CENTRAL VENOUS CATHETERIZATION

SUMMARY

Over 5 million central venous catheters (CVC) are inserted annually in the United States for hemodynamic monitoring or medication administration. CVC are associated with significant infectious, mechanical, and thrombotic complications and should be discontinued when they are no longer needed for patient monitoring or resuscitation. Proper insertion technique is essential in order to prevent CVC-related complications from occurring.

RECOMMENDATIONS

- **Level 1**
  - **Healthcare workers should be educated regarding the indications, proper insertion, maintenance, and appropriate infection control measures associated with CVC use.**
  - **Full barrier precautions (cap, mask, sterile gown, sterile gloves, and large full-body drape) should be utilized during each CVC insertion.**
  - **Good hand hygiene should be performed both before and after CVC insertion and maintenance.**
  - **Meticulous aseptic technique should be maintained during CVC insertion and care.**
  - **Skin asepsis should be obtained using 2% chlorhexidine gluconate prior to CVC insertion.**
  - **The subclavian vein is the preferred site of CVC insertion. The femoral vein should be used only when the subclavian and internal jugular sites are unavailable.**
  - **CVCs impregnated with either chlorhexidine / silver sulfadiazine or minocycline / rifampin should be utilized to reduce the risk of catheter-related bloodstream infection (CRBSI).**
  - **Either sterile gauze or a sterile transparent, semi-permeable dressing should be used to cover the catheter site. Gauze is preferable if the site is bleeding.**
  - **Antibiotic or antiseptic ointment should not be applied to catheter insertion sites with the exception of hemodialysis catheters.**
  - **CVCs should not be replaced on a routine basis.**
  - **When the catheter insertion site shows no signs of inflammation and CRBSI is not suspected, a CVC may be safely changed over a guidewire.**
  - **Promptly remove any CVC that is no longer essential to patient care.**
- **Level 2**
  - **A CVC with the minimum number of ports or lumens essential for the management of the patient should be utilized.**
  - **CVC insertion sites should be inspected daily for signs of infection or tenderness.**
  - **When adherence to aseptic technique cannot be ensured (i.e., when CVCs are inserted under emergency conditions), catheters should be replaced as soon as possible and always within 24 hours.**

continued…

EVIDENCE DEFINITIONS

- **Class I:** Prospective randomized controlled trial.
- **Class II:** Prospective clinical study or retrospective analysis of reliable data. Includes observational, cohort, prevalence, or case control studies.
- **Class III:** Retrospective study. Includes database or registry reviews, large series of case reports, expert opinion.
- **Technology assessment:** A technology study which does not lend itself to classification in the above-mentioned format. Devices are evaluated in terms of their accuracy, reliability, therapeutic potential, or cost effectiveness.

LEVEL OF RECOMMENDATION DEFINITIONS

- **Level 1:** Convincingly justifiable based on available scientific information alone. Usually based on Class I data or strong Class II evidence if randomized testing is inappropriate. Conversely, low quality or contradictory Class I data may be insufficient to support a Level I recommendation.
- **Level 2:** Reasonably justifiable based on available scientific evidence and strongly supported by expert opinion. Usually supported by Class II data or a preponderance of Class III evidence.
- **Level 3:** Supported by available data, but scientific evidence is lacking. Generally supported by Class III data. Useful for educational purposes and in guiding future clinical research.

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RECOMMENDATIONS (continued)

- **Level 2**
  - **Replace all CVCs for signs of catheter site purulence or hemodynamic instability with suspicion for CRBSI.**
  - **A chlorhexidine-impregnated sponge (i.e., Biopatch™) should be placed over the insertion site of each CVC.**
  - **When CRBSI is suspected, the intracutaneous segment of the catheter (rather than the tip) should be cultured in a semiquantitative manner.**
  - **Chest radiographs are not necessary following uneventful guidewire catheter exchange.**
  - **Difficult catheter insertions (i.e., body size, patient acuity) should be performed by the most experienced physician available.**
  - **CVCs should be utilized for the administration of vasoactive medications or total parenteral nutrition.**
- **Level 3**
  - **The date and time of each CVC insertion and removal should be documented in the medical record.**

INTRODUCTION

Central venous catheters (CVC) play a significant role in the therapeutic armamentarium of the surgeon and intensivist. Over 5 million of these catheters are inserted annually in the United States with greater than 50% of patients requiring ICU-level care having one or more of these devices inserted (1). Such insertion can be fraught with complications that can significantly impact patient morbidity and mortality (infection, pneumothorax, hemothorax, hematoma, thrombosis, arrhythmia, arterial puncture). The rate of catheter-related bloodstream infection (CRBSI) is approximately 5.3 per 1,000 catheter days with an associated cost per infection estimated at $25,000 to $56,000 and an attributable mortality of 12-25% (2). The following guidelines are intended to reduce the incidence of such complications by basing CVC use on well-documented scientific evidence. This is also a requirement of the 2009 National Patient Safety Goals (NPSG) as mandated by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) (3).

