

Venous Access Devices: Clinical Rounds

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ABSTRACT

Nursing management of venous access devices (VADs) requires knowledge of current evidence, as well as knowledge of when evidence is limited. Do you know which practices we do based on evidence and those that we do based on institutional history or preference? This article will present complex VAD infection and occlusion complications and some of the controversies associated with them. Important strategies for identifying these

complications, troubleshooting, and evaluating the evidence related to lack of blood return, malposition, infection, access and maintenance protocols, and scope of practice issues are presented.

Key words: Complications, oncology, venous access devices

Introduction

Only three decades ago, nurses administered drugs through short-term venous access devices (VADs). Today, numerous devices are available to access the venous system as well as

other body systems such as peritoneal, arterial, intrathecal, epidural, and pleural. The wide variety of access devices has enabled health-care professionals to develop complex

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treatment plans with the goal of increasing patient survival and to increase quality of life.

Regardless of the specific design or type of access device, routine maintenance care and the management of potential complications vary from institution to institution. Very few randomized, controlled trials have been conducted to definitively support nursing practice in maintenance care provided to VADs. Often, practice is dictated by the manufacturer recommendations, government regulations, or institution based. This article explores the strategies for identifying complex complications, troubleshooting techniques, and evaluating the evidence available to managing complex complications in long-term vascular access devices.

Long-term Venous Access Devices

Long-term VADs include peripherally inserted catheters (peripherally inserted central catheters), implantable ports, and tunnel catheters. These VADs are biocompatible, flexible and made of silicone material. Catheter distal tips are opened or closed with placement above or in the lower third of the superior vena cava at the cavoatrial junction.^[1-3] Closed distal tips are rounded with an internal three-way pressure sensitive valve opening inwardly with aspiration and outwardly with flushing or infusion. All long-term VADs are available in single or double lumens. Tunnel catheters are available in triple-lumen design.^[4,5]

Long-term VADs are indicated for all types of intravenous (IV) therapies and to obtain blood specimens. These devices can be used in all care settings for months to years if functioning adequately. Maintenance care varies among institutions with the lack of standardization and evidence-based practice.

Catheter Malposition

Catheter malposition may be primary, occurring at the time of insertion, or secondary, when a catheter tip spontaneously migrates to another venous location after placement.^[6] Malposition during insertion is typically recognized and corrected at the time of insertion.

Secondary migration has occurred at intervals ranging from days to months with the most common migrating site into the ipsilateral jugular vein. Other migrating areas can include brachiocephalic, subclavian, azygous, and axillary veins.^[1] Secondary migration can occur from vigorous use of the upper extremity, forceful flushing, or changes in intrathoracic pressure associated with coughing or emesis.

Catheter separation can occur with implantable ports where the catheter separates from the portal body. Separation can occur when the locking device is inadequately secured during placement or from forceful flushing.^[6] The catheter fragment can remain within the vein, embolize to the heart or lung, or retract into the tissue surrounding the portal body.

Pinch-off syndrome is defined as the mechanical compression of a catheter as it passes between the clavicle and first rib at the costoclavicular space.^[7] During placement, the catheter travels through the costoclavicular space next to the subclavian vein instead of inside the vein. Subsequently, the catheter is vulnerable to compression with shoulder movements.^[8] With continuous compression, gradual trauma to the catheter occurs resulting in a complete or partial breakage of the catheter. With complete breakage, the catheter migrates usually to the right ventricle or pulmonary artery.

Portal bodies can flip within the port pocket either partially or completely inverted. When portal bodies are not adequately sutured in the fascia during insertion, this will increase the risk of rotation. Shoulder movement, loss of excessive weight, large amount of breast tissue, or manipulation of the port (“Twiddler’s syndrome”) can also cause the port to rotate.^[9]

Signs and symptoms of malposition include sluggish or no blood return, edema at the exit site, inability to infuse or withdraw blood. Patients may complain of a tingling sensation, gurgling sounds, arm or shoulder pain, vague back discomfort, palpitations, or chest pain.^[4] Malposition can be diagnosed with imaging studies such as chest X-ray, cathetergram, or ultrasound.^[2] Correction of malposition or migration after placement depends on the cause. Catheters may be repositioned under fluoroscopic or ultrasound guidance. If unable to be repositioned, the device must be removed. If breakage or damage occurs, the device must be removed and fragments retrieved, using percutaneous technique.^[2,6]

