

Lynn Hadaway, MEd, RNC, CRNI®

Technology of Flushing Vascular Access Devices

Abstract



Maintenance of catheter lumen patency is an ongoing challenge. Catheter flushing is the primary nursing intervention used to prevent lumen occlusion from thrombotic and precipitate causes. The catheter and all devices attached to it must be regarded as a system in which each component directly affects the others. The technology of catheter flushing includes the flush solution itself, the source of these solutions, syringe design, mechanical pumps, needleless injection systems, and the design of the catheter. Effective catheter flushing is a combination of a technique and technology that requires an understanding of how both must work together.

Occlusion with all types of vascular access devices is a significant problem in current clinical practice. The primary nursing intervention used to maintain catheter lumen patency is flushing. This simple task is aimed at filling the entire catheter and any add-on devices with fluid to “lock” the system and prevent backflow of blood into the lumen.

Many devices designed to prevent blood reflux and thus improve catheter patency have entered the US healthcare market. The varieties of types and design features have caused much confusion. Healthcare professionals must consider catheter-flushing technology and its impact on catheter-related bloodstream infections (CR-BSIs). To assess all the technology involved with catheter flushing, healthcare professionals must look at all the components in the system and how they work together (Figure 1).

• EXPANDING THE PURPOSE OF FLUSHING

The *Infusion Nursing Standards of Practice* clearly defines 2 purposes of catheter flushing: to maintain catheter patency and to prevent contact between incompatible medications or fluids that could produce a precipitate.¹ To accomplish these goals, infusion specialists

Lynn Hadaway is President of Lynn Hadaway Associates, Inc. She has more than 30 years of experience as an intravenous nurse, educator, and consultant. She holds a master's in education, along with certification in professional staff development and infusion nursing, and has published extensively on infusion topics in numerous journals.
Address correspondence to: lynn@hadawayassociates.com (e-mail).

Flush solution
• Sodium chloride
• Heparin flush solution
• Ethylenediaminetetraacetate
• Ethanol
Containers or the source of flush solution
• Multidose vials
• Large-volume fluid bags
• Single-dose vials
• Prefilled syringes
Syringe design
Mechanical pumps
Needleless injection systems
Catheter design components
• Length
• Lumen priming volume
• Integral valves
• Impregnation with anti-infective substances

FIGURE 1.
System components affecting catheter flushing.

have traditionally used 0.9% sodium chloride and heparinized sodium chloride. Because of the overwhelming problem associated with CR-BSIs, healthcare professionals may soon be expanding the purpose for flushing and locking the catheter to include reduction of the intraluminal biofilm.

Biofilm is a community of microorganisms surrounded by a slime matrix whereby they protect themselves from antibiotics, white blood cells, and all other anti-infective mechanisms. It develops on virtually all indwelling vascular access devices, attaches to both the internal and external catheter surfaces, and has been found inside needleless injection devices as well. Planktonic or free-floating bacteria adhere to the catheter surfaces and begin to form a biofilm at very high flow rates.^{2,4}

During catheter insertion, resident flora in the deep layers of the epidermis attach to the outer catheter surface as it passes through the skin. Organisms enter the internal catheter lumen during hub manipulations such as medication administration, tubing and cap changes, and flushing procedures. Catheters dwelling for short periods acquire more biofilm on their outer surfaces, whereas more biofilm accumulates on the internal surface of longer-term devices. A recent study of short-term, nontunneled, noncuffed central venous catheters showed that both extraluminal and intraluminal pathways are significant sources of CR-BSI. Using pulse-field gel electrophoresis with 1,263 central venous catheters, 45% of the CR-BSIs were found to be extraluminally acquired; 26% were found to be intraluminally acquired; and the mechanism could not be determined in 29%.⁵

Biofilm detaches from the catheter surface by enlargement of cell clusters, by detachment and reattachment of single cells or clumps of cells, and by rolling motility much like a rippling effect. The mechanism by which a biofilm produces a bloodstream infection (BSI) is poorly understood. However, possible mechanisms include detachment of cells or clumps of biofilm, production of endotoxins, and alterations in the patient's immune system.^{6,7} The interaction between flushing techniques, technology, biofilm development, and subsequent BSI is not well understood and requires careful study. Nonetheless, each time a catheter is accessed, the primary goal should be to reduce the introduction of organisms into the lumen.

