Central Venous Catheter Insertion and Maintenance

A Tutorial on Recommended Practices

Introduction

Central venous catheters (CVCs) are a commonly used modality throughout the medical center and especially in the intensive care units, serving a vital role in the management of critically ill patients. By definition, these devices involve placement of a large-bore catheter into one of the body's main central veins. Typical sites include the internal jugular, subclavian, and femoral veins. Although indications vary among critically ill patients, these catheters are usually placed for vasopressor and medication administration, large-volume infusions, phlebotomy, or hemodynamic monitoring. Various CVC devices are available, including introducers, multi-lumen catheters, PICC lines, and hemodialysis catheters.

Due to their size and location, CVCs confer a much greater risk for bloodstream infection (BSI) than simple peripheral intravenous lines. When a BSI occurs in a critically ill patient, the additional costs and the risk of death can be extraordinary.

Abbreviations

BSI = bloodstream infection
CVC = central venous catheter
NNIS = National Nosocomial Infection Surveillance system
PICC = peripherally inserted central catheter
CDC = Centers for Disease Control and Prevention
ICU = intensive care unit
HCW = healthcare worker

Introduction (continued)

In most cases, episodes of catheter-related bacteremia cannot be traced back to one specific cause. Rather, these infections are viewed as resulting from the cumulative exposure to a series of known *potential* risk factors. These risk factors can be categorized according to the two phases of catheter care: **insertion** and **daily management**. This tutorial will discuss the most important of these risk factors, with a special emphasis on ways that providers can minimize the risks inherent in the insertion phase.

This website is intended for nurses and physicians working in our ICUs. Although individual facilities may differ, the topics outlined in this tutorial are universal and apply to most critical care settings. The guidelines in this tutorial are supported whenever possible by expert recommendations in the published literature. Of course, providers will ultimately need to make treatment decisions based on their own clinical judgment and individual patient characteristics.

Rationale

The use of CVCs have increased considerably in the ICUs. Approximately 48% of all ICU patients have CVCs at some point during their hospital stay, accounting for over 15 million CVC-days per year in ICUs in the United States. However, CVCs, like any venous catheter, disrupt the integrity of the skin, leading to a portal for pathogen entry and subsequent CVC-related BSI. The burden of CVC-related BSIs in the United States is not small nor insignificant. Approximately 90% of catheter-related BSIs occur with CVCs. The mortality attributable to CVC-related BSI is between 4% and 20%, and an estimated 500-4000 U.S. patients die annually due to BSI. The attributable cost per infection is an estimated $34,508–$56,000, and the annual cost of caring for patients with CVC-related BSIs ranges from $296 million to $2.3 billion.

Epidemiology

A few organisms are responsible for most cases of CVC-related bacteremia. Most of these organisms reside on the skin surface. Coagulase-negative staphylococcus is the most commonly isolated bacterium; however, several other pathogens are common causes of CVC-related infections. ***Table 1*** outlines the usual microbial causes of CVC-related BSI.

Pathogen	(%)
Coagulase-negative staphylococci	**37 %**
Gram-negative rods	**14 %**
Enterobacter species	**5 %**
Pseudomonas aeruginosa	**4 %**
Klebsiella pneumoniae	**3 %**
Escherichia coli	**2 %**
Staphylococcus aureus	**13 %**
Enterococcus	**13 %**
Candida species	**8 %**

Indications for CVC Placement

CVC placement may be required for many reasons, including:

1. Rapid delivery of pharmcotherapeutic drugs or compounds
2. Volume resuscitation
3. Hemodynamic instability/need for monitoring
4. Lack of sustainable peripheral access
5. Dialysis therapy
6. Long-term parenteral nutrition
7. Risk of intraoperative air embolism

Placement of a central venous catheter solely for ease of phlebotomy in a patient with adequate peripheral veins is strongly discouraged.

Teamwork & Quality Improvement

Due to the substantial morbidity due to CVC-related BSI, efforts to reduce CVC-related BSI require coordination between all providers on a patient's care team. Accordingly, the physician must inform the patient's nurse at the earliest opportunity whenever CVC insertion is anticipated (i.e. **not** while draping the patient!). This important step allows the nursing staff to arrange proper coverage, thereby ensuring the nurse's availability during the entire procedure. In general, a dedicated nurse should be at the bedside during every CVC insertion. Physicians should defer elective line insertions until a nurse is available.

By having a dedicated team of providers in the room, patient care is improved on several levels. First, the nurse functions as an assistant to the proceduralist who is otherwise unable to touch any object outside the sterile field. In addition, a team approach enhances patient safety. For example, if the nurse notices a break in sterile technique, the physician can be notified and the procedure stopped while the situation is remedied. Although some providers might feel uncomfortable making such suggestions, these types of behaviors improve patient safety and are essential for continuous quality improvement. Obviously, a patient's safety is more important than a provider's autonomy.