NPSG.07.04.01: Implement best practices or evidence-based guidelines to prevent central line–associated bloodstream infections

As of January 1, 2010…

- The hospital educates health care workers who are involved in these procedures about healthcare–associated infections, central line–associated bloodstream infections, and the importance of prevention. Education occurs upon hire, annually thereafter, and when involvement in these procedures is added to an individual's job responsibilities.
- Prior to insertion of a CVC, the hospital educates patients and, as needed, their families about central line–associated bloodstream infection prevention.
- The hospital implements policies and practices aimed at reducing the risk of central line–associated bloodstream infections.
- The hospital…measures central line–associated bloodstream infection rates, monitors compliance with best practices or evidence-based guidelines, and evaluates the effectiveness of prevention efforts.
- Use a catheter checklist and a standardized protocol for CVC insertion.
- Perform hand hygiene prior to catheter insertion or manipulation.
- For adult patients, do not insert catheters into the femoral vein unless other sites are unavailable.
- Use a standardized supply cart or kit that is all inclusive for the insertion of CVCs.
- Use a standardized protocol for maximum sterile barrier precautions during CVC insertion.
- Use a chlorhexidine-based antiseptic for skin preparation during CVC in patients over two months of age, unless contraindicated.
- Use a standardized protocol to disinfect catheter hubs and injection ports before accessing the ports.
- Evaluate all CVCs routinely and remove nonessential catheters.

OPTIONS FOR VASCULAR ACCESS

Peripheral intravenous catheters (PIV) are often under-utilized, especially in the ICU due to the ease and frequency of CVC insertion. PIV, however, are good routes of administration for fluids or intravenous medications. As they require replacement every 72 hours, they are not associated with significant rates of catheter-related bacteremia. Their use can be complicated by localized phlebitis. They should NOT be used to infuse vasoactive medications as extravasation of these medications can lead to tissue loss and significant morbidity. PIV inserted in emergency situations should be considered contaminated and at high risk for septic phlebitis. They should be replaced by a new PIV or CVC as soon as possible and no later than 24 hours after insertion. Their use should always be considered in the patient with fever and an indwelling CVC that is no longer essential to either patient monitoring or resuscitation.

A peripherally inserted central catheter (PICC) is a popular route for central venous access as it may be placed by specially trained technicians rather than physicians. Due to their peripheral insertion, they significantly minimize the risks of hemothorax and pneumothorax associated with CVC placement. They have, therefore, been considered to be both cost-effective and associated with lower morbidity. Smith et al. performed a retrospective comparison of PICC vs. CVC, however, and found PICCs to be associated with significantly greater rates of phlebitis and catheter malfunction (4). Complication rates were significantly higher in PICCs placed to administer either chemotherapy or parenteral alimentation, but not for home administration of antibiotics. PICCs should be avoided in the acute care setting due to their high incidence of catheter-related phlebitis and overall complication rates (4).

CVCs are used to provide secure access to the central circulation for medication administration, fluid resuscitation, and total parenteral nutrition. They are required for vasoactive medication administration. They are associated with higher rates of CRBSI than PIV. The remainder of this guideline will address the current evidence-based medicine support for the proper insertion and maintenance of CVCs.

RISK OF CENTRAL VENOUS CATHETERIZATION

CVC use is associated with certain inherent risks of complication. Efforts to reduce these risks should focus on two specific phases - CVC insertion and daily maintenance – as these aspects of CVC use are associated with the greatest risk for patient injury. Invasive catheter-related complications may generally be divided into three types: infectious, mechanical, and thrombotic.

As a foreign body, these catheters typically become colonized from one of four sources (in decreasing order of frequency): 1) migration down the catheter of microorganisms colonizing the surrounding skin (most commonly *Staphylococcus spp*)., 2) contamination of the catheter hubs, 3) hematogenous seeding from a remote source of infection, and 4) contaminated infusate (5,6). Methods intended to reduce the incidence of infection typically address one of these four areas of contamination. The rate of infectious complications following CVC placement has been variously reported to range from 5 to 26% (7).

CVC insertion may also be associated with mechanical complications including, but not limited to, failure to locate or cannulate the vein, puncture of adjacent anatomic structures, catheter misplacement, pneumothorax, hemothorax, mediastinal hematoma, and adjacent nerve injury (1). Mechanical complications are reported to occur in 5 to 19% of catheter insertions (7). Patients who require CVC are also at high risk for catheter-related thrombosis as a result of their critical illness. Thrombotic complications occur in 2 to 26% of patients (7).

DEFINITIONS (5,7)

- **Catheter colonization**: growth of greater than 15 colony forming units (CFU's) by semiquantitative culture
- **Catheter exit-site infection**: clinical signs of erythema with induration, pus, or tenderness within 2 centimeters of the catheter exit site and a positive catheter culture yielding greater than 15 CFU
- **Catheter-related bloodstream infection (CRBSI)**: Also known as "central line-associated bloodstream infection (CLABI). Simultaneous catheter colonization with greater than 15 CFU and peripheral blood cultures positive for the same organism, in the absence of any other apparent source of infection

LITERATURE REVIEW

All invasive procedures should be performed in a sterile manner with strict attention to aseptic technique. Practices that have been demonstrated to reduce the risk of CRBSI include: 1) use of maximal barrier precautions (i.e., surgical mask, cap, sterile gown, sterile gloves, large sterile drape) during CVC insertion, 2) catheter placement in the subclavian vein rather than the internal jugular or femoral vein, 3) changing catheters only when necessary, and 4) changing CVC dressings when they become non-occlusive, soiled, or bloody (8).