One method for eradicating the biofilm is to use different antimicrobial fluids to lock the catheter. Toward that end, 3 fluids have been studied: minocycline and disodium ethylenediaminetetraacetate (EDTA), tetra-sodium EDTA, and ethanol. Locking the catheter with a variety of antibiotic solutions is a technique used to treat existing infections to salvage catheters, but is not recommended for routine prophylaxis against CR-BSIs because of the potential for antibiotic resistance.

About 15 years ago, EDTA was suggested as a catheter-locking solution because it has an anticoagulant activity and inhibits the growth of *Staphylococcus* and *Candida* species. Animal studies using a combination of minocycline and disodium EDTA (M-EDTA) found this combination to be very effective at preventing bacteremia, septic phlebitis, and endocarditis. In vitro and ex vivo studies demonstrated the effectiveness of M-EDTA against fresh and mature biofilm on catheter surfaces.⁸⁻¹⁰ During a randomized, prospective trial with hemodialysis patients, M-EDTA produced a 9-fold reduction in BSI compared with heparin. Another prospective cohort study of implanted ports in pediatric cancer patients demonstrated no infections or thromboses with M-EDTA, as compared with the group receiving heparin flush, in which 2.23 infections per 1,000 catheter days were reported.¹¹

The dosage used in these studies was 3 mg of minocycline and 30 mg of EDTA per milliliter of sterile water, with 2 mL of this solution used to flush and lock the catheter for 24 hours. Minocycline has recently been withdrawn from the US market, thereby shifting the focus of research to the use of 40 mg of tetrasodium EDTA per milliliter. Two in vitro studies demonstrated significant reduction in the biofilm when exposed for 21 and 24 hours.^{10,12}

The use of ethanol to lock a catheter currently is in clinical trials evaluating the treatment of catheter-related infection. However, only one small study is available. Broviac catheters in 79 pediatric oncology patients with positive blood cultures and clinical signs of CR-BSI were treated with ethanol locks or antibiotics. The experimental group contained 18 patients treated 24 times with 2.3 mL of 74% ethanol solution for 20 to 24 hours, and the control group was 13 children who received 15 courses of systemic antibiotics. In the ethanol-treated group, 67%

showed no infectious signs or symptoms for 4 weeks after treatment, whereas only 47% of the group receiving antibiotics remained infection free.¹³

Several brands of polyurethane catheters have warnings against the use of alcohol on or in them. One in vitro study tested changes in one type of polyurethane during exposure to 70% ethanol for up to 9 weeks. The researchers reported no changes in mechanical or structural properties of the catheter, thus enhancing the possibility of using ethanol as a prophylactic locking solution.¹⁴ New formulations of polyurethane are more tolerant of alcohol. However, the manufacturers' instructions should always be followed.

Many questions remain to be answered, specifically the length of time these novel flush solutions must remain inside the catheter lumen to be effective at reducing the biofilm.

• FLUSH SOLUTION CONTAINERS

Traditionally, multiple-dose containers have been used to obtain catheter flush solution, including 30-mL vials of sodium chloride and 250-, 500-, or 1,000-mL bags of sodium chloride. However, the risks of using multiple-dose containers far outweigh their benefit.

