

Central venous catheterization

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Objective: To provide current information related to central venous catheterization.

Design: Review of literature relevant to central venous catheterization and its indications, insertion techniques, and prevention of complications.

Results: Central venous catheterization can be lifesaving but is associated with complication rates of approximately 15%. Operator experience, familiarity with the advantages and disadvantages of the various catheterization sites, and strict attention to detail during insertion help in reducing mechanical complications

associated with catheterization. Strict aseptic technique and proper catheter maintenance decrease the frequency of catheter-related infections.

Conclusions: Appropriate catheter and site selection, sufficient operator experience, careful technique, and proper catheter maintenance with removal as soon as possible are associated with optimal outcome. (Crit Care Med 2007; 35:1390–1396)

KEY WORDS: intensive care unit; intravenous cannulation; resuscitation; central venous access

Most patients admitted to an intensive care unit undergo intravenous cannulation (1). Peripheral venous cannulation usually is attempted first; peripheral veins are readily accessible. Also, large bore, relatively short catheters facilitate rapid fluid infusion, so they are commonly used during initial resuscitation efforts (2, 3). Central venous access is indicated when peripheral veins are inaccessible, for administration of potent vasoactive drugs such as norepinephrine or dopamine, when irritating or hypertonic solutions such as potassium chloride or parenteral alimentation are infused, when incompatible medications must be infused through a multilumen catheter, when acute or subacute hemodialysis or hemofiltration is needed, or for hemodynamic monitoring or transvenous cardiac pacing. Large bore central venous catheters also facilitate extremely rapid infusion of resuscitation fluid (4). More than 5 million central venous catheterizations (CVCs) are performed each year in the United States (5).

Cautions and Contraindications to CVC

Serious complications including death may occur during the insertion or maintenance phases of CVC (6–47). More than 15% of patients who undergo this procedure experience one or more complications (48–50). Operator training and experience are critical. Clinicians who have placed >50 central venous catheters have less than half the complication rates of clinicians with <50 catheterization attempts (49, 51). Help from an experienced clinician should be sought if an operator is unable to insert a central venous catheter after three attempts. The frequency of mechanical complications such as arterial puncture or pneumothorax after three or more attempts is six times greater than after a single attempt (6). Because CVC may be lifesaving, there are no absolute contraindications. Although coagulopathy increases the risk of hemorrhage during CVC, with careful site selection and meticulous technique, bleeding complications can be kept to a minimum. Because the subclavian vein and artery are not accessible to direct compression, the subclavian site is least appropriate for the patient with a bleeding diathesis (52, 53). Anatomical limitations such as morbid obesity make CVC more difficult and dangerous. When possible, catheters should not be placed through the site of cutaneous burn or infection. The risk of pneumothorax during CVC increases with hyperinflation of the lungs associated with chronic ob-

structive pulmonary disease or mechanical ventilation with large tidal volumes, or with increased positive end-expiratory pressure. Venous thrombosis in a planned catheterization site may dictate alternate site selection. Penetrating abdominal trauma or known inferior vena caval disruption makes femoral venous cannulation less attractive. An informed, calm patient facilitates safe CVC. When possible, informed consent should be obtained before the catheterization.

Catheter Selection

A large variety of central venous catheters are available for clinical use. They may have single or multiple lumens. The number of catheter lumens does not affect complication rate, so the number of lumens should be chosen to best meet clinical needs (54–57). Multilumen catheters are commonly selected and often negate the need for multiple CVC sites. Triple-lumen and quadruple-lumen catheters are extremely useful in the day-to-day care of critically ill patients. However, because of relatively small individual-lumen diameter and long catheter length (>20–30 cm), resistance to flow is high, making these catheters less than ideal for rapid fluid infusion.