General principles for invasive catheter insertion include the following:

- Maximal barrier precautions (cap, mask, sterile gown, sterile gloves, for all procedures)
- Good hand hygiene
- Appropriate patient positioning
- Proper skin antisepsis using 2% chlorhexidine gluconate
- Wide draping of sterile field
- Appropriate patient sedation and analgesia
- Careful choice of catheter insertion site
- Antimicrobial-coated central venous catheters
- Careful insertion technique
- Appropriate catheter dressings and catheter/site care
- Removal of unnecessary or infected CVCs

<u>Maximal Barrier Precautions</u>

Maximal sterile barrier precautions during CVC insertion including the use of a surgical cap, surgical mask, sterile gown, sterile gloves, protective eyewear, and a large sterile drape that covers the patient's entire body have been demonstrated to significantly reduce the incidence of CRBSI when compared to insertion using sterile gloves and a small drape alone (2,5,7). This should be considered the standard of care for any CVC insertion. Any deviation from these precautions or break in sterile technique, outside of an emergent life-threatening situation, should result in an immediate cessation of the procedure until the deviation can be corrected (2).

<u>Proper Hand Hygiene</u>

Hand washing is an extremely effective way to prevent nosocomial infections. Good hand hygiene, combined with proper aseptic technique during catheter insertion and manipulation, is an effective method for reducing infectious complications (2). Even if healthcare providers wear gloves, studies have consistently shown that hand washing immediately prior to the handling of a CVC reduces the incidence of infection. Good hand hygiene can be achieved using either antibacterial soap and water or a waterless, alcohol-based hand rub. This should be performed both before insertion and whenever the CVC is accessed or redressed.

<u>Appropriate Patient Positioning</u>

Proper patient positioning during CVC insertion is both important and frequently overlooked. The patient should be placed in the Trendelenburg position during CVC insertion in order to reduce the risk of air embolism. If air embolism is suspected, the patient should be immediately placed in steep Trendelenburg position with a left lateral decubitus tilt to prevent movement of air into the right ventricular outflow tract.

The patient should be placed on a FiO_2 of 1.0, and, if the catheter is in the heart, aspiration of air should be attempted. Placement of a towel roll between the patient's shoulder blades can assist in successfully accessing the subclavian vein.

Proper Skin Antisepsis

Povidone-iodine has traditionally been the most commonly utilized skin antiseptic for invasive procedures. A 2% chlorhexidine gluconate solution, however, has been demonstrated to be superior to povidone-iodine in preventing CRBSI (2). Current evidence supports the use of 2% chlorhexidine gluconate skin preparation prior to CVC insertion in adults and children; the safety of such solutions in neonates remains unclear. Povidone-iodine should be utilized only in patients with an allergy to chlorhexidine. Regardless of the antiseptic solution selected, it should always be allowed to dry thoroughly before any procedure is commenced.

Wide draping of sterile field

Maximal barrier precautions, as outlined above, are mandatory in order to decrease the risk of CRBSI. Use of a large sterile drape that completely covers the patient's entire body from head to toe represents a significant change from the traditional technique of CVC insertion. This has been demonstrated to significantly reduce the incidence of CRBSI when compared to insertion using a small drape alone (2,5,7). All CVC kits should include a large, full-body drape.

Appropriate patient sedation and analgesia

CVC insertion can be anxiety provoking for some awake patients. Verbal reassurance and explanation of the CVC insertion process is required. Some patients may require administration of small doses of an anxiolytic. Proper analgesia using appropriate insertion of local anesthetic is also essential. This can decrease the risk of iatrogenic mechanical complications (such as pneumothorax and hemothorax) through decreased patient movement, decrease the patient's level of discomfort, and improve the entire process for the patient.

Choice of Catheter Insertion Site

The density of skin flora at the CVC insertion site is a major risk factor for CRBSI. The subclavian vein is the preferred site of insertion as it has been shown to be associated with both a significantly lower infection rate and a lower risk of catheter-related thrombosis compared to the internal jugular and especially femoral veins (2,5,7).

CRBSI Rates by Insertion Site (9)

Catheter Insertion Site	CRBSI Rate
Subclavian vein	4 per 1,000 catheter days
Internal Jugular vein	8.6 per 1,000 catheter days
Femoral vein	15.3 per 1,000 catheter days

Subclavian catheterization is more likely than internal jugular catheterization to be complicated by pneumothorax and hemothorax, whereas internal jugular catheterization is more likely to be associated with arterial puncture. Internal jugular vein access may be preferred in patients with or at risk for renal failure in order to decrease the incidence of subclavian thrombosis, which could complicate subsequent upper extremity dialysis access creation. In addition to a high CRBSI rate, femoral catheterization is also associated with a high rate of hematoma and arterial puncture as well as a 25% incidence of deep venous thrombosis (2,7,10). As a result, femoral vein catheterization should be limited to circumstances that prevent the use of alternative sites. When absolutely necessary, femoral CVC insertions should be removed and changed to either a subclavian or internal jugular vein site as soon as possible (11).