Bacterial contamination of multiple-dose vials is reported to be as high as 23%. The vials contain benzyl alcohol as the preservative, which is bacteriostatic, not bacteriocidal. Gram-negative bacteria are the least sensitive to benzyl alcohol, and it has no effect on fungi or viruses.¹⁵ Bacteriostatic sodium chloride should not exceed more than 30 mL in a 24-hour period for adults, and is contraindicated for neonates.¹⁵ The adult restrictions were derived from an animal study, with data extrapolated to humans.¹⁵ The Food and Drug Administration (FDA) imposed neonatal restrictions in the mid-1980s.¹⁶

A prevalence study in a 1,300-bed hospital collected 227 open multiple-dose vials from 47 nursing units, including 77 (34%) with sodium chloride and 41 (18%) with heparin. No opening date was found on 113 (50%) of the vials. No label of the medication type appeared on 2 of the vials, and 7 vials had no concentration of the medication. Of 114 dated vials, 15 had been expired for up to 14 days, and 50% contained no preservative. One vial and 1 spike pin grew *Staphylococcus epidermis*, an organism common in CR-BSI. As a result of this study, multiple uses of preservative-free vials were eliminated in this hospital.¹⁷

Another study demonstrated that approximately 8% of syringes prepared by nurses were contaminated at the syringe tip, tip cap, or fluid. Lack of environmental control through the use of a laminar air-flow workbench and touch contamination explain the rate.^{18,19}

Numerous outbreaks of serious healthcare-acquired infections have been linked to multiple-dose vials used for

catheter flushing. This encompasses polymicrobial BSI from *Enterobacter cloacae*, *Pseudomonas aeruginosa*, malaria, hepatitis B and C, and human immunodeficiency virus (HIV). Explanations for these infections include poor hand hygiene practices and repeated access of the vial with a contaminated syringe.²⁰⁻²⁸

Use of large-volume fluid containers as a source for catheter-flushing solution has been a major concern for many years, yet the practice continues. Reported outbreaks include *Klebsiella pneumoniae* bacteremia in a liver transplant unit, *Pseudomonas cepacia* bacteremia among oncology clinic patients, and combinations of *Enterobacter cloacae*, *Klebsiella pneumoniae*, and *Citrobacter freundii* in medical and cardiac step-down units.²⁹⁻³¹ In 2003, a report published in the *Morbidity and Mortality Weekly Report* specifically stated: "Do not use bags or bottles of intravenous solution as a common source of supply for multiple patients."²⁸

Single-dose containers, including vials of preservative-free normal saline and prefilled syringes, are strongly recommended by the Institute for Safe Medication Practices and the Joint Commission for Accreditation of Healthcare Organizations (JCAHO) to achieve the National Patient Safety Goals. The INS standards of practice and the guidelines from the Centers for Disease Control also emphasize the use of single-dose containers.¹ The 2006 National Patient Safety Goals from JCAHO require that all medication containers be labeled, including those containing saline and heparin used for catheter flushing.

A single-dose container means single use. A vial should not be entered more than once, and a prefilled syringe should be attached only once to the injection site on the catheter system.

• SYRINGES

For many years, healthcare professionals have known that the syringe size has an impact on the risk of catheter damage. The basic principle is that smaller syringes generate greater amounts of pressure than larger syringes, thus leading to recommendations for the use of a 5- or 10-mL syringe for catheter flushing. Force must be applied to a syringe plunger to move it down the syringe barrel and push the fluid into the catheter, yet the nurse has no way to measure the amount of force being applied. Applied force meeting resistance in the catheter leads to increased intraluminal pressure and subsequent catheter rupture.³²⁻³⁴

The force required to move the plunger of most prefilled syringes is about 3.5 pounds per square inch (PSI). Approximately 29 PSI is produced when 3.5 PSI is applied to the plunger of a 3-mL syringe. For a 10-mL syringe, 11 PSI is produced when 3.5 PSI is applied to the plunger. Individual hand strength varies greatly as a result of size and musculature. Excessive force applied to

the plunger to overcome resistance inside the catheter lumen can lead to catheter damage, regardless of the syringe size.³²

Until recently, very little attention has been paid to the interaction between the syringe and the fluid flow dynamics inside the catheter. With a traditional syringe, flushing all fluid into the catheter lumen can result in compression of the tip on the end of the plunger rod. To detach the syringe from the catheter hub, the nurse's hand typically is removed from the plunger rod, thus allowing expansion of the compressed tip. This leads to blood reflux into the catheter lumen. Use of prefilled syringes designed to prevent this rebound problem may enhance catheter lumen patency.