Larger, shorter catheters are more conducive to rapid fluid administration. An 8.5-Fr introducer sheath is commonly used for this purpose. The sheath is designed for introduction of longer devices such as the pulmonary artery catheter. Nonetheless, because of its relatively

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short length (<10 cm) and large lumen size, the sheath is commonly used to facilitate very rapid fluid infusion during resuscitation attempts (3, 4). Many introducer sheaths are relatively stiff and have been associated with perforation of the superior vena cava and innominate veins. Air embolization has been associated with this type of catheter due to malfunction of the catheter introducer valve and with disconnection of the catheter side port (28, 29). Prompt removal of the sheath introducer is recommended after initial fluid resuscitation has been completed or after a pulmonary artery catheter has been removed.

Dialysis catheters are typically double-lumen, large bore catheters because of the high flows required for dialysis. They are commonly used for acute dialysis and during the several-week period needed for an arteriovenous fistula to mature. Use of the internal jugular, subclavian, and femoral veins spares the vessels of the upper extremities for future vascular access.

Long-arm catheters (also called *peripherally inserted central catheters*), tunneled catheters (Hickman, Broviac, Groshong), and totally implantable central venous catheters also have a place in the care of the critically ill patient but are not discussed here in detail (58–60).

Catheters impregnated with chlorhexidine and silver sulfadiazine and catheters impregnated with minocycline are associated with fewer catheter-related bloodstream infections than nonimpregnated catheters and should be considered in all cases (50, 61, 62).

Modified Seldinger Technique

Aubaniac (63) first described an approach to subclavian vein cannulation in 1952. In 1953, Seldinger (64) described a method of catheter replacement using a guidewire that improved upon Aubaniac's technique. A modified version of the Seldinger technique is used today as the standard approach to central venous cannulation (65–82).

Appropriate monitoring equipment such as electrocardiography and pulse oximetry should be in place before beginning the procedure. All necessary equipment for the procedure should be gathered. The operator should be fully familiar with the equipment used. The patient is then positioned appropriately, and anatomical landmarks are identified. Multiple investigations document that ul-

trasound guidance of CVC is associated with enhanced ease of catheter insertion and fewer complications. The technique is used to localize the vein and measure its distance beneath the skin. Ultrasound-guided CVC in the internal jugular site has been associated with an increased success rate, decreased mechanical complications, and more rapid catheter placement (83–85). Mixed results are reported with use of ultrasound during subclavian vein catheterization (84, 86, 87). This is probably because the subclavian vein is not as well visualized as the internal jugular vein. This technique requires training and is recommended especially for internal jugular vein catheterization attempts.

Next the patient's skin overlying the insertion site is cleaned. Chlorhexidine is superior to povidone/iodine or isopropyl alcohol for this purpose (88, 89). Careful hand washing and full sterile barrier protection with full-length sterile drapes, gowns, caps, masks, and gloves decrease catheter-related infections (90). Once the sterile field is created and the equipment assembled, the operator determines the needle entry site and angle and the depth of needle and catheter insertion. McGee et al. (91) demonstrated an intracardiac catheter tip placement in 47% of patients if a catheter insertion depth of 20 cm was used. In this study, a catheter insertion depth of 16.5 cm was optimal for adults of average size. For internal jugular and subclavian vein cannulations, the proper length of catheter needed may be estimated by laying the catheter over the chest. Alternatively, a formula proposed by Peres (92) based on patient height predicts correct catheter tip position in 95% of patients (93). The tip of the catheter should rest just above the junction of the superior vena cava and the right atrium. This position is approximately at the second intercostal space.

Once the length of catheter to be inserted has been determined, the entry site is infiltrated with 1% lidocaine. The catheterization needle (16–18 gauge) is then inserted with the bevel up to the specific predetermined angle and depth. Gentle suction is applied to the syringe at all times. Entry into the vein is signaled by a rapid flush of venous blood into the barrel of the syringe. If the vein is not encountered before reaching the predetermined depth of needle insertion, the needle is withdrawn slowly along the same pathway, with suction to the syringe applied. Often a flush of venous

blood will occur during withdrawal, indicating that the needle tip has collapsed the vein during advancement and has penetrated both the anterior and posterior walls. If the vein is not entered, the needle tip is withdrawn to the subcutaneous space. The needle is redirected and the procedure repeated. Redirection of the needle midcourse is strongly discouraged and may be associated with tissue laceration.