Venous Access Device Infection

Infection is a common complication of VADs classified as systemic or local. Systemic infections can be life-threatening; therefore, nurses must be able to assess for signs and symptoms for interventions to be implemented in a timely manner. Symptoms of a systemic infection include fever, chills, diaphoresis, hypotension, or mental status changes.^[4] Local infections occur at the insertion site, exit site, tunnel, or port pocket. Symptoms of local infection include edema,

tenderness, erythema, or drainage.^[10] Numerous risk factors have been cited to increase a patient's risk of VAD infection including prolonged neutropenia, older age, prolonged intensive care unit stay, increased VAD dwell time, low absolute neutrophil count (ANC), poor nutritional status, or device erosion.^[6,10,11]

The etiology of VAD-related infections has been attributed to several different sources with the most common source at the exit site.^[12] Bacteria enter the body at the exit site and migrate along the external surface of the catheter resulting in colonization of the distal tip. The catheter hub is another potential source of bacteria entrance during common manipulations such as blood draws or during flushing.^[11] Hematogenous seeding can occur where an infection at a distant site such as urinary tract seeds the device through the bloodstream, resulting in a VAD infection. Infectious complications have been associated with contaminated infusate. Parenteral nutrition and lipids provide the ideal growth environment for many types of organisms, and if contaminated products are infused, infection can result. Infections can occur when a fibrin sheath is present at the distal tip where organisms can adhere and reproduce.^[10]

The most common organisms to cause VAD-related infections are *Staphylococcus* and *Candida*. Other infectious organisms can include *Corynebacterium* species, *Klebsiella*, and *Enterobacter* species. Several strategies have been attempted to prevent infections; however, to date, evidence is limited in definitive recommendations.^[4] Central line bundles were created to decrease infections during VAD insertion. These strategies include frequent hand washing before and after care, using maximal sterile barrier precautions upon insertion, using chlorhexidine skin antisepsis, selecting optimal catheter site, cleaning catheter hub before access, reviewing the necessity of the VAD daily, and removing the device if not needed.^[13-17]

Many institutions have incorporated sterile technique (sterile mask, gown, or gloves) for maintenance care. To date, there is no research to stipulate what is the best mechanism (sterile versus nonsterile) to care for VADs.^[4,18] Dressings are used to protect the exit site; however, no statistical difference has been found when gauze dressings are compared to transparent dressings for decreasing the overall infection rates. Research does lend to using chlorhexidine-impregnated dressings in decreasing infection rates.^[19] Evidence does support using consistent maintenance procedures with aseptic technique. Routine surveillance is important to monitor infection rates and to make changes in maintenance care as needed. Patient

and caregiver education is vital to ensure consistent care is being given.^[4,20]

Blood cultures are used to diagnosis VAD-related infection obtained from a peripheral site and the VAD. No definitive recommendation can be made on how to obtain blood cultures, the frequency to obtain cultures, discard volumes, or the use of discard blood for a sample.^[5,20,21] Blood cultures should be drawn before beginning antibiotic therapy and at least every 24 h with a temperature spike. If the infusate is suspected, cultures should be taken. A culture of the catheter tip can be performed if the VAD must be removed.^[10,22,23] If there is a higher percentage of organisms in the device culture versus the peripheral culture, a catheter-related infection is confirmed.

Treatment for systemic infection includes administering IV antibiotics sensitive to the organism isolated. If the VAD is multi-lumen, the antibiotic should be rotated per lumen with subsequent administrations. No definitive recommendation can be made for prophylactic antibiotic lock therapy. However, if the patient is immunocompromised or has a low ANC, antibiotic lock therapy should be instituted.^[5,20] The antibiotic lock method, volume, and dwell-time remain controversial.