Antimicrobial-Coated Central Venous Catheters

Antimicrobial-coated CVC are now commonplace and have been found to both reduce the risk of CRBSI and its cost (7). Maki et al. performed a prospective, randomized, controlled trial of such catheters demonstrating that their use significantly reduces the incidence of CRBSI from 7.6 to 1.6 infections per 1,000 catheter days (relative risk 0.21; p=0.03) (6). Subsequent systematic literature reviews have demonstrated that antimicrobial-impregnated catheters not only reduce the incidence of CRBSI, but also

decrease complications and are cost-effective (2,10). Minocycline-rifampin impregnated catheters have been demonstrated to be equivalent to chlorhexidine-silver sulfadiazine impregnated catheters (7).

CVC Insertion Technique

Proper and continued education of healthcare providers has been shown to decrease the incidence of CRBSI. Catheters inserted by and/or maintained by inexperienced providers have an increased risk for infection. Further, standardization of the insertion technique and aseptic precautions also decreases the risk for infection. Prevention of CRBSI is a team-effort: in general, a dedicated nurse should be at the bedside during every CVC insertion. Physicians should defer elective CVC insertions until a nurse is available. If any member of the team notes a deviation in technique (such as a contaminated sterile field, etc…), the physician performing the procedure should be immediately notified and the deviation in technique corrected before the procedure continues further.

The ability to recognize the risk factors for difficult catheterization is essential. A history of failed catheterization attempts, a complex body habitus (as noted above), the need for catheterization at sites of prior surgery, skeletal deformity, or scarring all suggest that catheterization may be difficult. Insertion by a physician who has performed more than 50 CVC procedures is half as likely to result in a mechanical complication compared to a physician who has performed fewer than 50 insertions (7). When a difficult catheterization is anticipated, the procedure should be performed or supervised by an experienced physician and the use of ultrasound should be considered (11). During internal jugular CVC placement, the use of ultrasound guidance reduces the number of mechanical complications, the number of catheter placement failures, and the time required for insertion. Randolph et al. performed a meta-analysis of 8 clinical studies evaluating the use of bedside ultrasound in the placement of CVCs (12). This technology significantly reduced the incidence of mechanical complications compared to traditional insertion techniques (relative risk 0.22; 95% CI: 0.10-0.45).

Mansfield et al. studied the success and complications associated with subclavian vein catheterization in 821 patients (1). Multivariate analysis identified that prior major surgery in the region, a body-mass index (weight in kilograms divided by the square of the height in meters) greater than 30 or less than 20, previous catheterization, and multiple attempts at vein localization were significantly associated with both complications and failure. If only a single needle pass was attempted, the complication rate was 4%, as compared with 11% for two passes, and 24% for three or more passes. Similarly, the failure rate was 1.6% for one pass, 10% for two passes, and 43% for three or more passes. The strongest predictor of complication was a failed catheterization attempt. If access to the vein has not been successfully achieved after three passes of the needle, a new physician should attempt to insert the CVC. The authors recommended that CVCs in high-risk patients (as defined above) should be attempted by the most experienced physician available.

Kilbourne et al. studied the videotaped CVC insertions of 86 patients (13). The overall needle insertion failure rate (defined as insertion of a needle into the skin that did not result in successful passage of a guidewire into the vein) was 78.2%. The mean number of failed attempts per successful CVC insertion was 3.2 (5.5 on the right and 2.1 on the left; p=0.016) while that for failed CVC insertion was 8.0 attempts. Based upon the significant increase in difficulty with right subclavian CVC insertion for right-handed operators, the patient's left side is recommended if the clinical situation permits. The authors identified the following common errors in CVC insertion.

Six Most Common Technical Errors in Subclavian Vein CVC Insertion (13)

Technical Error	Rate	Explanation
Improper insertion position relative to the clavicle	32.3%	Failure to insert the needle at a recommended distance of about 1 cm inferior and lateral to the middle or medial third of the clavicle. Close proximity to the clavicle creates a steep angle for cannulating the vein beneath the clavicle.
Insertion of the needle through the clavicular periosteum	21.9%	In an effort to "walk" the clavicle down to locate the vein posteriorly, using significant force or aggressively pushing the needle can drive it through, instead of beneath, the periosteum. In addition to increasing the rate of unsuccessful venipunctures, this complicates subsequent dilation and passage of the catheter over the guidewire.
Taking too shallow of a trajectory of the needle	16.1%	After the needle is passed posterior to the clavicle, the angle is dropped significantly, causing the needle to only nick the vein anteriorly.
Improper or inadequate anatomic landmark identification	14.7%	Failure to palpate two bony landmarks, the sternal notch and the middle to medial third of the clavicle, before and during each attempt. It is relatively easy to lose track of one's line of insertion amid needle manipulation and sterile draping.
Aiming the needle too cephalad	7.5%	In order to avoid the pleural apex (and pneumothorax), the needle trajectory is superior to the sternal notch. This places both the subclavian vein and artery at risk for injury.
Failure to keep the needle in place for wire passage	7.5%	Backward retraction of the needle with syringe removal can prematurely pull the needle out of the vein and cause inability to pas the wire. Operators who do not have the guidewire on the field or must turn their body to retrieve it from the catheter tray are most prone to this mistake.