• MECHANICAL PUMPS

Two types of mechanical pumps can be used to accomplish catheter flushing after infusion of intermittent medication. The first is a mechanical pump with a multichamber bag (eg, Autodose, Tandem Medical, San Diego, CA), most commonly used in homecare rather than hospitals. The bag contains 4 separate chambers: 1 each for sodium chloride, the drug and diluent, sodium chloride, and heparinized sodium chloride. The preattached tubing has a manifold that allows each fluid to run sequentially. The bag is placed inside the pump containing a flat spring plate. The tubing is connected to the catheter hub, the pump doors are closed, and the start button is activated, allowing the fluid in each chamber to flow in the correct sequence.³⁵

An elastomeric balloon pump can be filled with sodium chloride and connected to the catheter hub to produce a constant flow of sodium chloride at 0.5 mL per hour. The intermittent medication is given through a side injection port on the pump tubing.³⁶

• NEEDLELESS INJECTION SYSTEMS

Concern over needlestick injuries led to the development of needleless injection systems (NIS). In 1992, the FDA called for the elimination of all needles used to connect multiple intravenous administration sets together.³⁷ The Bloodborne Pathogen Standard from the Occupational Safety and Health Administration (OSHA) now mandates these devices.

Through the years, healthcare professionals have seen many changes in the design of these systems (Table 1). Although the product labeling does not always indicate the type of fluid displacement, these devices can be divided by the type of fluid movement through them. A negative-displacement needleless injection system will allow blood to reflux into the catheter lumen when the tubing or syringe

is disconnected. One of the positive-pressure flushing techniques is required when a negative-displacement device is used (Table 2). A positive-displacement needleless injection system will reserve a small amount of fluid to push toward the catheter tip at disconnection of the syringe or tubing, thus preventing blood from remaining inside the lumen. A neutral displacement needleless system will not allow fluid to move in either direction when tubing or a syringe is disconnected.

Negative- and positive-displacement devices are dependent upon flushing technique, making it imperative that all nurses understand the type of device being used. A positive-pressure flushing technique is required with a negative-displacement device. INS defines positive pressure as a constant, even force within a catheter lumen preventing reflux of blood by clamping while injecting or by withdrawing from the catheter hub while injecting.¹ Positive-pressure flushing techniques will prevent proper function of a positive-displacement NIS and should not be used with these devices.

Some facilities have policies calling for a clamp on the catheter to keep it closed when not in use. In the facilities that also use a positive-displacement device, the nurse must disconnect the tubing or syringe, allow sufficient time for the positive fluid displacement, then close the catheter clamp.

Blood reflux into the catheter lumen results from syringe plunger rod compression and syringe or tubing disconnection. Although a positive-displacement NIS will displace the blood reflux caused by disconnection, there is no available research on its ability to overcome syringe compression reflux in addition to disconnection reflux.

The length of catheter lumen affected by blood reflux depends on the catheter lumen size. Catheters with a smaller lumen diameter will have more length filled with blood, whereas larger lumens will have a shorter length of reflux. Blood moving into the catheter lumen will have limited contact only with the heparinized sodium chloride left in the lumen.

• NEEDLELESS INJECTION SYSTEMS AND INFECTION

The latest guidelines on prevention of CR-BSI from the Centers for Disease Control and Prevention (CDC) address the infection risk with NIS use, stating that it does not substantially increase the incidence of CR-BSI when used according to manufacturers' instructions. The use of NIS has reduced the risk of needlestick injuries to healthcare workers and the subsequent risk for transmission of occupational exposure to bloodborne diseases.³⁸

Recently released data have raised the issue of a potential increased risk for BSI related to these devices. Five institutions have documented a significant increase in BSIs after changing from a split-septum or blunt-cannula de-