Local infections are treated with oral or IV antibiotics. The area is cleaned daily with chlorhexidine, and sterile gauze and tape dressing are applied. Warm compresses can be used at the site for comfort. Tunnel and port infections can be treated by packing the subcutaneous tissue with antibiotic gauze in conjunction with IV antibiotics. Usually, tunnel and port infections warrant device removal. However, not all VADs must be removed unless the patient has a persistent or recurrent infection, persistent symptoms after antibiotics are given, or if the organism is a fungus, Gram-negative bacilli, or yeast.^[10,23,24]

Occlusion

The etiology of occlusions in VADs can be attributed to either mechanical or intraluminal causes; further, they are classified as being either partial or complete. Mechanical causes of occlusions may include migration of the catheter, rotation of the port, kinks or catheter fractures, or pinch-off syndrome.^[6] Incomplete occlusions are characterized by the ability to flush solution through the catheter lumen with resistance felt upon attempt to withdraw fluid or blood.

The most common etiology associated with occlusion is the presence of blood or fibrin build-up in the intraluminal

space of the catheter. In addition, a well-defined high-risk profile is described in Table 1.^[5,6,25-34]

Fibrin sheath formation is the most common cause of partial occlusion of VADs.^[25] Intraluminal fibrin formation forms when blood cells become enmeshed within a fibrin matrix, creating a lace-like mesh that traps additional blood cells, producing a fibrin sheath which can extend beyond the distal tip of the catheter and into the vessel itself. The sheath adheres to the catheter's intraluminal surfaces, acting as a one-way valve by allowing fluid to flush easily into the catheter, but creating a suction-like occlusion when attempts to withdraw fluid or blood occur. A mural thrombus consists of clot formation inside the vessel wall and is often associated with complete obstruction. Catheter-related deep vein thrombosis (DVT) is most commonly seen in the subclavian, axillary, brachial, or brachiocephalic veins.^[25,35]

Registered nurse participants in an educational workshop about complications associated with VADs self-report occlusions to be a common complication observed in their practice, and one for which response relies heavily on historical practices and policies, rather than on the most recent evidence.^[36]

However, data support rigorous attention to preventive strategies as key for reduction in occlusion rates. Early recognition of those at increased risk should be considered when managing patients with VADs. Ultrasound-guided insertion techniques decrease malposition risks and should be used whenever available.^[1,5,26]

Table 1: High risk profile for development of venous access device occlusions	
Risk factor	Potential result
Use of TPN	Calcium/phosphate in TPN solution can cause precipitate to form Lipid deposits can form if solution is not used within specified time limit Use of incompatible solutions
Incompatible medications	Use of incompatible medications can result in precipitation, crystallization of drug, causing partial or complete occlusion
Comorbid patient and treatment factors Hypercoagulable status Some malignancies Prior VTE Sludge formation in catheter lumens PICC in place while undergoing surgery Malpositioned catheter tip Large gauge or multi-lumen catheters Some treatment types	Increases risk of fibrin sheath formation, mural thrombi, and catheter-related DVT
Insufficient evidence for maintenance procedures	Evidence is lacking to support specific flushing protocols demonstrated to prevent occlusions

TPN: Total parenteral nutrition, VTE: Venous thromboembolism, PICC: Peripherally inserted central catheter, DVT: Deep vein thrombosis

Unfortunately, data recommending the most efficacious maintenance procedures to prevent occlusions remain inconclusive. Data suggest no difference in the rate of occlusion when using heparin versus normal saline flush maintenance procedures,^[37] yet others report higher incidence of complications when using saline flush only.^[38] The use of tissue plasminogen activator (t-PA) as a lock or infusion maintenance to prevent occlusions cannot be supported by evidence. Most studies evaluating its use as continuous infusion are in the hemodialysis population, and in arteriovenous fistulas; in this population, t-PA push protocols versus dwells of various times offered no statistical significance in the prevention of occlusions.^[39,40] Likewise, there is no definitive evidence to support the use of heparin-bonded catheters as prophylaxis to prevent catheter-related thrombus formation. However, the evidence does support that low-molecular-weight heparin (LMWH) or low-dose warfarin should not be used to prevent thrombus in VADs in patients with cancer.^[5,27,41-44]