Teamwork & Quality Improvement (continued)

Studies have shown that CVCs inserted by inexperienced providers have higher rates of infectious and mechanical complications. If a proceduralist has placed less than five (5) central lines, a more experienced provider must properly supervise the procedure. The ICU leadership feels that protecting patient safety is the responsibility of all providers on a patient's team. Accordingly, the nursing staff is encouraged to ensure our inexperienced providers follow these standard guidelines

Hand Washing

Good hand hygiene before catheter insertion or maintenance is critical to reduce CVC-related infections. Even if providers wear gloves, studies have consistently shown that hand washing immediately prior to the handling of a line reduces the incidence of infections. Use of a waterless, alcohol-based gel is at least as effective as traditional soap and water. All staff are expected to adhere to good hand hygiene practices both before and after contact with patients and their environment.

Fingernails

Hand washing is an extremely effective way to prevent nosocomial infections, but fingernails often harbor microorganisms after thorough hand cleansing. Lengthy or artificial fingernails increase this tendency for pathogenic organisms to remain on the hands. For this reason, the Association of Operating Room Nurses has officially banned artificial nails in the operating room. In general, health care providers should avoid wearing artificial nails at work and should keep their nails neatly trimmed.

Catheter Insertion Site

A catheter in a peripheral vein has a much lower chance of infection than a catheter in a central vein. In fact, the majority of serious catheter-related infections are associated with CVCs, not peripheral lines. A catheter's insertion site directly influences the subsequent risk for catheter-related infection. The density of skin flora at the insertion site is a major risk factor for CVC-related BSI. Certain insertion sites are easier to maintain in a clean and dry manner. Catheters inserted into an internal jugular vein are associated with higher risk for infection than those inserted into a subclavian vein. Recent studies suggest the femoral site is associated with a higher risk for deep venous thrombosis and infection than the other two sites. In general, the subclavian site is the preferred site in order to reduce the risk of infection. However, this recommendation must be balanced against issues such as patient comfort, anatomic deformity, and risk of mechanical complications (e.g., bleeding and pneumothorax).

Catheter Insertion Site (continued)

Studies have shown that the risk of infection or mechanical complications increases with each needle stick. If multiple attempts do not result in successful canalization, providers are encouraged to ask for assistance from a more experienced colleague. In these challenging line placement situations, providers must remain particularly attuned to their patient's level of comfort and anxiety. The use of ultrasound guidance to localize the vein prior to insertion has also been found to reduce the number of needle sticks required for CVC placement.

Maximal Barrier Precautions

Compared with peripheral venous catheters, CVCs carry a substantially greater risk for infection. Therefore, central lines should always be placed using maximal sterile barrier precautions (persons placing the CVC wear cap, mask, sterile gown, and sterile gloves, while a large sterile drape should cover the patient's head and extends below the patient's waist). The drape should be large enough to reduce the risk of catheter and guidewire contamination. In neonates and young children, the drape should cover the entire body. Studies have consistently shown that the use of maximal barrier precautions reduces the incidence of CVC-related BSIs when compared against standard precautions (sterile gloves and sterile towels). Of note, maximal barrier precautions are also recommended for any guidewire exchanges.

Prophylactic Antibiotics During Insertion/Topical Antimicrobial Ointment

At present, prophylactic treatment prior to CVC insertion is not recommended. Prophylaxis with intravenous vancomycin or teicoplanin during catheter insertion did not reduce the incidence of CVC-related infections, and indiscriminate use of antimicrobials independently selects for the acquisition of resistant organisms. Several topical ointments have been studied at the catheter insertion site. One randomized study showed that prophylactic povidone-iodine ointment reduces hemodialysis catheter infections. Studies with prophylactic mupirocin have shown that it prevents overall infections, but the ointment ultimately induces mupirocin resistance and damages the integrity of polyurethane catheters. Rates of catheter colonization with Candida also increase after application of an antimicrobial ointment that has no fungicidal activity. Overall, many studies show conflicting results and no strong recommendations exist regarding the use of antimicrobial ointments. If applying one of these ointments to a CVC insertion site, always check for compatibility with the catheter material.

Patient Positioning

Inexperienced providers occasionally overlook the step of properly positioning the patient. Proper positioning includes ensuring the patient is both comfortable and lying flat (or in slight Trendelenberg). Sedation and analgesia issues should be considered before starting the procedure. Several other steps can also optimize a provider's performance: adjusting the bed height, turning on all the lights, and handing-off pagers.

