White Paper

Reducing the Risk of Catheter-related Complications:

Evaluation of the LifeShield™ TKO™-5 Anti-Reflux Device in Two Hospitals

Julie Shomo, BS, BSN, CRNI

Julie is President of Infusion Solution LLC, a company providing education on vascular access, and consulting in infusion therapy. With 23 years of experience in infusion therapy, Julie continues to practice in vascular access, using those experiences with patients and nurses to fuel education program development for nurses in IV Therapy. Her speaking engagements and publications in *Journal of Infusion Nursing* and *Managing Infection Control* focus on patient safety and prevention of complications.

France Paquet, RN, MSc

France Paquet is a clinical practice consultant on vascular accesses for the McGill University Hospital (Quebec, Canada). France holds a Master in Nursing. She has published articles in peer-reviewed journals such as *Rehabilitation Nursing, Dynamics* and *Perspective Infirmière* on PICC insertion and on respiratory nursing and is an editorial reviewer for the journal of infusion nursing. France is a trainer for nurses in the art of PICC line insertions.

Introduction

In healthcare institutions, intravenous (IV) catheters are everywhere. Administration of medications, chemotherapy, and stem cell infusions depend on them. They are necessary for drawing blood samples. Monitoring of patients and providing nutrition often rely on them.[1] One estimate is that up to 90% of all hospitalized patients receive some form of IV therapy during their stay.[2] Central venous catheters (CVCs) account for more than 7 million insertions annually in the U.S.,[3] with 2.1 million of these placed in critical care patients.[4]

As important as these devices are, risks remain. Infections, either systemic or local, may develop. Thrombolytic or nonthrombolytic occlusions may partially or totally block flow. Mechanical complications, such as pneumothorax, hematoma, or accidental arterial puncture may occur.[5] But complications can be reduced or prevented with careful insertion and monitoring procedures, and with advanced technology. According to one source, "Bloodstream infections from catheters are nearly 100 percent preventable with clear, actionable steps."[6]

Two hospitals, one in Texas and one in Canada, compared occlusion and potential infection rates using the needleless Baxter InterLink® injection site and the LifeShield™ TKO™-5 anti-reflux device. The trial and results are described here.

Central Venous Catheters

There are several CVC types, all of which usually terminate in the superior vena cava. Percutaneous CVCs, which have up to five lumens and can be placed at the bedside, are for short-term use and are inserted into the subclavian, internal jugular, femoral, or, more recently, axillary veins. Peripherally inserted central catheters (PICCs), which have one to three lumens, are inserted into a peripheral vein and used for medium- to long-term treatment. Subcutaneous CVCs are surgically placed below the skin and used for medium- to long-term treatment; they include tunneled catheters and implanted ports. Implanted ports, which are placed entirely beneath the skin and are for long-term use, e.g., administration of chemotherapy.[7-9]

Complications

OCCLUSIONS

Occlusions may be partial or total, and non-thrombotic, mechanical, or thrombotic. A partial occlusion is defined as one in which flow is reduced or there is fibrin

over the end of the catheter.[10] With a total occlusion, there is no blood return, and flushing and medication administration are not possible.[10]

Non-thrombotic occlusions are caused by collection of drug or other infusion precipitates that block flow. Mechanical occlusions may be caused by kinked or twisted external tubing, poor internal positioning of the catheter, catheter migration, or patient movement[10,11] (Table 1).

Thrombotic occlusions are caused by blood collection at the tip of the catheter that blocks flow within the catheter and forms a clot. One cause is blood reflux, which frequently occurs as part of IV therapy,[12] and has been shown to result in partial or complete occlusions in 3% to 79% of CVC insertions.[13-15,16]

Sources of catheter tip reflux include syringe plunger reflux, movement of blood during attachment or removal of a syringe from an unclamped catheter, and physiological reflux. Syringe plunger reflux can occur with some plungers that compress when the syringe is emptied completely. When forward pressure by the finger on the syringe barrel is released, the compressed barrel tip pulls back and the vacuum within the system pulls a small amount of blood back into the catheter tip. Leaving 0.5 mL in the flush syringe before removal can help prevent syringe plunger reflux.

During attachment and removal of a syringe from an unclamped catheter, blood moves back and forth in the catheter tip and will adhere to the inner lumen of the catheter if not flushed out. One way to minimize this reflux is by clamping the catheter prior to syringe removal.