Depending on whether partial or complete and its location, the signs and symptoms of occlusion vary. Inconsistent or positional ability to flush or withdraw fluid from any VAD should warrant further evaluation. Mural thrombi may cause pain or edema in upper extremities or the neck; DVT signs may include warmth, edema, and palpable cord of the upper extremity.^[45] Diagnosis is based on history, identified risk profile, and presenting symptoms. A chest X-ray may be of benefit to rule out mechanical problems; however, a cathetergram (dye study) will demonstrate the degree of patency present within the catheter, as well as the presence of a fibrin sheath. Ultrasound evaluation maintains a high degree of specificity and sensitivity for identification of fibrin-related occlusions.^[45]

Treatment is finding specific. If intraluminal fibrin sheath is confirmed, numerous studies support the efficacy of 2 mg t-PA as effective management; however, no recommendations can be made based on evidence regarding optimal dwell times or numbers of repeat doses. Based on available data, and until clinical research supports specificity in these parameters, manufacturer dosages and dwell times should be followed.^[5,46,47]

Mechanical thrombolysis may be achieved in some cases under fluoroscopic guidance by use of a hair wire, followed by aspiration of fibrin pieces.^[47]

A VAD-related upper extremity DVT warrants removal of the device if it is dysfunctional, if infection is suspected in the clot, if nonresponsive to fibrinolytic treatment, and if

symptoms continue. Systemic coagulation with LMWH alone or followed by warfarin until VAD is removed (and continued for the subsequent 3 months after removal) is the standard of care.^[5,46-48]

Ongoing controversy persists regarding whether or not to use a VAD when a blood return is not present. Although there can be no definitive recommendation made based on evidence, strong expert opinion consensus recommends that specific analysis is performed before any use under these circumstances. Placement verification through the use of imaging studies should ensure prior to use; although no one “best” imaging study can be recommended, chest X-ray can detect migration, kinks, pinch-off syndrome, and some tip location concerns; computed tomography - scan is sensitive to detection of fracture, and malposition; ultrasound imaging is superior for tip placement evaluation and identification of clots; and cathetergram/dye study detects overall intactness, detection of backflow, and other obstructions.^[49-52]

Nursing interventions specific to evaluation of a catheter that lacks blood return are outlined in Table 2.^[4,50-52]

Controversy persists regarding the most effective flushing protocol for VADs. Due to inconsistent variables and low numbers of study participants, comparisons of efficacy between heparin solutions of various concentrations versus saline-only flushes are inconclusive.^[37,38,53-55] Based on the available data, evidence-based standard of care consists of flushing all VADs with 0.9% normal saline after blood sampling and following medication administration; pulsatile flushing techniques are recommended. No definitive recommendation can be made regarding heparin solutions versus saline solution use, the most effect flush volume, or frequency.

Documentation and Legal Issues

Concurrent concerns related to access device management include the challenges of meaningful documentation practices that both support patient safety and protect nurses from litigation. As complex care providers, oncology nurses perform independent assessments and act on these findings, perform invasive procedures, infuse high-risk therapies, and perform low-volume yet high-risk interventions frequently. While bound to the scope of practice and standards specific to their role, licensure, state laws of nursing practice, and institutional policies, the legal metric by which nurses are evaluated include measure against what a similarly educated and experienced nurse might do in the same situation.^[56] Without effective communication

of care delivered through documentation, nurses are at risk of being evaluated based on the part of ineffective documentation practices.

Professional negligence includes the concepts of duty to perform that is something was expected from the nurse to be done for the patient, breach of duty, or departure from the standard of care, causation that is the breach of duty caused an injury and damage, meaning damage to the patient is sustained.^[57] Failure to apply the standard of care can be interpreted as what a reasonably prudent nurse, in the same or similar position, would have done, which may include acts of commission or omission, or acts outside of scope of practice. As it relates to VADs, common acts of negligence are noted in Table 3.^[4,50,58,59]

Patient documentation, or lack thereof, may be the only evidence available if litigation should occur. Although the advent of the electronic medical record (EMR) has improved legibility of patient records, EMR checkboxes can encourage “over-checking” or documentation either too late (or too early); further, they may provide limited or no space for