TABLE 1

Needleless Injection Systems

Types	Description	Advantages	Disadvantages	Nursing Implications
Negative-displacement Devices				
<i>Allow for blood to move into the catheter lumen upon disconnection</i>				
Split-septum system	Accepts a blunt cannula attached to the administration set or syringe. Blunt cannulas available with 2 designs: • Straight fluid pathway • Fluid exit port on each side of cannula Fluid flow rates ~17 L/hr.	Useful with emergency medications in prefilled syringes with needles. Clear housing allows for viewing internal contents.	Allows use of needles in nonemergency situations, increasing potential for needlestick injuries. Allows for blood reflux when fluid container runs dry and tubing remains connected.	Requires a positive pressure flushing technique. Septum requires disinfection with alcohol. Requires immediate disconnection of infusion tubing when fluid container is empty.
Two-piece mechanical valve system	Valve housing attached to catheter hub, then closed with a separate sterile end cap. Fluid flow rates up to 24 L/hr.	Luer-activated mechanism. Will not accept needles. Clear housing allows for viewing internal contents.	Supply of sterile end caps must be available. Reuse of end caps or leaving end cap off could increase potential for contamination. Connection surface cannot be disinfected. Allows for blood reflux when fluid container runs dry and tubing remains connected.	Requires a positive pressure flushing technique. Requires immediate disconnection of infusion tubing when fluid container is empty.
One-piece mechanical valve system	Closed valve housing attached to catheter hub; accessed with standard Luer tip of syringe or tubing. Fluid flow rates range from 6.4 to 9.3 L/hr.	Luer-activated mechanism. Will not accept needles. Connection surface can be disinfected with alcohol.	Color of device may obscure view of internal contents. Allows for blood reflux when fluid container runs dry and tubing remains connected.	Requires a positive pressure flushing technique. Connection surface requires disinfection with alcohol. Requires immediate disconnection of infusion tubing when fluid container is empty.
Luer accessible split septum	Split-septum connection surface; fluid pathway is opened by the standard Luer tip of a syringe or tubing. Fluid flow rate of 32 L/hr.	Connection surface can be disinfected with alcohol. Clear housing allows for viewing internal contents.	Allows for blood reflux when fluid container runs dry and tubing remains connected.	Requires a positive pressure flushing technique. Connection surface requires disinfection with alcohol. Requires immediate disconnection of infusion tubing when fluid container is empty.
Positive-displacement Devices				
<i>Contain a fluid reservoir; upon disconnection of syringe or tubing, fluid is pushed into the lumen to displace intraluminal blood</i>				
	One piece Luer-activated mechanical valve. Variety of designs for the connection surface. Fluid flow rates range from 4.8 to 15 L/hr.	Anecdotal reports of reduced lumen occlusion. Directions for saline-only flushes for some brands, allowing elimination of heparin flush.	Angled or raised surface for connecting tubing or syringes. Color of device obscures view of internal contents.	Positive pressure flushing technique can not be used because it will overcome the positive displacement mechanism.

(continued)

TABLE 1 *Continued*

Needleless Injection Systems

Types	Description	Advantages	Disadvantages	Nursing Implications
			Allows for blood reflux when fluid container runs dry and tubing remains connected.	Connection surface requires disinfection with alcohol. Check the brand-specific instructions for information about elimination of heparin flush solution. Requires immediate disconnection of infusion tubing when fluid container is empty.
Neutral-displacement Devices				
<i>Mechanism that prevents fluid from moving in either direction upon tubing or syringe disconnection</i>				
One-piece system	Luer-activated mechanical valve. Fluid flow rate of 7.7 L/hr.	Luer-activated connection. Directions for saline-only flushes, allowing the elimination of heparin flush solution.	Color of device obscures view of internal contents. Allows for blood reflux when fluid container runs dry and tubing remains connected.	Function is not dependent on flushing technique. Connection surface requires disinfection with alcohol.
Pressure-sensitive valve system	Housing containing a round disk with a pressure-sensitive slit valve, closed with a separate sterile end cap.	Valve closes when a small column of fluid remains in attached tubing, preventing blood reflux while tubing remains connected. Saline-only flushes may be used, eliminating the need for heparin flush solution.	Supply of sterile end caps must be available. Reuse of end caps or leaving end cap off could lead to contamination. Connection surface cannot be disinfected.	Function is not dependent on flushing technique.

vice to a device with a Luer-activated mechanical valve. In 3 of these facilities, the BSI rates returned to the original level after a change back to the split-septum device. Two hospitals that have not changed the NIS product have reported high rates of BSI even with reeducation on catheter insertion and maintenance guidelines.³⁹ More research is

required to determine whether this problem is caused by infection control practices such as failure to clean the injection surfaces or by characteristics of the device design.