Physiological reflux is also important to understand. During infusion into a catheter, an open pathway from the tubing into the vein is in place. When the pressure of the fluid infusing is greater than the vascular resistance, fluid flows forward. However, intravascular pressure is increased by physiological processes such as patient movement, coughing, vomiting, or mechanical ventilation and can often overcome the forward pressure of the fluid even when an infusion pump is in use. This increased vascular pressure forces blood into the tip of the catheter. When the episode that caused the pressure, such as coughing, stops, the infusion begins to flow forward into the patient again. However, if the flow rate is low, the flushing action of the infusion is not adequate to clear the blood from the catheter lumen, causing adherence to the catheter wall. This starts the occlusion process and potential for biofilm formation. Because it is not possible to visually view the central catheter tip, this reflux is often not addressed.

Other influences on formation of thrombotic occlusions include catheter material, tip location, duration of use, [17] and improper flushing[10,11,18] (Table 1). Thrombotic occlusions may increase the risk of central line-associated bloodstream infections (CLABSIs*).[17] This may be due to catheter colonization on the external catheter surface, contamination on the catheter hub that is accessed without proper disinfection, or infection elsewhere in the body that seeds the catheter hematogenously.[19] Also, most indwelling vascular catheters are engulfed by a fibrin sheath that forms soon after insertion.[20] This sheath has a sticky surface, which allows pathogens to adhere to it and may become a nidus of infection.[20]

Table 1: Factors that influence formation of occlusions[10,11,12,18]

Thrombotic	Non-Thrombotic	Mechanical
Blood reflux	Collection of drug or other precipitates	Kinked/twisted tubing
Tip location		Poor catheter positioning
Catheter material		Catheter migration
Duration of use		Patient movement
Improper flushing		

To dissolve a partial or complete occlusion, a thrombolytic agent such as alteplase may be administered. However, a thrombolytic is not effective for occlusions caused by medication precipitates. These may be dissolved with another agent, such as hydrochloric acid, sodium bicarbonate, or ethanol, depending on cause.[16,21,22] It is essential that compatibility between the solution and catheter material be determined before any solution is used.[23,24] If a clot cannot be dissolved, the catheter should be removed, if possible, or replaced.[25,26]

INFECTIONS

A recent publication by the Centers for Disease Control reports 92,011 CLABSIs annually in the U.S.[27] CRBSIs* for PICCs alone account for 0.4 to 14.7 cases per 1,000 catheter days.[10,13,28] Of the 2.1 million critically ill patients who require CVCs, about 34,000 experience CRBSIs annually.[4] Mortality associated with CVC-related bacteremia in critically ill patients has been reported to be 12% to 25%.[8]

*CLABSIs and CRBSIs

It should be noted that these terms, though often used interchangeably, actually represent slightly different criteria. According to the Association for Professionals in Infection Control and Epidemiology (APIC), the term CLABSI is used for surveillance purposes to identify bloodstream infections in patients with central lines. A more rigorous definition applies to CRBSI, which includes precise laboratory findings and other specific criteria. The term CRBSI is more likely to be used in clinical research.[29]

CRBSIs may be intraluminal, caused by microbes that invade IV fluids or the route of fluid flow, or extraluminal, caused by contamination outside the catheter, e.g., on the catheter hub or tubing.[3,5] There are numerous factors commonly associated with an increased risk for infection[17,26] (Table 2). These factors include, but are not limited to, those noted in Table 2. The type of CVC plays a role, with percutaneous catheters associated with the greatest risk. Multilumen catheters may increase risk as does length of hospital stay. The site of catheter insertion is a factor, with the femoral route presenting the greatest potential for infection. A rate of 4.5 infections per 1,000 catheter days with femoral insertion, compared with 1.2 per 1,000 catheter days with subclavian insertion, has been reported.[30] Risk of infection increases the longer the catheter is in place and when catheter patency is poor. Finally, patient characteristics can be factors. These include immunodeficiency, low CD4 cell counts, high APACHE scores, active infections at other sites, and the presence of other IV devices.[18,28]

Table 2: Factors that influence risk of infection[11,26]

Factors		
Type of CVC	Length of time catheter is in place	Patient characteristics
Number of lumens	Line care	
Catheter insertion site	Maintenance of catheter patency	

The Economic Costs

In addition to increased morbidity and mortality among patients, IV catheter-related complications require additional resources—sometimes substantial—from the institution. Estimates of the economic impact vary, but sources suggest that each bloodstream infection costs a hospital $29,000[31] to $35,000,[32] with more than 500,000 episodes per year reported.[32] This translates to annual healthcare costs in the U.S. of $2.3 billion due to prolonged hospitalization and additional therapies.[33]

In 2005, the Centers for Medicare and Medicaid Services (CMS) Deficit Reduction Act (DRA) declared that treatment for conditions acquired during hospitalization would no longer be reimbursed by Medicare or Medicaid. As of October 1, 2008, CRBSIs were specifically included in this group. Since then, healthcare institutions have put into place practices that would hopefully avoid catheter-related complications.