Table 2: Nursing evaluation of access device lacking blood return

Type of device	Intervention
Central VADs	Attempt to flush with normal saline, using gentle pulsatile technique Reposition patient Ask patient to cough and deep breathe Obtain provider order for de-clotting procedure
Midline catheter or peripheral venous catheter	Remove and re-insert
Only after verification of VAD intactness, position, patency, and lack of backflow which is confirmed by imaging study, and only after no other VAD option is available	Obtain provider order for the use of VAD with no blood return

VADs: Venous access device

Table 3: Common acts of negligence associated with venous access devices

Failure to follow the standard of care associated with
Patient risk assessment
Medication administration: Including preadministration verification and medication reconciliation
Equipment use
Identification and labeling of access device lines
Assessment or monitoring parameters: Including ongoing patient assessment, verification of blood return before, during, and after line use
Access or de-access procedures
Communication regarding patient status, drug verification, or drug delivery
Prevention of infection or occlusion: Including use of flushing solution appropriately; use of barrier precautions or strict aseptic technique, as required
Act on a known assessment finding
Stop the negligence of another individual

specialty documentation, such as verification of informed consent, cumulative dosing, use of topical anesthesia, or risk evaluation for extravasation. Nurses must advocate for EMR system configurations that assure that specialty documentation needs are met fully, both for the safety of patients and of professionals. Critical documentation for the oncology patient with a VAD includes such standards of care as evidenced that a risk evaluation was performed, that the infusion was stopped at first complaint of discomfort, and that protocols for extravasation or hypersensitivity reactions are followed meticulously.

The most effective strategies to mitigate personal risk of litigation related to VAD management are to adhere to standards of care and to practice within an identified scope of practice.^[50] Knowledge of and adherence to policies and procedures, standards, guidelines, practice acts, and job descriptions demonstrate that practice can be compared to what a reasonably prudent nurse would do in similar circumstances. Provision of comprehensive care, including thorough assessment that begins with device selection, risk evaluation, and adherence to insertion, access, maintenance, and troubleshooting procedures, protects both patient and professional. Finally, assuring that documentation includes all aspects of the comprehensive care given, including education provided and evaluation of learning, supports the high standard of care being delivered. Finally, identification of personal and professional learning needs, attainment of certification or competency specific to oncology access device care, and awareness of personal risky behaviors or short-cuts demonstrates ongoing commitment to personal competency.

Conclusion

Over the last four decades, VADs have become a standard component of caring for patients with cancer in all settings. Despite the common use of VADs, the current standardized procedures for maintenance care and managing complications is limited. The key to establishing evidence to support practice lies in the further development of nurse, scientist, and clinician collaborations to implement multisite research. It is only through evidence-based findings that traditional practice will be challenged and practice controversies will be resolved.