A large teaching facility reported a 4-fold increase in BSI after changing from a mechanical valve to a positive-displacement mechanical valve. Critical care nurses re-

TABLE 2

Positive Pressure Flushing Techniques

Technique	Use with	Additional Considerations
As the last 0.5 to 1 mL of fluid is flushed inward, withdraw the blunt cannula, allowing the last amount of flush solution to fill the dead space.	Blunt cannula systems	Gloves are required with this method because there will be a spray of blood-tinged fluid on the hand holding the hub.
Flush all fluid into the catheter lumen; maintain force on the syringe plunger as a clamp on the catheter or extension set is closed; then disconnect the syringe.	Luer-activated systems Negative displacement systems	

ported leaking and cracking with the new NIS and were able to demonstrate difficulty with cleaning the connection surface by using dye. A return to the original mechanical valve resulted in a decrease in the BSI rates.⁴⁰

Another facility identified a rise in BSI rates associated with the change of NIS and documented that 17% of blood drawn from the catheters show positive results for many organisms, mostly coagulase-negative staphylococci. A survey of nursing practice also showed that 31% of nurses failed to disinfect the NIS before accessing the catheter.⁴¹

A study in a pediatric population compared a split-septum device with a positive-displacement mechanical valve device. In the group with the split-septum device, there were 151 catheter lumens. The positive-displacement device group had 161 catheter lumens. Peripherally inserted central catheters (PICCs) and tunneled and nontunneled catheters ranging from 1.9- to 12-Fr were included. Complete occlusions, defined as inability to aspirate or infuse, occurred in 11.9% of the split-septum group and 3.7% of the positive-displacement group. Partial occlusions, defined as ability to infuse but not aspirate from the catheter, were observed in 3.3% of the split-septum group and 8.1% of the positive-displacement group. Catheter infection, defined as infections per 1,000 catheter days, was reported to be 8.8 in the split-septum group and 15.5 in the positive-displacement group. The authors reported statistical significance only for complete occlusions, with a *P* value of 0.012.⁴²

In vitro studies have found biofilm from gram-negative bacteria inside NIS. Whole blood can enhance biofilm formation and adhesion, although blood aspiration is necessary for assessment of catheter patency. This raises questions about the frequency of changing NIS, but no studies have confirmed the optimal interval. The CDC guidelines recommend changing needleless devices in the same interval as the IV administration set.³⁸ INS allows for changing at least every 7 days, which could be appropriate for catheters used to administer intermittent medications.¹

Concern for residual blood inside an NIS leads some facilities to change them with each blood sampling procedure. This concern may not be limited to blood sampling procedures because a brisk blood return is necessary before a catheter is used to administer medication. The color of many devices prevents the nurse from actually seeing what remains inside the NIS after flushing. No studies are available for an examination of this issue.

Flushing procedures result in excessive hub manipulation. When the SASH (saline, administer medication, saline, heparin) method is used, the hub is manipulated 8 times with a connection and disconnection for each fluid. Elimination of the heparin still requires 6 connections and disconnections.