Twenty centimeter (cm) long catheters are suitable for the vast majority of adult patients. In general, CVCs should be inserted to 15 cm at the level of the skin in the right subclavian and internal jugular vein positions and 18 cm at the level of the skin in the left subclavian and internal jugular vein positions (these recommendations should be adjusted based upon patient size and anatomy). CVCs should rarely be inserted to their full length except in large or obese patients. Catheters should be secured to the skin using suture or staples as well as the locking device provided with each catheter. A loosely-anchored CVC that slides back and forth at the skin insertion site increases the risk for contamination of the insertion tract. Since skin flora are the most common infecting organisms in CRBSIs, proper CVC anchoring is strongly recommended.

Two excellent videos depicting proper CVC insertion and maintenance are available online through the *New England Journal of Medicine* website through the following links:

- Central Venous Catheterization - http://content.nejm.org/cgi/video/356/21/e21/
- Central Venous Catheterization: Subclavian Vein - http://content.nejm.org/cgi/video/357/24/e26/

Catheter Site Dressings and Catheter/Site Care

The existing data suggests that transparent semi-permeable polyurethane dressings (i.e., Tegaderm™, OpSite™, etc…) are equivalent to sterile gauze in their ability to prevent CRBSI (2). Further, such dressings assist in securing the catheter, permit continuous visual inspection of the catheter insertion site, permit patients to bathe and shower without saturating the dressing, require less frequent changes than standard gauze dressings, and save nursing time (2). If blood is oozing from the insertion site, however, sterile gauze dressings changed frequently are preferable to avoid accumulation of blood that might serve to promote insertion site colonization (6). Placement of a chlorhexidine-impregnated sponge (Biopatch™)

around the catheter insertion site has been demonstrated to significantly reduce the risk of catheter colonization and CRBSI from 1.3 to 0.4 infections per 1,000 catheter days (relative risk 0.24; 95% CI 0.009-0.65) (14). Such dressings must be placed properly with the "blue" side facing up away from the patient ("blue towards the sky").

The use of prophylactic antibiotics has not been demonstrated to reduce the risk of CRBSI and their use should be avoided due to concern that such therapy will lead to emergence of antibiotic-resistant organisms. Prospective, randomized trials have failed to demonstrate a benefit to applying antibiotic or antiseptic ointment (e.g., bacitracin, mupirocin, neomycin, polymixin) to CVC insertion sites with the exception of hemodialysis catheters (2,6). Such practices increase the rate of catheter colonization by *Candida species* (as they do not possess fungicidal activity), promote the emergence of antibiotic-resistant bacteria, can damage the integrity of intravascular catheters, and do not lower the rate of CRBSI (2,5,7).

Excessive manipulation of catheters increases the risk for CRBSI (likely because of the greater risk for a breach in aseptic technique each time the catheter is accessed). As a result, whenever possible, the number of times a CVC is accessed should be minimized in order to decrease this risk. Prior to accessing any line, hands should be washed, gloves should be worn, and the hub should be sterilized with an alcohol swab.

<u>CVC Replacement and Removal of Clinically Unnecessary or Infected CVCs</u>
Prophylactic routine CVC exchange, as compared to guidewire exchange on an "as needed" basis, has been demonstrated to increase the risk of catheter-related infection and is associated with a higher rate of mechanical complications (14). Cook et al. identified that although guidewire exchange may be associated with an increased risk of catheter-related infection (relative risk 1.26-1.52), the risk of mechanical complications (e.g., pneumothorax, hemothorax, etc…) was decreased by almost 50% compared to new-site replacement (relative risk 0.48) (15). If the patient is hemodynamically dependent upon vasoactive medications, and interruption of the medication for guidewire catheter exchange is not possible, a new CVC should be inserted at a new site so that the medication can continue uninterrupted.
CVCs should not be replaced on a scheduled basis. CVCs may remain in place unless an indication for removal arises as follows.

Absolute indications for CVC change or removal:

- A positive blood culture drawn greater than 48 hours after the catheter was inserted
- A grossly infected insertion site (new site)
- A non-functioning catheter (i.e., occluded ports)
- Clinical suspicion of line-related sepsis (fever spike >38.3º C or >1.5º C above baseline without clear cause)
- A positive intracutaneous segment on a previously guidewire-exchanged line (new site)

Relative indications for CVC change or removal:

- Clinical suspicion of secondary seeding of the line from a primary septic source (fever spike >38.3º C or >1.5º C above baseline in a patient with a known septic source)
- Lack of a sterile port for parenteral nutrition
- Requirement of an introducer for pulmonary artery catheter insertion

If infection is suspected and the insertion site is clean, the CVC may be changed over a guidewire and the intracutaneous segment sent for semiquantitative culture (16). If the segment has no significant growth (i.e., < 15 CFU), the catheter may be left in place. If there is purulence or erythema at the insertion site, a new catheter should be placed at a new site and the intracutaneous segment of the old catheter should be cultured. Two blood cultures should be drawn to evaluate the possibility of bacteremia with one culture drawn through the CVC and the other peripherally. A negative blood culture drawn from a CVC indicates that the presence of a CRBSI is unlikely.