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Conflicts of interest

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References

1. Brass P, Hellmich M, Kolodziej L, Schick G, Smith AF. Ultrasound guidance versus anatomical landmarks for internal jugular vein catheterization. *Cochrane Database Syst Rev* 2015;1:CD006962.
2. Bowen ME, Mone MC, Nelson EW, Scaife CL. Image-guided placement of long-term central venous catheters reduces complications and cost. *Am J Surg* 2014;208:937-41.
3. Thomopoulos T, Meyer J, Staszewicz W, Bagetakos I, Scheffler M, Lomessy A, *et al*. Routine chest X-ray is not mandatory after fluoroscopy-guided totally implantable venous access device insertion. *Ann Vasc Surg* 2014;28:345-50.
4. Camp-Sorrell D, Matey L. Access device standards of practice for oncology nursing. Pittsburgh, PA: Oncology Nursing Press; 2017. [In press].
5. Schiffer CA, Mangu PB, Wade JC, Camp-Sorrell D, Cope DG, El-Rayes BF, *et al*. Central venous catheter care for the patient with cancer: American Society of Clinical Oncology clinical practice guideline. *J Clin Oncol* 2013;31:1357-70.
6. Ast D, Ast T. Nonthrombotic complications related to central vascular access devices. *J Infus Nurs* 2014;37:349-58.
7. El Hammoumi M, El Ouazni M, Arsalane A, El Oueriachi F, Mansouri H, Kabiri el H. Incidents and complications of permanent venous central access systems: A series of 1,460 cases. *Korean J Thorac Cardiovasc Surg* 2014;47:117-23.
8. Tamura A, Sone M, Ehara S, Kato K, Tanaka R, Nakasato T, *et al*. Is ultrasound-guided central venous port placement effective to avoid pinch-off syndrome? *J Vasc Access* 2014;15:311-6.
9. Busch JD, Herrmann J, Heller F, Derlin T, Koops A, Adam G, *et al*. Follow-up of radiologically totally implanted central venous access ports of the upper arm: Long-term complications in 127,750 catheter-days. *AJR Am J Roentgenol* 2012;199:447-52.
10. Chesshyre E, Goff Z, Bowen A, Carapetis J. The prevention, diagnosis and management of central venous line infections in children. *J Infect* 2015;71 Suppl 1:S59-75.
11. Freire MP, Pierrotti LC, Zerati AE, Araújo PH, Motta-Leal-Filho JM, Duarte LP, *et al*. Infection related to implantable central venous access devices in cancer patients: Epidemiology and risk factors. *Infect Control Hosp Epidemiol* 2013;34:671-7.
12. Bustos C, Aguinaga A, Carmona-Torre F, Del Pozo JL. Long-term catheterization: Current approaches in the diagnosis and treatment of port-related infections. *Infect Drug Resist* 2014;7:25-35.
13. Institute for Healthcare Improvement. How-to guide: Prevent central line-associated blood stream infection, 2012. Accessed November 10, 2016 Available from <http://www.ihl.org/resources/Pages/Tools/HowtoGuidePreventCentralLineAssociatedBloodstreamInfection.aspx>.
14. Duffy EA, Rodgers CC, Shever LL, Hockenberry MJ. Implementing a daily maintenance care bundle to prevent