Reducing Catheter-Related Complications

Catheter-related complications can be complex and challenging. Numerous groups provide guidelines, many of which overlap, to reduce IV catheter-related infections. Vigilance in assessment and maintenance of catheter patency is increasingly emphasized. In addition, new technology has been designed to help address this problem.

GUIDELINES

Centers for Disease Control (CDC), in conjunction with the Healthcare Infection Control Practices Advisory Committee (HICPAC), have developed specific evidence-based recommendations to reduce CRBSIs.[34,35] Overall, prevention is focused on three areas—prior to, during, and after catheter insertion—as described by the Society of Healthcare Epidemiology of America (SHEA) and the Infectious Diseases Society of America (IDSA).[36]

These ideas are captured in the Institute for Healthcare Improvement's (IHI) central-line bundle of best practices, which has been shown to reduce CRBSI rates.[37] It is most effective when all components are applied together[38]:

- Hand hygiene
- Maximal barrier precautions on insertion
- Chlorhexidine skin antisepsis
- Optimal catheter site selection (subclavian vein is preferred for nontunneled catheters)
- Daily review of line, plus prompt removal of unnecessary lines

MAINTAINING CATHETER PATENCY

Maintaining catheter patency requires careful assessment of patency before use, appropriate flushing technique, and prompt treatment of partial or complete occlusions.

Catheter patency must be assessed prior to administration of medication or solution; this is done by checking for blood return.[26] Appropriate flushing technique helps retain patency and reduces the potential for development of biofilm once a catheter has been inserted. When blood is flushed completely from the catheter, it does not adhere to the inner wall and promote biofilm formation when bacteria are present. Each institution should have a flushing protocol that describes frequency, solution (heparin or saline) concentrations and volume, and procedures to follow. In general, the concentration and volume of flushing fluid depends on the size and type of catheter in

place. Current guidelines from the Infusion Nurses Society (INS) suggest that volume of flush solution should be twice that of the catheter capacity, plus any add-on devices.[26] Clinicians should be aware of potential interactions between medication and flushing solution, and variables among devices that may require different procedures. Flushing is necessary after infusion of blood products or albumin, which are highly viscous and more likely to be associated with thrombosis, and is recommended before and after administration of any medication, and between medications if multiple infusions are necessary.[23,39,40]

As described in the Occlusions section, declotting should be performed as required according to institution protocols. Daily assessment of the continuing need for the catheter should be conducted as long as the catheter is in place.

TECHNOLOGY

New technology to address the problem of catheter occlusions has resulted in the development of needleless valved catheters, pressure-activated safety valves, neutral and positive displacement devices, and three-way valves.[10] Some manufacturers have created syringe barrels that do not compress, which helps avoid syringe plunger reflux. Also, neutral or positive displacement connectors may help prevent the reflux that can occur with syringe connection/disconnection. However, the physiological reflux that can occur while fluid is being infused is not addressed by most needleless connectors. Because occlusions continue to be a problem, anti-reflux devices have been developed to prevent reflux.[41] The anti-reflux device can be incorporated into the catheter itself or is available in needleless connector form that can be added to any catheter.

The Bard Groshong™ device has a three-way valve at the distal tip of the catheter that is placed inside the body. A slit in the tip remains closed when it is not being used for infusion or flushing. The Bard PowerPICC Solo™ has a valve with three slits in the catheter hub that is placed outside the body. An infusion goes through the middle slit; on aspiration, fluid comes through the top and bottom slits. The Boston Scientific Pressure Activated SafetyValve PASV® is placed in the hub of the catheter outside of the body. The valve is pressure-activated and stays closed when not in use. The Hospira LifeShield™ TKO™-5 is a pressure-activated anti-reflux add-on device. The TKO™ is the only valve available in a needleless connector that helps protect against reflux, even when fluids are being infused. Use of the LifeShield™ TKO™-5 is described in this paper.