CVC catheters may remain in place indefinitely provided that they continue to provide useful physiologic information, they continue to function (without technical problems), and there is no evidence of suspected CRBSI. If any of these conditions occur, the catheter should be changed over a guidewire and then treated according to the results of the semiquantitative intracutaneous segment culture. If the culture is positive (>15 colonies), the catheter should be removed at once and a new site used. If the culture is negative (< 15 colonies), the new catheter can remain in place. If a CVC is simply being discontinued due to lack of clinical need, the catheter does not need to be cultured.

CVCs should be removed as soon as they are no longer necessary to support the patient's ongoing resuscitation and care. Any CVC inserted in the emergency or trauma room should be considered contaminated, as it is the exception rather than the rule that aseptic insertion technique is used in such emergency situations. For this reason, emergently placed CVC should be changed over a guidewire or to a new site as soon as hemodynamic and respiratory stability permits, but certainly within 24 hours of initial placement. Properly inserted and maintained CVCs are virtually never a source for sepsis in the first 72 hours after placement. After 72 hours, the risk of CRBSI increases.

Improving the Rate of CRBSI

Warren et al. performed an observational evaluation of lectures, posting of CRBSI rates, and use of a self-study module on the prevention of CRBSI in a community hospital (8). The rate of CRBSI decreased from 4.9 per 1,000 catheter days to 2.1 per 1,000 catheter days as a result of the educational effort (relative risk 0.43; 95% confidence interval (CI): 0.22-0.84). The percentage of subclavian vein CVC insertions increased from 25% to 41% ($p<0.001$). These findings were accompanied by a decrease in the incidence of sepsis from 16% to 12% ($p=0.03$).

Warren et al. subsequently performed a multicenter trial in 13 ICUs among 6 academic centers to prove that revising existing CVC insertion and care policies as well as implementing educational programs that highlight best practices in CVC utilization improve CRBSI rates (17). After establishing CRBSI rates, the educational process was implemented and infections were followed for the subsequent 18 months. With staff education, the percentage of femoral CVCs decreased from 12.9% to 9.4% (relative ratio 0.73; 95% CI: 0.61-0.88) and the percentage of dated CVC dressings increased from 26.6% to 34.3% (relative ratio 1.29; 95% CI: 1.17-1.42). The overall rate of CRBSI decreased significantly from 11.2 to 8.9 per 1,000 catheter days (relative ratio 0.79; 95% CI: 0.67-0.93). As a result of their intervention, the authors concluded that 13 deaths attributable to CRBSI were averted, 260-286 hospital days were avoided, and $3.1 to $4.4 million in excess hospital costs were saved.

Berenholtz et al. evaluated the implementation of five interventions intended to reduce the rate of CRBSI (18):

1) educating the staff regarding evidence-based infection control practices
2) creating a CVC insertion cart with all necessary supplies
3) daily evaluation to remove unnecessary CVCs
4) checklist to ensure compliance with evidence-based guidelines
5) empowering nurses to stop CVC insertion if the guidelines were not followed

As a result of implementing these strategies, the authors reduced the incidence of CRBSI from 11.3 per 1,000 catheter days to 0 per 1,000 catheter days. Although the infection rate increased slightly to 0.54 per 1,000 catheter days over the next 15 months, the rate subsequently dropped back to 0. The authors argue that simple interventions are capable of virtually eradicating CRBSI as a cause of preventable morbidity and mortality in the ICU setting.

Pronovost et al. studied 103 ICUs in Michigan that implemented an educational program to reduce the incidence of CRBSI (19). Among 375,757 catheter days, the mean CRBSI rate decreased from 7.7 to 1.4 infections per 1,000 catheter days ($p<0.002$). These improvements were maintained throughout the 18 months of the study.

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APPENDIX 1: CENTRAL VENOUS CATHETER INSERTION PROCEDURE

Supplies needed at bedside

- Mask
- Cap
- Sterile gown
- Sterile gloves
- Large sterile full-body drape
- Central venous catheter insertion kit
- 2% chlorhexidine gluconate skin prep
- Sterile saline flush syringes

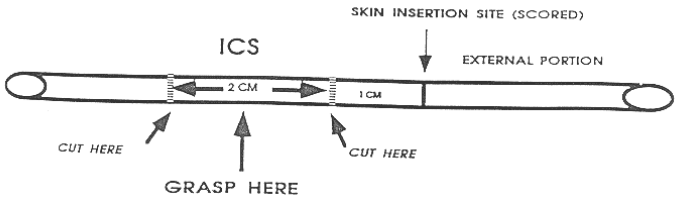
Procedure:

1. Explain the procedure to the patient including the potential risks and benefits, obtain informed consent, and answer any questions the patient may have.
2. Confirm the patient is not allergic to either chlorhexidine gluconate or lidocaine.
3. Place the patient on a bedside EKG monitor or pulse oximeter OR communicate with patient throughout procedure to ensure systemic perfusion and absence of cardiac arrhythmias.
4. Place the patient in Trendelenburg position with a towel roll between the patient's shoulder blades.
5. Don the mask, cap, and sterile gloves.
6. Widely prep the proposed catheter insertion site and surrounding skin (approximately 10 inches in diameter) with the chlorhexidine solution, allowing it to dry completely.
7. Don the sterile gown and new pair of sterile gloves.
8. Widely drape the entire patient applying the drape so that the hole in the plastic portion of the drape overlies the intended insertion site.
9. Infiltrate the skin of the proposed insertion site with 1% lidocaine.
10. For the subclavian vein, confirm the relative position of the sternal notch and the middle third of the clavicle. Insert the needle 1 cm below and 1 cm latter to the middle third of the clavicle. The needle tip should be aimed at the sternal notch. The barrel of the syringe should always be parallel to the floor to avoid injury to the lung. Pulling the patient's ipsilateral arm down may facilitate localizing the vein. Advance the needle until blood flows freely into the syringe.
11. For the internal jugular vein, the junction of the sternal and clavicular heads of the sternocleidomastoid muscle should be identified. Insert the needle 1 cm below the junction of these muscles. The needle tip should be aimed in the direction of the ipsilateral nipple with the barrel of the syringe maintained at a 45 degree angle. Advance the needle until blood flows freely into the syringe.
12. For the femoral vein, the femoral artery pulse should be identified. Insert the needle medial to the palpable femoral pulse with the barrel of the syringe angled cephalad and maintained at a 45 degree angle to the skin. Advance the needle until blood flows freely into the syringe.
13. Once the vein has been localized, stabilize the needle and detach the syringe. Immediately insert the guidewire into the needle and pass it into the vein. Stop if resistance is felt. The guidewire should pass easily. If not, gently remove the wire, reattach a syringe, and reconfirm free aspiration of blood before reattempting guidewire passage. DO NOT pull the guidewire back through the needle if resistance is felt as this may shear the guidewire tip embolizing it into the central circulation.
14. With the guidewire passing easily through the needle, observe the patient's monitor closely for arrhythmias OR communicate with the patient to ensure that they remain conscious. If arrhythmias occur, withdraw the guidewire until they cease.
15. Create a stab wound in the skin at the guidewire insertion site using a scalpel.
16. Gently pass the dilator over the wire and into the skin. DO NOT "hub" the dilator. Remove the dilator.
17. Pass the CVC over the guidewire maintaining control of the wire at all times. Insert the catheter to an appropriate position based upon the patient's size.
18. Aspirate blood from all ports to confirm appropriate positioning. Flush each port with sterile saline.
19. Suture the catheter and apply a chlorhexidine-impregnated patch (Biopatch™) around the catheter.
20. Assist the nurse in applying a sterile, occlusive dressing.
21. Document the CVC insertion in the medical record including the time and date of insertion.

APPENDIX 2: CENTRAL VENOUS CATHETER GUIDEWIRE EXCHANGE PROCEDURE

Supplies needed at bedside

- Mask
- Cap
- Sterile gown
- Sterile gloves
- Large sterile full-body drape
- Central venous catheter insertion kit
- 2% chlorhexidine gluconate skin prep
- Sterile saline flush syringes
- 1 sterile specimen cup
- 1 suture removal kit



Procedure:

1. Explain the procedure to the patient including the potential risks and benefits, obtain informed consent, and answer any questions the patient may have.
2. Confirm the patient is not allergic to either chlorhexidine gluconate or lidocaine.
3. Place the patient on a bedside EKG monitor or pulse oximeter OR communicate with patient throughout procedure to ensure systemic perfusion and absence of cardiac arrhythmias.
4. Discontinue all infusions through the CVC and cap all infusion ports (EXCEPTION: Patients dependent upon vasoactive medication infusions to maintain adequate blood pressure may have these medications continued during the catheter exchange procedure)
5. If present, remove the patient's pulmonary artery catheter from the introducer.
6. Place the patient in Trendelenburg position.
7. Don the mask, cap, and sterile gloves.
8. Widely prep the proposed catheter insertion site and surrounding skin (approximately 10 inches in diameter) with the chlorhexidine solution, allowing it to dry completely. Pay careful attention to adequately prepping the external portion of the CVC, and all lumens including their corresponding hubs and caps.
9. Don the sterile gown and new pair of sterile gloves.
10. Widely drape the entire patient applying the drape so that the hole in the plastic portion of the drape overlies the intended insertion site. The catheter and caps should protrude through the drape.
11. With a sterile scalpel, remove the sutures holding the catheter in place.
12. For an introducer, detach the side-arm and insert the guidewire through the introducer lumen.
13. For a multi-lumen catheter, divide the clear plastic tubing of the distal (brown) port just behind the plastic triangle where the lumens join the catheter. Insert the guidewire through the cut tubing.
14. Advance the guidewire into the superior vena cava while watching the patient's bedside monitor for evidence of arrhythmias OR communicate with the patient to ensure that they remain conscious. If arrhythmias occur, withdraw the guidewire until they cease.
15. Leaving the guidewire in place, remove the existing catheter and place it on the sterile drape for later culture.
16. Pass the new CVC over the guidewire and insert the catheter to an appropriate position based upon the patient's size.
17. Aspirate blood from all ports to confirm appropriate positioning. Flush each port with sterile saline.
18. Suture the catheter and apply a chlorhexidine-impregnated patch (Biopatch™) around the catheter.
19. Pick up the previous catheter with sterile forceps or hemostat. With sterile scissors, cut a 2-3 cm segment beginning approximately 1 cm below the point at which the catheter exited the skin. This is the "intracutaneous segment" or ICS (see diagram above).
20. Send the ICS for semiquantitative culture, labeled as "intracutaneous segment". Include site of insertion (i.e., right internal jugular triple lumen catheter). The lab will report the colony count with Gram stain result within 24-48 hours. Counts greater than 15 CFU per plate are considered positive and require removal of the central venous catheter and reinsertion at a new site as soon as possible.
21. Assist the nurse in applying a sterile, occlusive dressing.
22. Document the CVC insertion in the medical record including the time and date of insertion.