Insertion Site Prep

Although povidone-iodine (Betadine) has traditionally been the most widely used antiseptic, 2% aqueous chlorhexidine gluconate is actually superior for reducing CVC-related BSIs. Unless contraindicated, use 2% chlorhexidine for skin antisepsis except in neonates under 30 days of age. In this age group, a lower concentration of chlorhexidine should be used (0.5%). If the patient is allergic to chlorhexidine, use povidone-iodine. Allow the antiseptic to air dry on the site before insertion. If hair must be removed prior to line insertion, clipping is recommended. Shaving is not appropriate because razors cause local skin abrasions that subsequently increase the risk for infection.

Antibiotic Impregnated Catheters

Several studies have demonstrated that using antiseptic/antibiotic impregnated CVCs can significantly reduce BSIs, at least in catheters remaining in place up to 30 days. Although several types are available, the rifampin-minocycline and chlorhexidine-silver sulfadiazine impregnated catheters are the most popular. One of these catheters costs approximately three times more than a non-impregnated catheter. In addition, there is still concern that widespread use of these catheters will increase the incidence of rifampin and minocycline resistance among pathogens, especially staphylococci. At this time, experts recommend using antibiotic impregnated catheters ONLY if the infection rate remains high despite adherence to other proven strategies (i.e., education and training, maximal sterile barrier precautions, and 2% chlorhexidine for skin antisepsis).

Anchoring Lines

Catheters must be properly anchored after insertion. Unfortunately, many providers underestimate the importance of this step. A loosely-anchored catheter slides back and forth, increasing the risk for contamination of the insertion tract. Since skin flora are the most common infecting organisms in CVC-related BSIs, proper anchoring is strongly recommended. Likewise, the contamination shield should always be used on pulmonary artery catheters.

Dressing

Although transparent (semipermeable) dressings are popular for CVC insertion sites, studies have not demonstrated a clear benefit for transparent dressings versus ordinary sterile gauze. Both dressing types have similar rates of catheter-related BSI, and, therefore, the choice of dressing is simply a matter of personal preference. However, if blood is oozing from the catheter insertion site, absorbent gauze dressing is preferred. In general, gauze dressing should be changed at least every 2 days. Transparent dressings should be changed at least every 7 days. Studies have not shown any benefit from more frequent changes if the dressing is clean and intact. However, a dressing should always be changed if it becomes damp, loosened, or soiled.

Manipulating & Accessing Lines

Excessive manipulation of catheters increases the risk for CVC-related BSI, probably because of the greater risk for a breach in aseptic technique each time the catheter is accessed. Whenever possible, providers should limit the number of times a line is accessed in order to minimize this risk. Performing non-emergent blood draws at scheduled times (regardless of when they are ordered) is one possible strategy to limit catheter manipulation.

The multiple demands on critical care providers can contribute to catheter-related infections. For example, studies have shown that reducing the nurse:patient ratio from 1:1 to 1:2 independently increases the risk for developing a CVC-related BSI. This effect is possibly due to hurried providers bypassing standard precautionary steps. Prior to accessing any line, hands should be washed, gloves should be worn, and the hub should be sterilized with an alcohol swab. Although alcohol possesses antimicrobial properties, the friction from actually wiping a hub is the most important feature of this step. Providers should pay keen attention to the potential for touch contamination when accessing a hub.

Catheter Removal & Replacement

Since infection risk increases the longer a catheter remains in place, providers must continually evaluate the need for every CVC. Providers should review the need for a CVC on **at least** a daily basis and remove any unnecessary catheters. If a CVC is no longer required and peripheral access has been established, the CVC should be removed. The insertion site should be palpated daily, with thorough inspection of the site if local tenderness or other signs of a possible infection are noted. If purulence is ever noticed at the insertion site, remove the catheter immediately and place a new catheter at a different site. Placement of a new catheter over a guidewire in the presence of bacteremia is unacceptable, because the infection likely originated from the skin tract between the insertion site and the vein. Removal of a CVC for fever alone is unnecessary.

Catheter Removal & Replacement (continued)

A strategy of replacing catheters at scheduled time intervals does not reduce rates of CVC-related bacteremia. Likewise, routine guidewire exchanges also fail to prevent infections. If no infection is suspected, catheter replacement over a guidewire is an accepted technique for replacing a malfunctioning catheter or exchanging a pulmonary artery catheter for a CVC. Of note, CVC removal exposes patients to risk of air embolus. To minimize this risk, providers should ensure the patient is lying flat (or in slight Trendelenberg) when removing a CVC. Instruct patients to take in a deep breath, and then pull the line when the patient exhales. Apply firm pressure to the site for at least 10 minutes, longer if the patient has an underlying bleeding tendency.

Training and Education

Studies have shown that provider education and training directly impact the risk for CVC-related infections. Several important points everyone should know:

- Catheters inserted by inexperienced providers have an increased risk for infection.
- Catheters maintained by inexperienced providers have an increased risk for infection.
- Frequent provider education decreases the risk for infection.
- Standardization of aseptic technique decreases the risk for infection.
- Specialized “Line Teams” decrease the risk for infection.