What is a "valve"?

The term "valve," used frequently in IV therapy, is not well defined and may be a source of confusion because the term is used to describe devices that have significantly different characteristics. For example, the needleless connector that protects the open end of catheters is often referred to as a valve (but may also be called a cap, or a positive-pressure cap...or even by other terms). "Valve" is often used to describe the mechanical portions of some positive displacement needleless connectors that have springs or other moving parts. These have been associated with higher rates of bloodstream infection, as noted by the FDA, and are currently undergoing postmarket studies.[42] The pressure-activated valve in TKO-5 has no moving parts or dead space where blood can escape clearance by flushing.

Hospira LifeShield™ TKO™-5

The TKO-5 anti-reflux pressure-activated device contains a three-position bi-directional, dome-shaped silicone valve within the needleless connector rather than in the catheter itself. The valve opens and closes according to vascular pressure. It is designed to operate like an automatic IV clamp and remains closed when IV fluids are not flowing. This prevents fluid flow from the bloodstream into the tip of the catheter. During infusions, the valve opens outward, towards the patient's vascular system, and allows IV fluids to flow through at normal gravity infusion pressures (low cracking pressure of 8 – 10 inches of water or head-height) at a rate of 70 mL per minute, or 4,200 mL per hour at 30 inches of gravity pressure. When it is necessary for the clinician to draw a blood sample, a syringe or vacutainer easily opens the valve inward at higher pressures (6.5 PSI is required), away from the patient. The straight fluid path can be easily flushed with normal saline, and the device is clear so the clinician can see when blood has been properly flushed. The TKO-5 is non-pyrogenic, non-latex, non-polyvinylchloride (PVC), and is metal-free. It does not conflict with magnetic resource imaging (MRI), is compatible with most blunt cannulas, and attaches directly to any standard luer connector.

A previous, year-long project compared the use of the Baxter InterLink® injection site with that of the LifeShield TKO-5. It showed that 7.6% (58) of 764 catheters using Baxter InterLink that were placed over 30 weeks required thrombolytic intervention. In the subsequent 26 weeks, 784 catheters using the LifeShield TKO-5 were placed, which resulted in 0.8% (6) thrombolytic interventions. This led to costs of $18,798.12 for managing thrombolytic interventions with InterLink, vs. $3,446.40 for interventions with TKO-5.[43]

Trials of TKO-5 in Two Hospitals

Trials comparing complication rates between TKO-5 and Baxter InterLink needleless connectors were conducted in two hospitals. Both TKO-5 and InterLink are needleless connectors with a split-septum design. The greatest difference between the two is the anti-reflux valve inside the TKO-5.

The first trial was conducted at Integrity Transitional Hospital (ITH), a 64-bed acute-care hospital located in Denton, Texas, that is part of a group of hospitals serving the North Texas area. It specializes in management of patients who require extended acute care, such as those with multi-system health complications, those requiring extensive wound care, or those needing a wide variety of respiratory services. Average length of stay is 25 days. Most ITH patients have a CVC of some sort, with the greatest percentage having PICCs.

The second trial was conducted at the Montreal Chest Institute (MCI), founded in 1909, which is one of five hospitals affiliated with McGill University Health Center in Montreal, Quebec, Canada. The facility includes a 25-bed medical ward, a 7-bed ICU, a 10-bed day hospital, and a 40 long-term bed facility, providing intensive, acute, long-term, and ambulatory care on diseases of the chest. Average length of stay is 12.4 days.

Methodology

This trial was designed to evaluate the TKO-5 device by comparing its complication rates with those of InterLink. In both facilities, CVC complications were measured over 21 days using the InterLink device. The catheters and devices evaluated were either already in place at the beginning of the trial period, or were newly inserted during the trial period. After 21 days, patients on the InterLink device who continued to need a catheter were switched to the TKO-5 device. Any new catheters inserted were to use the TKO-5 devices. Complications in these patients were measured for additional time periods.

At ITH, evaluations were made comparing complications during the 21-day InterLink period with the 21-day TKO-5 period. At MCI, data continued to be collected after the initial 21-day TKO-5 period. These reflected both existing and new TKO-5 insertions over a third 21-day period, then over a 56-day period. All of these data sets were available for comparison. Both institutions used the same flushing protocol for both devices: 0.9% NaCl 10 mL flush before medication administration and 0.9% NaCl 10 mL flush followed by 3 mL heparin (10 units/mL) flush following medication administration. When not in use, each catheter lumen was flushed with 0.9% NaCl 10 mL followed by 3 mL heparin (10 units/mL) flush every 8 hours.

