively. Other means of anticoagulation include subcutaneous heparin and low-molecular-weight heparin.[56]

Infection

"Unfortunately, vascular access is associated with substantial and generally underappreciated potential for producing iatrogenic disease, particularly bloodstream infection originating from infection of the percutaneous devices used for vascular access or from contamination of the infusate administered through the device (p. 75)".[75]

To think that our efforts to deliver life-saving solutions and medication may actually be causing disease and death is alarming. However, strong statistical and clinical evidence supports this concern. Our efforts must be directed at prevention, not merely diagnosis and treatment.

A primary problem in discussing catheter-related infection and comparing data from a variety of sources is the lack of consistent definitions and data collection methods. The Guidelines for Prevention of Intravascular Device-Related Infections as spelled out by the Hospital Infection Control Practices Advisory Committee (HICPAC) contain recommended definitions for all types of device-related infections (Table 7).

Approximately 200,000 bloodstream infections occur annually, and the majority are associated with the use of intravascular devices.[74] Bloodstream infections secondary to urinary tract or surgical wound infections and pneumonia have remained stable over the past decade, whereas primary bloodstream infections have increased twofold in the same period. This increase is linked to the increased use of infusion therapy and all types of central venous catheters.[75]

Short peripheral catheters have a higher risk of phlebitis and when left in place longer than 48 hours are associated with a 2% to 5% risk of bacteremia.[75] Midline catheters have lower rates of phlebitis than short peripheral catheters, and lower rates of infection than central venous catheters. Also, PICCs have an infection rate lower than that of nontunneled central venous catheters. Tunneled catheters have lower rates of infection than nontunneled central catheters. However, two recent studies found no significant differences in infection rates between tunneled and nontunneled catheters. Totally implanted devices have the lowest rates of infection.[74]

Percutaneously inserted noncuffed single- and multiple-lumen central catheters have the highest risk. Septicemia rates usually range from 3% to 5%, but some hospitals report rates as high as 10%.[75] Of all catheter-related bloodstream infections, 90% are caused by nontunneled central venous catheters.[74]

A large body of information about catheter-related infections in hospitals exists. However, very few studies have attempted to collect data from homecare and long-term care facilities. Graham et al.[76] studied infection rates in 300 homecare patients including short peripheral, PICC, and percutaneous nontunneled and tunneled catheters. These researchers found a 2% incidence of bacteremias or 4.6 cases per 10,000 catheter days. White and Ragland[77] reported similar findings of a 1.5% incidence of bacteremia, representing 4.2 bacteremias per 10,000 catheter days.

Within the past decade, coagulase-negative staphylococci, particularly *Staphylococcus epidermidis,* have become the most prevalent pathogen isolated in catheter-related infections (Table 8). This demonstrates that this microorganism is recognized as a true pathogen, and also that the patient's skin and the hands of healthcare workers are the predominant sources of pathogens. Gram-negative species such as *Enterobacter, Acinetobacter, Serratia marcescens,* or nonaeruginosa pseudomonads, are found in contaminated pressure-monitoring devices and IV solutions.[74]

A large body of scientific data points to skin flora as the source of infection. Microorganisms migrate from the skin down the catheter tract and colonize the catheter tip. Another enlarging body of data shows the catheter hub is an important source of microorganisms, especially for long-term catheters. Hematogenous seeding of the catheter from an infection at a distant site also can cause catheter infections. Catheter material and its surface irregularities contribute to infection. Polyvinyl chloride and polyethylene are less resistant to adherence of microorganisms, with Teflon, silicon elastomer, and polyurethane being more resistant to adhesion. Microorganisms also contribute the ability to adhere to host proteins such

as fibronectin commonly found on catheters. For instance, coagulase-negative staphylococci stick to catheter surfaces more easily than other organisms.[74]

Clinical management of catheter-related infection depends on recognition of the clinical features and appropriate culturing techniques. Signs and symptoms may be nonspecific including fever, chills, hypotension, shock, hyperventilation, nausea, vomiting, diarrhea, confusion, and seizures. More specific evidence includes a patient not at risk for sepsis, local inflammation at the catheter insertion site, no obvious local infection, and an abrupt onset associated with shock.[75]

Techniques used for obtaining cultures are critical to appropriate diagnosis and treatment. Two blood cultures should be taken from peripheral veins by separate venipunctures. Proper skin antisepsis and handling of the sample is mandatory to prevent contamination. The volume of blood for each sample should be 30 ml and not less than 20 ml. This allows for 10 to 15 ml in the aerobic and anaerobic media, an amount sufficient for detecting bacteremia. A blood sample obtained through the suspect catheter will show a 10-fold or greater concentration of organisms compared with a sample obtained from a peripheral site. This technique can be beneficial in diagnosing infections in tunneled catheters and implanted ports.[75]

Culture methods of the catheter segments contribute to the ability to make accurate diagnoses. Semiquantitative or quantitative techniques are recommended.[74,75] For a semiquantitative culture technique, the skin around the insertion site should be cleansed with alcohol. After removal of all drainage, ointment, or other cellular debris, the site should be allowed to dry. If there is any drainage from the site, it should be gram-stained and cultured separately. The catheter must be retracted perpendicularly to the skin with care to avoid contact between the catheter and the skin.