- central line-associated bloodstream infections in pediatric oncology patients. *J Pediatr Oncol Nurs* 2015;32:394-400.
15. Flodgren G, Conterno LO, Mayhew A, Omar O, Pereira CR, Shepperd S. Interventions to improve professional adherence to guidelines for prevention of device-related infections. *Cochrane Database Syst Rev* 2013;28:CD006559.
 16. Stone PW, Pogorzelska-Maziarz M, Herzig CT, Weiner LM, Furuya EY, Dick A, *et al.* State of infection prevention in US hospitals enrolled in the National Health and Safety Network. *Am J Infect Control* 2014;42:94-9.
 17. Walz JM, Ellison RT 3rd, Mack DA, Flaherty HM, McIlwaine JK, Whyte KG, *et al.* The bundle “plus”: The effect of a multidisciplinary team approach to eradicate central line-associated bloodstream infections. *Anesth Analg* 2015;120:868-76.
 18. Flynn JM, Keogh SJ, Gavin NC. Sterile v aseptic non-touch technique for needleless connector care on central venous access devices in a bone marrow transplant population: A comparative study. *Eur J Oncol Nurs* 2015;19:694-700.
 19. Pedrolo E, Danski MT, Vayego SA. Chlorhexidine and gauze and tape dressings for central venous catheters: A randomized clinical trial. *Rev Lat Am Enfermagem* 2014;22:764-71.
 20. O’Grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, Heard SO, *et al.* Guidelines for the prevention of intravascular catheter-related infections. *Am J Infect Control* 2011;39 4 Suppl 1:S1-34.
 21. Septimus E. Clinical guide for collecting cultures. Centers for Disease Control and Prevention. 2015. Accessed November 10, 2016. Available from: <http://www.cdc.gov/getsmart/healthcare/implementation/clinicianguide.html>
 22. Herrera-Guerra AS, Garza-González E, Martínez-Resendez MF, Llaca-Díaz JM, Camacho-Ortiz A. Individual versus pooled multiple-lumen blood cultures for the diagnosis of intravascular catheter-related infections. *Am J Infect Control* 2015;43:715-8.
 23. Kaur M, Gupta V, Gombar S, Chander J, Sahoo T. Incidence, risk factors, microbiology of venous catheter associated bloodstream infections – A prospective study from a tertiary care hospital. *Indian J Med Microbiol* 2015;33:248-54.
 24. Lorente L, Martín MM, Vidal P, Rebollo S, Ostabal MI, Solé-Violán J; Working Group on Catheter Related Infection Suspicion Management of GTEIS/SEMICYUC. Should central venous catheter be systematically removed in patients with suspected catheter related infection? *Crit Care* 2014;18:564.
 25. Baskin JL, Reiss U, Wilimas JA, Metzger ML, Ribeiro RC, Pui CH, *et al.* Thrombolytic therapy for central venous catheter occlusion. *Haematologica* 2012;97:641-50.
 26. Geerts W. Central venous catheter-related thrombosis. *Hematology Am Soc Hematol Educ Program* 2014;2014:306-11.
 27. D’Ambrosio L, Aglietta M, Grignani G. Anticoagulation for central venous catheters in patients with cancer. *N Engl J Med* 2014;371:1362-3.
 28. Anderson DM, Pesaturo KA, Casavant J, Ramsey EZ. Alteplase for the treatment of catheter occlusion in pediatric patients. *Ann Pharmacother* 2013;47:405-9.
 29. Jasti N, Streiff MB. Prevention and treatment of thrombosis associated with central venous catheters in cancer patients. *Expert Rev Hematol* 2014;7:599-616.
 30. Pai VB, Plogsted S. Efficacy and safety of using L-cysteine as a catheter-clearing agent for nonthrombotic occlusions of central venous catheters in children. *Nutr Clin Pract* 2014;29:636-8.
 31. Restrepo D, Laconi NS, Alcantar NA, West LA, Buttice AL, Patel S, *et al.* Inhibition of heparin precipitation, bacterial growth, and fungal growth with a combined isopropanol-ethanol locking solution for vascular access devices. *J Pediatr Surg* 2015;50:472-7.
 32. Elyamany G, Alzahrani AM, Bukhary E. Cancer-associated thrombosis: An overview. *Clin Med Insights Oncol* 2014;8:129-37.
 33. Chopra V, Ratz D, Kuhn L, Lopus T, Lee A, Krein S. Peripherally inserted central catheter-related deep vein thrombosis: Contemporary patterns and predictors. *J Thromb Haemost* 2014;12:847-54.
 34. Clemence BJ, Maneval RE. Risk factors associated with catheter-related upper extremity deep vein thrombosis in patients with peripherally inserted central venous catheters: Literature review: part 1. *J Infus Nurs* 2014;37:187-96.
 35. Zwicker JL, Connolly G, Carrier M, Kamphuisen PW, Lee AY. Catheter-associated deep vein thrombosis of the upper extremity in cancer patients: Guidance from the SSC of the ISTH. *J Thromb Haemost* 2014;12:796-800.
 36. Matey L, Camp-Sorrell D. 31st Annual Oncology Nursing Society Annual Congress, “Venous Access Devices: Clinical Rounds,” Personal Communication, April 27th, 2016, San Antonio.
 37. Heidari Gorji MA, Rezaei F, Jafari H, Yazdani Cherati J. Comparison of the effects of heparin and 0.9% sodium chloride solutions in maintenance of patency of central venous catheters. *Anesth Pain Med* 2015;5:e22595.
 38. López-Briz E, Ruiz Garcia V, Cabello JB, Bort-Marti S, Carbonell Sanchis R, Burls A. Heparin versus 0.9% sodium chloride intermittent flushing for prevention of occlusion in central venous catheters in adults. *Cochrane Database Syst Rev* 2014;10:CD008462.
 39. van der Merwe E, Luscombe R, Kiai M. The use of tissue plasminogen activator as continuous infusion into an arteriovenous hemodialysis access in the hemodialysis unit: A case series. *Can J Kidney Health Dis* 2015;2:2.
 40. Manns BJ, Scott-Douglas N, Tonelli M, Ravani P, LeBlanc M, Dorval M, *et al.* An economic evaluation of rt-PA locking solution in dialysis catheters. *J Am Soc Nephrol* 2014;25:2887-95.
 41. Kahn SR, Lim W, Dunn AS, Cushman M, Dentali F, Akl EA, *et al.* Prevention of VTE in nonsurgical patients: Antithrombotic therapy and prevention of thrombosis, 9th edition: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest* 2012;141:E195s-226s.
 42. Lavau-Denes S, Lacroix P, Maubon A, Preux PM, Genet D, Vénat-Bouvet L, *et al.* Prophylaxis of catheter-related deep vein thrombosis in cancer patients with low-dose warfarin, low molecular weight heparin, or control: A randomized, controlled, phase III study. *Cancer Chemother Pharmacol* 2013;72:65-73.
 43. Akl EA, Ramly EP, Kahale LA, Yosucio VE, Barba M, Sperati F, *et al.* Anticoagulation for people with cancer and central venous catheters. *Cochrane Database Syst Rev* 2014;10:CD006468.
 44. Shah PS, Shah N. Heparin-bonded catheters for prolonging the patency of central venous catheters in children. *Cochrane Database Syst Rev* 2014; 2:CD005983.
 45. Fallouh N, McGuirk HM, Flanders SA, Chopra V. Peripherally inserted central catheter-associated deep vein thrombosis: A narrative review. *Am J Med* 2015;128:722-38.
 46. Ragsdale CE, Oliver MR, Thompson AJ, Evans MC. Alteplase infusion versus dwell for clearance of partially occluded