MEASUREMENTS

Complications data were defined as:

- **Partial occlusion—** flushing is possible, but some resistance or sluggishness is noticeable
- **Complete occlusion—** neither flushing nor blood withdrawal is possible
- **Suspected infection—** physician orders line removal or administration of antibiotic specific to suspected pathogen in line infection; due to the short duration of the trial, and a low potential for enough patient days to show a significant difference in infection rates, a delineation of actual infection as defined by blood culture results and other criteria, was not included in the study protocol
- **Withdrawal occlusion—** flushing is possible, but blood withdrawal is not
- **Declotting agent required—** a thrombolytic (alteplase) is administered to dissolve an occlusion

Table 3: Montreal Chest Institute Catheter Data

	Total no. of catheters	No. of open-ended PICCs	No. of closed-ended PICCs (Bard Groshong)	No. of open-ended ports	Total catheter days	Average catheter dwell time (days)
InterLink 1st 21 days	13	2	10	1	102	7.8
TKO-5 2nd 21 days	9	3	5	1	165	18.3
TKO-5 3rd 21 days	12	4	6	2	123	10.3
TKO-5 subsequent 56 days	20	10	8	2	331	16.6

In the first 21-day period with InterLink at MCI, 13 catheters (both existing and new insertions) were evaluated for a total of 102 catheter days. Average dwell time was 7.8 days. In the second 21-day segment, which reflected switches to TKO-5 from InterLink as well as new TKO-5 insertions during the 21 days, 9 catheters were evaluated for a total of 165 total catheter days and an average dwell time of 18.3 days, more than twice that with InterLink. Ongoing evaluations continued for a third 21-day period and a subsequent 56-day period. Dwell time was 10.3 days in the third 21-day period, with 12 catheters in place and 123 total catheter days, and 16.6 days during the subsequent 56-day period, with 20 catheters in place for a total of 331 catheter days (Table 3). The additional data for the third 21 days and the subsequent 56 days are presented in this paper as continuing evidence of TKO-5 efficacy in reducing central catheter complications.

Table 4: Montreal Chest Institute complications, number per evaluation period

	Partial occlusions	Complete occlusions	Suspected infections	Withdrawal occlusions	Declots using tPA
Inter-Link 1st 21 days	2	3	0	0	5
TKO-5 2nd 21 days	0	0	0	0	0
TKO-5 3rd 21 days	0	0	0	0	0
TKO-5 subse-quent 56 days	0	0	0	0	0

*Table 5: Montreal Chest Institute complications (complications/1000 catheter days)**

	Partial occlusions	Complete occlusions	Suspected infections	Withdrawal occlusions	Declots using tPA
Inter-Link 1st 21 days	19.6	29.4	0	0	49.0
TKO-5 2nd 21 days	0	0	0	0	0
TKO-5 3rd 21 days	0	0	0	0	0
TKO-5 subse-quent 56 days	0	0	0	0	0

*Number of complications divided by total number of catheter days multiplied by 1000

More partial occlusions and complete occlusions were noted with InterLink than with TKO-5 in any of the subsequent TKO-5 periods (Table 4). No suspected infections or withdrawal occlusions were seen with either device, although it was necessary to use alteplase to dissolve clots five times when the InterLink device was in use. These MCI data were translated to a commonly understood representation (number of complications per 1000 catheter days, Table 5). Partial occlusions with InterLink were 19.6/1000 catheter days, and declots were 49.0/1000 catheter days. No trial-defined complications were shown with TKO-5 in any time period. **Partial occlusions with InterLink were 19.6/1000 catheter days, complete occlusions were 29.4/1000 catheter days and declots were 49.0/1000 catheter days.**

Table 6: Integrity Transitional Hospital Catheter Data

	Total no. of catheters	No. of open-ended PICCs	No. of percutaneous CVCs	No. of open-ended ports	Total catheter days	Average catheter dwell time (days)
InterLink 1st 21 days	46	39	5	2	444	9.7
TKO-5 2nd 21 days	30	21	6	3	332	11.1

At ITH, 46 InterLink catheters (existing and new insertions) were evaluated during the first 21 days, compared with 30 TKO-5 devices (existing and new insertions) over the second 21 days. There were more catheter days (444 vs 332) but a shorter average catheter dwell time with InterLink (9.7 vs 11.1 days) compared with TKO-5 (Table 6).