For short catheters, the entire intravascular segment is amputated. For longer catheters, two segments are taken: the catheter tip and the intracutaneous segment. Catheter segments are placed in separate sterile transport containers and sent to the laboratory for culture, ideally within 2 hours. In the laboratory, the catheter segments are rolled across a blood agar plate and incubated for 72 hours.[78]

Decisions about what to do with the VAD suspected of infection depends on the type of device. Percutaneous, nontunneled catheters should be removed when there is no other obvious source of infection and there is inflammation at the insertion site, or when bacteremia or candidemia have been established. If the catheter is left in place and treated, the risk of recurrent bacteremia is about 20%.[75] Leaving the catheter in place can lead to septic thrombophlebitis in peripheral veins, septic thrombosis of large central veins, and endocarditis.

Tunneled catheters with bacteremia from coagulase-negative staphylococci can be cured by antibiotics infused through the catheter for 7 to 10 days. Removal of the catheter should be considered when there is infection of the tunnel or exit site, endocarditis, or septic thrombosis, or when the infecting pathogen is *Staphylococcus aureus, Corynebacterium, Bacillus, Xanthomonas, Malessezia,* or a mycobacterium species. When implanted ports are the cause of bacteremia or fungemia, the device should be explanted because they are rarely curable without removal.[75]

Prevention strategies hold the answer to decreasing many catheter-related infections. When thinking about prevention, first thoughts focus on routine removal and replacement of the catheter. Catheter dwelling time is one of the leading predictors of infection. However, this factor must be balanced against the patient's need for vascular access and other potential access sites. For peripheral catheters, rotating the site every 48 to 72 hours will minimize phlebitis and therefore the risk of infection.[74,75] The INS *Intravenous Nursing Standards of Practice* (revised 1998) state that the catheter should be removed every 48 hours, with consideration for 72-hour rotation if the phlebitis rate is consistently 5% or less for 3 months.[79] The optimal time for rotation of midline, PICC, or central venous catheters is unknown. Research has not yet established a recommended dwelling time for these devices.[74,79]

Key preventive measures include:

- vigorous handwashing, preferably with an antiseptic preparation before insertion and handling of any infusion system
- maximal barrier precautions during central venous catheter insertion including long-sleeved sterile gown, mask, cap, large sterile drape, and sterile gloves[74,75]
- skin antisepsis with 1% to 2% tincture of iodine, 10% povidone-iodine, or 70% alcohol. Although not commercially available in the United States at this time, 2% chlorhexidine has shown greater efficacy in reducing in device-related bacteremia than the others.[75] Techniques for applying the solution must include a circular motion, working from the inside to the outside, using adequate scrubbing technique for 1 full minute, and allowing the solution to dry.[75]
- dressings that are either sterile gauze or transparent membranes, which should be replaced when the catheter is rotated, or when it becomes damp, loose, or soiled.[74] A definitive time for dressing change was not recommended in the HICPAC Guidelines. However, the INS *Intravenous Nursing Standards of Practice* (revised 1998) state that gauze dressings should be changed every 48 hours. Frequency of transparent membrane dressing is unknown or undetermined.[79]
- administration sets that are changed at 72 hours according to the HICPAC Guidelines.[74] The INS *Intravenous Nursing Standards of Practice* (revised 1998)

call for changes every 48 hours routinely, with consideration for 72-hour intervals if peripheral phlebitis rates are consistently 5% or less and central venous catheter infection rates remain stable. The INS *Intravenous Nursing Standards of Practice* (revised 1998) also distinguish between primary continuous and primary intermittent administration sets, with recommendations for changing the latter at 24 hours.[79]

- dedicated personnel such as IV teams ensure a high level of asepsis during catheter insertion and care that are cost-effective.[74,75]

This is just a partial list of preventive strategies, and many controversies exist between reputable organizations. It is imperative for each healthcare organization to employ these documents as the foundation for internal policies and procedures. The most appropriate strategies for each healthcare facility or agency should be based on an assessment of patient populations and outcome data specific to that provider.

• CONCLUSION

Technological developments continue to improve the products we use. By the time this article reaches the reader, new catheter designs, dressing materials, flushing products, or some totally new innovation could have reached the healthcare market. It is imperative that each healthcare provider remain cognizant of these changes and employ them appropriately to decrease the loss of catheter and vein patency.

Each healthcare organization is unique. Common diagnoses, age groups, and complication rates all differ. Organizational system structure, the knowledge and skills of nursing staff, the mix of caregivers (RNs, LPNs, unlicensed personnel), and reimbursement sources vary greatly from one facility or agency to another. Therefore, it is critical to understand the factors that define your organization. This knowledge combined with published standards and guidelines as well as technological advances establishes the foundation for improving patient outcomes.

Problems involving the loss of catheter and vein patency are mostly preventable. Prevention, however, will require a collaborative effort involving organization management, all disciplines of professionals (nurses, pharmacists, and physicians), and the patient and family to alter clinical outcomes.

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