- central venous catheters in critically ill pediatric patients. *Pediatr Crit Care Med* 2014;15:e253-60.
47. Oh JS, Choi BG, Chun HJ, Lee HG. Mechanical thrombolysis of thrombosed central venous port. *Cardiovasc Intervent Radiol* 2014;37:1358-62.
48. National Comprehensive Cancer Center. Cancer-associated Venous Thromboembolic Disease. Version 1; 2016. Available from: <http://www.nccn.org>. [Last accessed on 2016 Nov 10].
49. Gibson F, Bodenham A. Misplaced central venous catheters: Applied anatomy and practical management. *Br J Anaesth* 2013;110:333-46.
50. Menonna-Quinn D. Administration considerations. In: Polovich M, Olsen M, LeFebvre KB, editors. *Chemotherapy and Biotherapy Guidelines and Recommendations for Practice*. 4th ed. Pittsburgh, PA. Oncology Nursing Society; 2014. p. 121-35.
51. Gonzalez T. Chemotherapy extravasations: Prevention, identification, management, and documentation. *Clin J Oncol Nurs* 2013;17:61-6.
52. Schulmeister L. Extravasation management: Clinical update. *Semin Oncol Nurs* 2011;27:82-90.
53. Goossens GA, Jérôme M, Janssens C, Peetermans WE, Fieuws S, Moons P, *et al*. Comparing normal saline versus diluted heparin to lock non-valved totally implantable venous access devices in cancer patients: A randomised, non-inferiority, open trial. *Ann Oncol* 2013;24:1892-9.
54. Schallom ME, Prentice D, Sona C, Micek ST, Skrupky LP. Heparin or 0.9% sodium chloride to maintain central venous catheter patency: A randomized trial. *Crit Care Med* 2012;40:1820-6.
55. Lyons MG, Phalen AG. A randomized controlled comparison of flushing protocols in home care patients with peripherally inserted central catheters. *J Infus Nurs* 2014;37:270-81.
56. Karno S. Nursing malpractice/negligence and liability. In: Grant P, Ballard D, editors. *Law for Nurse Leaders: A Comprehensive Reference*. New York: Springer; 2011. p. 249-80.
57. Reising D. Make your nursing care malpractice proof. Available from: <http://www.americannursetoday.com/make-your-nursing-care-malpractice-proof/> [Last accessed on 2016 Nov 10].
58. Edwards D, Anstey S, Kelly D, Hopkinson J. An innovation in curriculum content and delivery of cancer education within undergraduate nurse training in the UK. What impact does this have on the knowledge, attitudes and confidence in delivering cancer care? *Eur J Oncol Nurs* 2016;21:8-16.
59. Miola J. Negligence and the legal standard of care: What is "reasonable" conduct? *Br J Nurs* 2009;18:756-7.