Another study involving homecare patients reported on the consecutive use of 3 NIS types over 14 months and highlighted infection differences between homecare and hospitalized patients. The first device was a Luer-

activated negative-displacement NIS; the second was a 2-piece negative-displacement NIS requiring a sterile end cap; and the third was a split-septum and blunt-cannula system. In this study involving 1,014 patients and 98,483 catheter-days, 53 case patients with 65 episodes of BSI were identified. The authors reported a decrease in BSI when the NIS was changed every 2 days rather than once per week. The BSIs in this group of homecare patients also had a distribution of pathogens different from that of typical hospital patients. In the homecare patients, 49% of the BSIs were attributable to hydrophilic gram-negative bacteria, and only 17% involved gram-positive cocci such as *Staphylococcus aureus* and coagulase-negative staphylococci. The authors were able to eliminate contaminated infusate and the flushing fluid through culturing of those fluids, leaving exposure to tap water during bathing or swimming as the most likely source.⁴³

Research is needed to identify the factors associated with NIS and BSI, but healthcare professionals can immediately increase the emphasis on appropriate disinfection of the injection port with each connection. This simple step can be accomplished with either 70% alcohol or povidone-iodine and is strongly recommended in the CDC guidelines.³⁸

● CATHETER TECHNOLOGY

Three brands of catheters are manufactured with integral valves designed for the prevention of blood reflux into the catheter lumen. The 3-position valve located near the closed internal catheter tip (Groshong, Bard Access Systems, Salt Lake City, UT) was the original design. A new valve design allows for infusion out of the internal tip while aspiration of blood comes from side ports (LifeValve, RITA Medical, Fremont, CA). A third design places the 3-position valve inside the catheter hub (PASV, Boston Scientific Corp., Natick, MA).

The Groshong valve can be found on midline catheters, PICCs, nontunneled and tunneled central catheters, and implanted ports. Instructions state that these catheters should be flushed with a 5-mL minimum of sodium chloride. The LifeValve is available on implanted ports and should be flushed with a 10-mL minimum of sodium chloride. The PASV catheters include midlines, PICCs, and tunneled and implanted ports, and should be flushed with a 10-mL minimum of sodium chloride. Instructions for all 3 types of valves state that heparin is not required. However, it is not contraindicated for use in these catheters.

● CATHETER DESIGN FACTORS

Catheter length adds resistance to fluid flow. Healthcare professionals must remember never to flush against

resistance. Injection of fluid from a syringe should not feel “hard” to push. Resistance requires a careful assessment to determine the cause and correct it before the catheter is used.

The polymer used to make the catheter determines the size of the internal lumen and thus the volume of fluid held within the lumen. Silicone catheters have a thicker wall and smaller internal lumens, whereas polyurethane catheters have thinner walls and larger lumens. Each brand of catheter provides product literature with the exact priming volume for the untrimmed catheter. If the catheter has been cut to a patient-specific length, this volume will be decreased in proportion to the decreased length.

The outer diameter of the catheter is the measurement through the center of the lumen from one outer wall to the opposite outer wall. This measurement is important to the size of the vein lumen. The inner diameter, measured through the lumen center from one inner wall to the opposite inner wall, will dictate the flow rate through the lumen, the amount of pressure the catheter can tolerate, and the priming volume for the lumen.

Anti-infective technology may reduce the amount of biofilm and enhance lumen patency. Nontunneled central venous catheters are impregnated with 3 antimicrobial agent combinations including chlorhexidine-silver sulfadiazine, rifampin-minocycline, and silver-platinum. The rifampin-minocycline combination is now available in a PICC.

• TECHNOLOGY VERSUS TECHNIQUE

Numerous human factors affect the procedures associated with catheter flushing. Does the nursing staff know the specific type of NIS being used? Do they use the appropriate flushing technique for that type of NIS? Are they using syringes correctly? Are they cleaning the injection surface before connecting each tubing or syringe?

To ensure catheter lumen patency, neither technique nor technology can stand alone. The entire system must be assembled and all factors considered when products are chosen. Altering 1 piece may not prove successful in efforts to eliminate occlusion problems. Another consideration is that nothing in the catheter-NIS-syringe system will alter what is happening inside the vein around the catheter. Intraluminal occlusion and extraluminal occlusion from fibrin and vein thrombosis create similar clinical signs and symptoms with infusion and aspiration. Evidence-based practice requires well-designed studies to answer the many questions surrounding flushing technology.

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