Surveillance for CVC-Related BSI

An important component of prevention of CVC-related BSIs is the accurate identification of all infections using standardized definitions. In most facilities, infection control and infectious diseases staff are responsible for collecting this data. The Centers for Disease Control and Prevention have developed a rigorous definition for CVC-related BSI, which is recommended for all facilities. Use of this standardized definition allows direct comparison to nationwide benchmarks.

Laboratory-confirmed CVC-related BSI (must meet **at least 1** of the following criteria):

Criterion 1: Patient with CVC has a recognized pathogen cultured from 1 or more blood cultures *and* organism cultured from blood is *not* related to an infection at another site.

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CDC Definition of CVC-Related BSI (continued):

Criterion 2: Patient with CVC has at least *one* of the following signs or symptoms: fever, chills, or hypotension *and* at least *one* of the following:

a. Common skin contaminant (e.g., coagulase-negative staphylococci) is cultured from two or more blood cultures drawn on separate occasions

b. Common skin contaminant (e.g., coagulase-negative staphylococci) is cultured from at least 1 blood culture from a patient with CVC, and the physician institutes appropriate antimicrobial therapy

And signs and symptoms and positive laboratory results are *not* related to an infection at another site.

Criterion 3: Patient 1 year of age with CVC has at least *one* of the following signs or symptoms: fever, hypothermia, apnea, or bradycardia *and* at least *one* of the following:

a. Common skin contaminant is cultured from *two* or more blood cultures drawn on separate occasions

b. Common skin contaminant is cultured from at least one blood culture from a patient with an intravascular line, and physician institutes appropriate antimicrobial therapy

Final Thoughts

Some providers view CVC insertion as a "doctor phase" while daily catheter maintenance is seen as a "nursing phase." Unfortunately, this viewpoint challenges the notions of teamwork and shared responsibility that are essential for infection reduction. Furthermore, this erroneous observation simply ignores the overwhelming evidence that all providers have an impact on the many risk factors mentioned above.

Knowledge alone is not sufficient for changing behavior—you must also take the necessary actions. Please realize that you have a direct impact on infection rates and the quality of medical care in the ICU. If you have any questions about something in the ICU, ask someone. If you have suggestions to improve care in the ICU, speak up.

Further Reading

1. National Nosocomial Infections Surveillance (NNIS) System Report, Data Summary from January 1992-June 2001, issued August 2001. Am J Infect Control 2001;29(6):404-21.
2. Recommended practices. Surgical hand scrubs. AORN Recommended Practices Coordinating Committee. Aorn J 1990;52(4):830-6.
3. Berenholtz SM, Pronovost PJ, Lipsett PA,et al. Eliminating catheter-related bloodstream infections in the intensive care unit. Crit Care Med 2004;32(10):2014-20.
4. Boyce JM, Pittet D. Guideline for Hand Hygiene in Health-Care Settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSAHand Hygiene Task Force. Infect Control Hosp Epidemiol 2002;23(12 Suppl):S3-40.
5. McCarthy MC, Shives JK, Robison RJ, Broadie TA. Prospective evaluation of single and triple lumen catheters in total parenteral nutrition. JPEN J Parenter Enteral Nutr 1987;11(3):259-62.

Further Reading (continued):

6. Mermel LA. Prevention of intravascular catheter-related infections. Ann Intern Med 2000;132(5):391-402.
7. Mermel LA, McCormick RD, Springman SR, Maki DG. The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: a prospective study utilizing molecular subtyping. Am J Med 1991;91(3B):197S-205S.
8. O'Grady NP, Alexander M, Dellinger EP, et al. Guidelines for the prevention of intravascular catheter-related infections. Centers for Disease Control and Prevention. MMWR Recomm Rep 2002;51(RR-10):1-29.
9. Pittet D, Tarara D, Wenzel RP. Nosocomial bloodstream infection in critically ill patients. Excess length of stay, extra costs, and attributable mortality. Jama 1994;271(20):1598-601.
10. Raad, II, Hohn DC, Gilbreath BJ, et al. Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. Infect Control Hosp Epidemiol 1994;15(4 Pt 1):231-8.
11. Soufir L, Timsit JF, Mahe C, et al. Attributable morbidity and mortality of catheter-related septicemia in critically ill patients: a matched, risk-adjusted, cohort study. Infect Control Hosp Epidemiol 1999;20(6):396-401.
12. Wall RJ, Ely EW, Elasy TA, et al. Using real time process measurements to reduce catheter related bloodstream infections in the intensive care unit. Qual Saf Health Care 2005; 14:295-302.