Table 7: Integrity Transitional Hospital complications, number per evaluation period

	Partial occlusions	Complete occlusions	Suspected infections	Withdrawal occlusions	Declots using tPA
Inter-Link 1st 21 days	20	5	0	14	3
TKO-5 2nd 21 days	3	1	0	6	0

*Table 8: Integrity Transitional Hospital complications (complications per 1000 catheter days)**

	Partial occlusions	Complete occlusions	Suspected infections	Withdrawal occlusions	Declots using tPA
Inter-Link 1st 21 days	45.0	11.3	0	31.5	6.8
TKO-5 2nd 21 days	9.0	3.0	0	18.1	0

*Number of complications divided by total number of catheter days multiplied by 1000

In all categories except suspected infections, more complications occurred with InterLink than with TKO-5, though partial occlusions (20 vs 3), complete occlusions (5 vs 1), and withdrawal occlusions (14 vs 6) were seen with both devices. No declots were necessary with TKO-5, vs 3 declots with InterLink (Table 7). Complication rates with InterLink at ITH were greater than with TKO-5 (Table 8).

Both institutions showed more complications with InterLink than with TKO-5, though the complication rate for both devices was higher at ITH. This result may have been due to differences in hospital protocols. At MCI, all partial and total occlusions were immediately treated with a thrombolytic agent, while at ITH, thrombolysis was not undertaken until a complete occlusion formed in the catheter. Thus, each complete occlusion documented in the ITH trial was preceded by both a partial and withdrawal occlusion, all of which are documented in the data.

Conclusion

Catheter-related occlusions and infections put patients at risk and increase institutional costs. They can delay delivery of necessary IV therapy, require expensive drugs for declotting and other therapies, and are associated with extended hospital lengths-of-stay.[44,45] Blood reflux frequently occurs as part of IV therapy[12] and is a major cause of occlusion.[45] In fact, as much as 25% of all CVC usage ends in occlusion,[45] which may lead to biofilm formation and subsequent catheter-related bloodstream infections.[20,46]

Institutions now have incentives to reduce reflux and potential infections. Because transparency in reporting of infections is increasing, savvy consumers become aware of incidents of infection at an institution, and will more likely choose a hospital based on their perceived risk for contracting an infection during their stay. The lack of reimbursement for certain hospital-acquired infections, as ruled by CMS, now encourages facilities to prevent complications to avoid the added costs of prolonged hospital stays and therapies of CVC-related complications.

This trial showed that fewer complications occurred at both ITH and MCI with TKO-5 than with InterLink, even with different management protocols. Though economics were not part of this evaluation, it could be speculated that costs were greater with InterLink, simply because more declots were required in both institutions. None were needed with TKO-5.

Based on this trial, TKO-5 is currently the standard CVC device used in both institutions. Informal evaluations among nurses suggest that most found TKO-5 to result in fewer complications and was easy to use. A well-designed clinical trial is needed to clarify the advantages of TKO-5 in preventing occlusions and infections among patients with central venous catheters.

References:

1. Boersma RS, Jie K-SG, Verbon A, van Pampus ECM, Schouten HC. Thrombotic and infectious complications of central venous catheters in patients with hematological malignancies: review. *Annals of Oncology*. 2008;19:433-442.
2. Hanchett M. Visualizing the IV fluid path as an emerging concept in infection control. *Infection Control Today*. http://www.infectioncontroltoday.com/articles/410/410_421feat2.html. Published February 2004. Accessed July 19, 2011.
3. Richardson D. Vascular access nursing: standards of care and strategies in the prevention of infection: a primer on central venous catheters, part 2 of a 3-part series. *J Assoc Vasc Access*. 2007;12:19-27.
4. Patel BM, Dauenbauer CJ, Rady MY, et al. Impact of peripherally inserted central catheters on catheter-related bloodstream infections in the intensive care unit. *J Patient Saf*. 2007;3(3):142-148.
5. McGee DC, Gould MK. Prevent complications of central venous catheterization. *N Engl J Med* 2003;348:1123-33.
6. APIC. Preventable bloodstream infections still a problem in hospitals, infection prevention group finds. Press release, July 12, 2010, New Orleans. Available at: http://www.apic.org/AM/Template.cfm?Section=Featured_News_and_Events&CONTENTID=15870&TEMPLATE=/CM/ContentDisplay.cfm Accessed March 8, 2011.
7. Hamilton H. Complications associated with venous access devices: part one. *Nurs Stand*. 2006;20(26):43-50.
8. Raad I, Hanna H, Maki D. Intravascular catheter-related infections: advances in diagnosis, prevention, and management. *Lancet Infect Dis*. 2007;7(10):645-657.
9. Masoorli S, Angeles T. Getting a line on central venous access devices. *Nursing*. 2002;32(4):36-43.
10. Moureau N. Keeping lines open: maintaining CVC patency. ProCE: 2009. Available at: www.proce.com/monographs/v10avabooklet-interenet.pdf Accessed March 8, 2011.
11. Stachnik J. Prevention of central line–associated bloodstream infections: catheter care and maintenance. ProCE. Available at: www.proce.com/hai_css/pdf/Module%203_Catheter%20care.pdf Accessed March 8, 2011.
12. Hadaway L. Reopen the pipeline for I.V. therapy. *Nursing*. 2005;35(8):54-61.
13. Moureau N, Poole S, Murdock MA, Gray SM, Semba CP. Central venous catheters in home infusion care: outcomes analysis in 50,470 patients. *J Vasc Interv Radiol*. 2002 Oct;13(10):1009-16.
14. Walshe LJ, Malak SF, Eagan J, Sepkowitz KA. Complication rates among cancer patients with peripherally inserted central catheters. *J Clin Oncol*. 2002 Aug 1;20(15):3276-81.
15. Wingerter L. Vascular access device thrombosis. *Clin J Oncol Nurs*. 2003 May-Jun;7(3):345-8.
16. McKnight S. Nurse's guide to understanding and treating thrombotic occlusion of central venous access devices. *Medsurg Nurs*. 2004;13(6):377-382.
17. Krzywda E, Andris D. Twenty-five years of advances in vascular access: bridging research to clinical practice. *Nutr Clin Pract*. 2005;20(6):597-606.
18. Segreti J, Garcia-Houchins S, Moureau N, Morgan R, Gorski L, Shomo J, Zack J, et al. *Healthcare-Associated Infections: A Focus on Catheter-Related Bloodstream Infections. 2009 HAI Consensus Development Conference White Paper*. ProCE. 2009. Available at: www.proce.com/documents/HAI%20Conference%20-%20White%20Paper.pdf Accessed March 8, 2011.
19. Mermel LA, Farr BM, Sheretz RJ, et al. Guidelines for the management of intravascular catheter-related infections. *Infection Control & Hospital Epidemiology*. 2001;22(4):222-242.
20. Raad II, Luna M, Khalil SAM, Costerton JW, Lam C, Bodey GP. The relationship between the thrombotic and infectious complications of central venous catheters. *JAMA*. 1994;271:1014-1016.
21. Gorski L, Perucca R, Hunter M. Central venous access devices: care, maintenance, and potential complications. In: *Infusion Nursing. An Evidence-based Approach*. Alexander M, Corrigan A, Gorski L, Hankins J, Perucca R, eds. 3d ed. St. Louis, MO: Saunders Elsevier; 2010:495-515.
22. Gorski L, Czaplewski L. Peripherally inserted central catheters. *Home Healthcare Nurse*. 2004;22(11):573-773.
23. Hadaway L. Technology of flushing vascular access devices. *J Infus Nurs*. 2006;29(3):129-145.
24. Crnich C, Halfmann J, Crone W, Maki D. The effects of prolonged ethanol exposure on the mechanical properties used for intravascular access. *Infect Control Hosp Epidemiol*. 2005;26(8):708-714.