Once the vein is entered, the syringe is rotated so that the bevel of the needle opens to the vessel lumen. The needle is then immobilized with the free hand and the syringe removed from the needle. The operator's thumb is quickly placed over the needle hub to decrease the risk of air embolism. Some needle/syringe kits are designed to allow placement of the guidewire directly through the syringe without removing it. The guidewire is then advanced into the vein. Minimal to no resistance should be met. Guidewires placed from the internal jugular or subclavian sites are long enough to reach the heart and may cause ectopy, necessitating careful attention to electrocardiographic monitoring and depth of guidewire insertion (94).

When the guidewire is in place, the needle is withdrawn from the insertion site while the guidewire is held motionless. A scalpel and dilator are used to open the skin and dilate the subcutaneous tissue. Using a rotating motion, the operator advances the catheter over the guidewire to the predetermined depth. The guidewire is then removed, and free flow of venous blood from the catheter lumen is confirmed. Intravenous fluid is then connected to the catheter. If the catheter is properly positioned, blood should be easily aspirated from each of the catheter lumens. Each catheter lumen is aspirated and then filled with sterile intravenous fluid to ensure that all air has been removed from the catheter lumens. The catheter is secured to the skin with suture or staples, and a sterile dressing is applied. For subclavian and internal jugular CVC, a chest radiograph is obtained next to document proper catheter position and to check for potential complications such as pneumothorax.

During subclavian and internal jugular vein catheterization, aspiration of air into the central circulation is possible when syringes, guidewires, and tubing are exchanged (28–30). Patients breathing spontaneously, particularly those with large intrapleural pressure changes,

are at particular risk. Care should be taken to occlude intravascular catheter hubs whenever they are disconnected.

Catheterization Sites

Multiple approaches to individual catheterization sites have been described (65–82, 95). Only the most commonly used approaches are reviewed here; however, a clear understanding of multiple approaches enhances the chance of safe and successful CVC. Approaches to the right internal jugular vein and the right subclavian vein are shown in Figure 1. The approach to the right femoral vein is shown in Figure 2.

The infraclavicular approach to the subclavian vein begins with placement of the patient in a 15° head-down (Tren-

delenburg) position to ensure filling of the subclavian vein. Some patients with high central venous pressures do not tolerate this position well and should be monitored carefully during the procedure. The right or left subclavian vein may be used. A towel roll often is placed vertically beneath the patient along the thoracic spine to help lower the patient's ipsilateral shoulder, thus better exposing the subclavian vein. The operator is positioned at the side of the bed, and the patient's head is turned away from the site to be cannulated. The skin is punctured approximately 1 cm caudal to the junction of the medial and middle thirds of the clavicle. The needle is advanced beneath the clavicle parallel to the frontal (horizontal) plane and directed toward the sternal notch. The angle of the needle

should never dip below the frontal plane; this increases the risk of entering the pleural space, thus predisposing the patient to pneumothorax. The needle is advanced to a depth of 3–5 cm depending on the patient's size and anatomy.

The central approach to the internal jugular vein also begins with Trendelenburg positioning. The right or left sides may be used. The right internal jugular vein is often preferred because of the relatively straight pathway to the superior vena cava. The left internal jugular vein joins the left subclavian vein at an approximate right angle that is sometimes difficult to negotiate. The apex of the left lung rises more cephalad than the right, increasing the risk of pneumothorax on the left. Also, injury of the thoracic duct is more common with left internal jugular catheterization attempts. The operator is positioned at the head of the bed, and the patient's head is turned away from the site to be cannulated. The operator identifies the triangle formed by the medial and lateral portions of the sternocleidomastoid muscle and the clavicle. The clavicle serves as the base of the triangle. The internal jugular vein courses from the apex of the triangle toward the base, parallel to the long axis of the body. The carotid artery courses in a similar direction but is medial and deep to the internal jugular vein. Identifying the pulsation of the carotid artery before beginning is often warranted. The skin is punctured at the apex of the triangle, and the needle is directed caudally at a 45° angle to the frontal plane and slightly laterally toward the ipsilateral nipple. The needle is advanced to a depth of 3–5 cm depending on the patient's size and anatomy.