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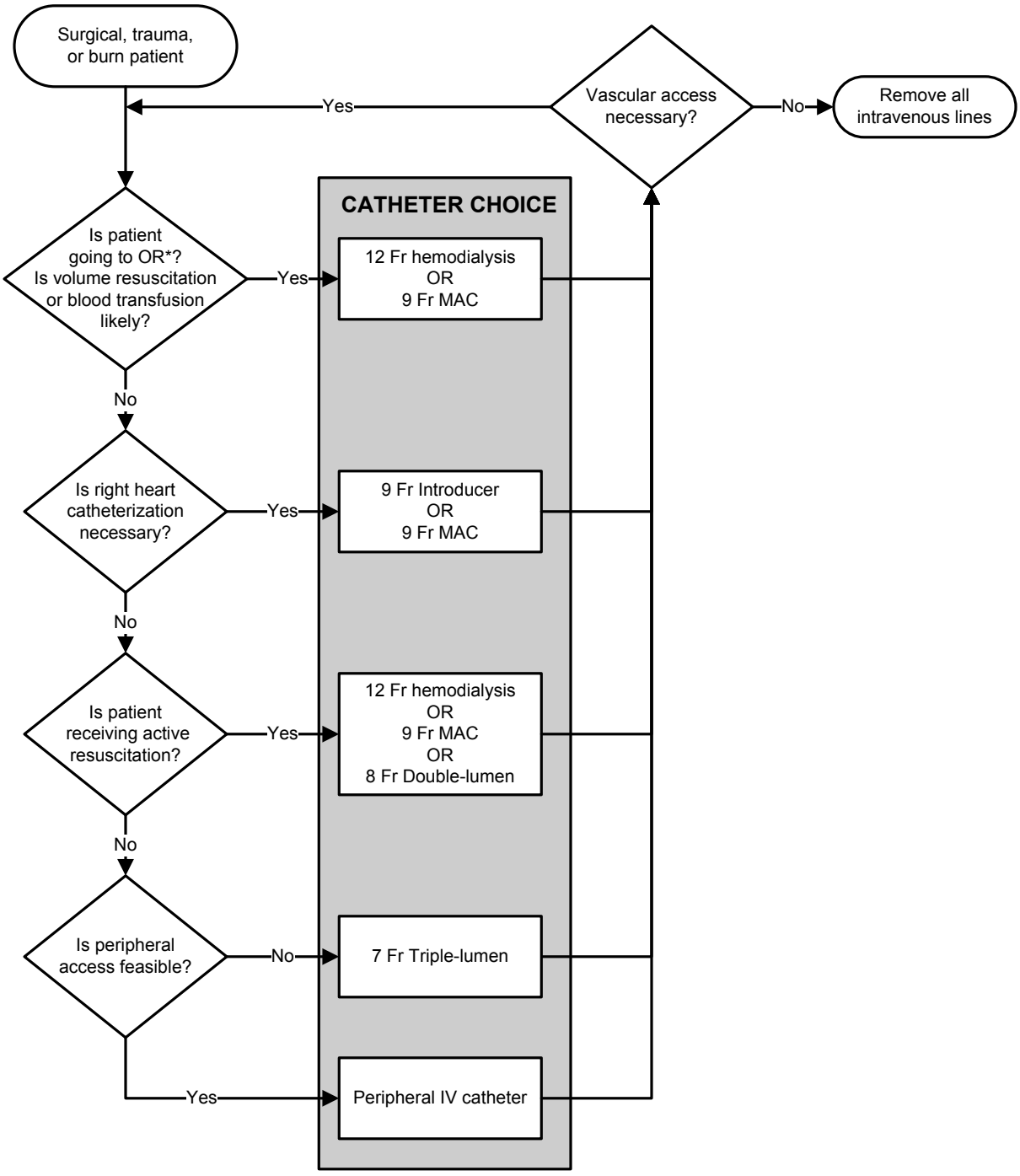
APPENDIX 3: CVC CHOICE FOR SURGICAL PATIENTS BY INDICATION



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