25. Schallom L, Shomo JE. Keeping the lines open with evidence-based practices and advanced technologies. ProCE: 2008, Available at: www.proce.com/monographs/Keeping%20the%20Lines%20Open%20with%20Evidence-Based%20Practice%20and%20Advanced%20Technologies.pdf Accessed March 8, 2011.
26. Infusion Nurses Society. Infusion nursing standards of practice. *J Infus Nurs*. 2011;34(1 suppl 1):S1-S110.
27. Scott RD, CDC. *The Direct Costs of Medical Care*. 2009. Available at : www.cdc.gov/ncidod/pdf/Scott_CostPaper.pdf. Accessed March 28, 2011.
28. Saidar N, Maki DG. Risk of catheter-related bloodstream infections with peripherally inserted central venous catheters used in hospitalized patients. *Chest*. 2005;128:489-495.
29. APIC. *Guide to the Elimination of Catheter-Related Bloodstream Infections*. Association for Professionals in Infection Control and Epidemiology; 2009. Available at: www.apic.org. Accessed January 15, 2011.
30. Merrer J, DeJonghe B, Golliot F, et al. Complications of femoral and subclavian venous catheterization in critically ill patients. *JAMA*. 2001;286:700-707.
31. Maki DG, Stolz SM, Wheeler S, et al. Prevention of central venous catheter-related bloodstream infection by use of an antiseptic-impregnated catheter: a randomized controlled trial. *Ann Intern Med*. 1997;127:257-266.
32. Menyhay SZ, Maki DG. Disinfection of needleless catheter connectors and access ports with alcohol may not prevent microbial entry: the promise of a novel antiseptic-barrier cap. *Infect Control Hosp Epidemiol*. 2006;27(1):23-27.
33. O'Grady N, Alexander M, Dellinger E, et al. Guidelines for the prevention of intravascular catheter-related infections. *MMWR Recomm Rep*. 2002;41(RR-10):1-32.
34. Centers for Disease Control and Prevention. Guidelines for the prevention of intravascular catheter-related infections. *MMWR Recomm Rep*. 2002;51(RR-10):1-32.
35. Siegel JD, Rhinehart E, Jackson M, Chiarello L, and the Healthare Infection Control Practices Advisory Committee. 2007 guideline for isolation precaution: preventing transmission of infectious agents in healthcare settings. http://www.cdc.gov/ncidod/dhqp/pdf/isolation2007.pdf. Accessed February 25, 2011.
36. Marschall J, Mermel L, Classes D. Strategies to prevent central line-associated bloodstream infections in acute care hospitals. *Infect Control Hosp Epidemiol*. 2008;29(suppl 1):S22-30.
37. Venkatram S, Rachmale S, Kanna B. Study of device use adjusted rates in health care-associated infections after implementation of "bundles" in a closed-model medical intensive care unit. *J Crit Care*. 2010 Mar;25(1):174.e11-8. Epub 2009 Aug 13.
38. Institute for Healthcare Improvement. Implement the central line bundle. Available at: www.ihi.org/IHI/Topics/CriticalCare/IntensiveCare/Changes/ImplementtheCentralLineBundle.htm Accessed February 25, 2011.
39. Miller P. Central venous access devices. *Radiol Technol*. 2006;77(4):297-305.
40. Asch M. Venous access: options, approaches and issues. *Can Assoc Radiol J*. 2001;52(3):153-164.
41. Hadaway L, Richardson D. Needleless connectors: a primer on terminology. *J Infus Nurs* 2010;33(1):1-10.
42. Food and Drug Administration (FDA). Letter to infection control practitioners regarding positive displacement needleless connectors. July 28, 2010. Available at: www.fda.gov/MedicalDevices/Safety/AlertsandNotices/ucm220459.htm#b. Accessed April 12, 2011.
43. Mitch S. Revolutionary change in IV therapy utilizing the LifeShield® TKO™-5 anti-reflux device: white paper. 2008. Available at: www.hospira.com/Files/LifeShield%20TKO-5%20Change%20in%20IV%20Therapy%20White%20Paper.pdf Accessed March 8, 2011.
44. Blot SI, Depuydt P, Annemans L, Benoit D, Hoste E, De Waele JD, et al. Clinical and economic outcomes in critically ill patients with nosocomial catheter-related bloodstream infections. *Clinical Infectious Diseases*. 2005;41:1591-1598.
45. Deitcher S, Fesen MR, Kiproff PM, et al. Safety and efficacy of alteplase for restoring function in occluded central venous catheters: results of the cardiovascular thrombolytic to open occluded lines trial. *J Clin Oncol*. 2002;20(1):317-324.
46. Timsit JF, Misset B, Carlet J, Boyer JM, Farcas JC, Martin JB, Renaud B. Central vein catheter-related thrombosis in intensive care patients: incidence, risk factors, and relationship with catheter-related sepsis. *Chest*. 1998;114:207-213.

For more information on Advancing Wellness™, contact your Hospira representative at **1-877-9HOSPIRA** or visit **www.hospira.com**

Hospira, Inc. 275 North Field Drive, Lake Forest, IL 60045 PI1-3335-Jun., 11

Hospira