Femoral vein cannulation begins with the patient in a supine position with the legs slightly abducted. The right and left sides may be used. The operator is positioned on the side of the bed. The anterior superior iliac spine and pubic tubercle are identified. The inguinal ligament courses between these bony landmarks. The abdominal compartment lies cephalad to the inguinal ligament, and the leg lies caudad. Attempts at femoral venous access above (cephalad to) the inguinal ligament are discouraged, as they may lead to needle or catheter entry into the abdominal compartment or hemorrhage into the retroperitoneal space. The femoral artery courses directly deep to the inguinal ligament and is readily identified in most patients by its pulsation. The femoral vein lies approximately 1 cm me-

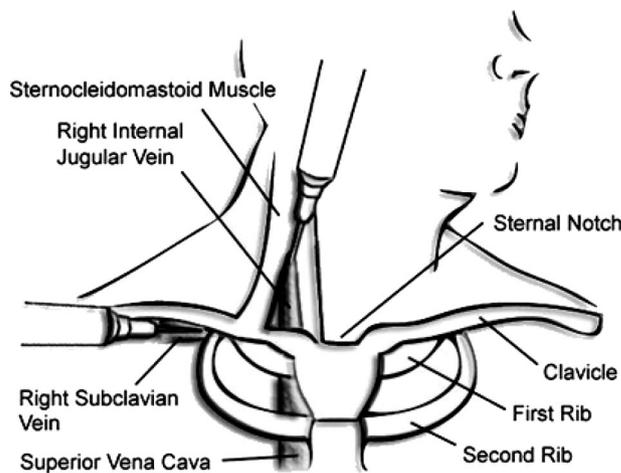


Figure 1. The central approach to the right internal jugular vein and the infraclavicular approach to the right subclavian vein.

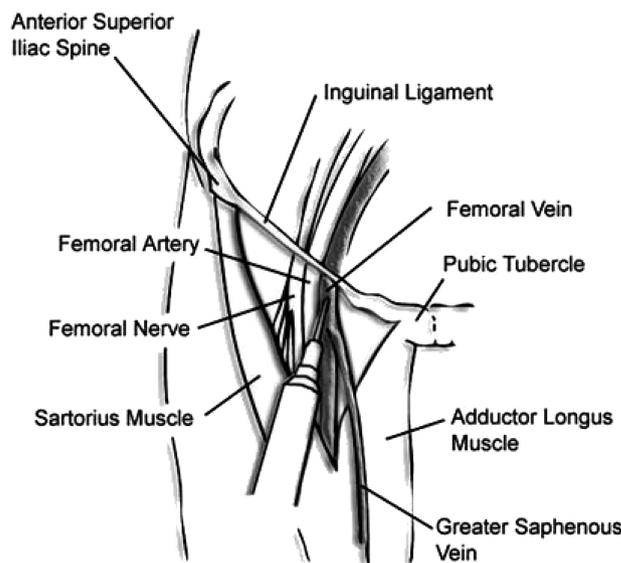


Figure 2. The approach to the right femoral vein.

dial to the femoral artery and runs in a parallel direction. The skin is punctured 1–2 cm below (caudad to) the inguinal ligament and approximately 1 cm medial to the femoral pulse. The needle is directed cephalad and advanced at an approximate 45° angle. The needle is advanced to a depth of 3–5 cm depending on the patient's size and anatomy.

Preventing Complications

More than 15% of patients undergoing CVC experience some sort of complication (48–50). Arterial puncture, hematoma, and pneumothorax are the most common mechanical complications of CVC (96). Venous thrombosis and catheter-related infections are also common and can be life threatening (5, 14, 32–38, 97–99).

Mechanical Complications. Internal jugular and subclavian vein cannulation attempts have similar overall risk of mechanical complications. The internal jugular site is more likely to be associated with arterial puncture (common carotid artery) than the subclavian site. This complication is usually very well tolerated, provided that it is recognized early in the procedure and proper pressure is applied to control bleeding. The subclavian vein site is more commonly associated with pneumothorax and hemothorax than the internal jugular site. To prevent this complication, the operator should never let the introducer needle drop below the horizontal plane. The operator should be aware of return of air into the syringe barrel, signifying violation of the pleural space and risk of pneumothorax. A chest radiograph should be carefully reviewed after each internal jugular and subclavian vein cannulation attempt, to look for the possibility of pneumothorax. The operator is cautioned against bilateral CVC attempts from the internal or subclavian vein sites if pneumothorax is suspected. Although the presence of a unilateral pneumothorax can usually be handled without difficulty, the presence of bilateral pneumothoraces is very poorly tolerated. Mechanical complications of femoral vein cannulation include arterial puncture, hematoma, and the possibility of arteriovenous fistula development.

Under most circumstances, the operator can easily distinguish an inadvertent arterial puncture by the pulsatile nature of flow and the red color of arterial blood. In patients with significant hypoxemia and/or reduced circulatory flow, this dis-

tingtion can sometimes be difficult. If in doubt, the operator may insert a small 18-gauge catheter over the guidewire and then determine the pressure waveform of the vessel cannulated. This practice will allow easy determination of an arterial or venous cannulation site. Likewise, to distinguish an arterial cannulation from a venous cannulation, a sample of blood can be sent from the vessel for determination of PO_2 and oxyhemoglobin saturation.

Venous Thrombosis. Venous thrombosis has been reported in as many as 21% of femoral vein catheterizations (12). The internal jugular site has a lower occurrence rate, but the internal jugular site has a reported association with venous thrombosis approximately four times greater than that of subclavian vein cannulation (14). The precise clinical relevance of catheter-related venous thrombosis remains in dispute. However, because of the size of the femoral veins, most clinicians respect the potential for femoral vein thrombi to embolize (14–17).

Catheter-Related Infections. Catheters impregnated with chlorhexidine and silver sulfadiazine and catheters impregnated with minocycline are associated with fewer catheter-related bloodstream infections than nonimpregnated catheters. Impregnated catheters should be considered in all cases, especially when the institutional catheter-related infection rate exceeds 2% (61, 62, 100–102). Use of the subclavian site is associated with fewer catheter-related infections than the internal jugular or femoral sites, making it a preferred site in many patients (6, 12, 49, 61, 99, 102). Use of maximal sterile-barrier precautions during catheter insertion decreases the risk of catheter-related infection (90). Application of antibiotic ointment at the site of skin puncture has been shown to increase the rate of fungal colonization (103) and promote growth of antibiotic-resistant bacteria (104). Antibiotic ointments should therefore not be used (105). Use of subcutaneous silver-impregnated cuffs is controversial but has not been associated with a reduction in catheter-related bloodstream infections (103, 106, 107). Catheter hubs are commonly contaminated (108). Care should be taken to access a catheter hub no more often than absolutely necessary. When the catheter hub is accessed, strict sterile technique should be followed. Antiseptic-coated hubs have been shown to decrease the risk of catheter-related infections (109, 110). Data are conflicting regarding the

optimal type of catheter dressing (gauze vs. transparent polyurethane) and the timing of dressing changes (111–114). Therefore, no firm recommendations can be made about dressings and dressing changes at this time. Investigations do not support routine catheter removal and replacement on a scheduled basis (105, 115–117). Central venous catheters should be removed as soon as they are no longer needed. Routine catheter exchanges over a guidewire are not recommended (115). The catheter should be removed and a new catheter inserted if the clinician suspects the possibility of catheter-related infection because of systemic toxicity or purulence at the site of catheter insertion.

Conclusions

CVC can be lifesaving but is associated with complication rates of approximately 15%. Operator experience, familiarity with the advantages and disadvantages of the various catheterization sites, and strict attention to detail during insertion help reduce mechanical complications associated with catheterization. Strict aseptic technique and proper catheter maintenance decrease the frequency of catheter-related infections. Routine scheduled catheter changes are not warranted. In all cases, central venous catheters should be removed as soon as they are no longer needed.

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