REVIEW & SPECIAL ARTICLE

Current Practice in Central Venous Catheterization

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Currently, there is a decreasing trend in the utilization of central venous catheters among medical practitioners. However, the continued relevance of central venous catheters persists, particularly in scenarios involving emergent or critically ill patients where peripheral venous access proves challenging. The insertion of central venous catheters facilitates rapid delivery of fluids and pharmacotherapy crucial for resuscitative efforts. Employing real-time ultrasound guidance enhances procedural safety from mechanical injuries, increases success rate with limited attempt and diminishes associated risks like pneumothorax, arterial puncture, and hemorrhage. Emphasizing infection prevention remains paramount. The present article underscored contemporary and safer procedural methodologies for central venous catheterization, alongside adept management of procedural complications.

Keywords: Central venous catheterization; Central line; Arterial injury

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Central venous catheterization (CVC) is currently utilized less frequently by anesthesiologists than in previous years. This trend may be attributed to advancements in perioperative fluid management strategies, which now rely on the concept of fluid responsiveness. This concept hinges on cardiac output monitoring techniques that do not necessitate the measurement of central venous pressure (CVP). The reliability of CVP in predicting fluid responsiveness is diminished due to its low sensitivity and specificity(1). Furthermore, the incidence of mechanical complications associated with CVC is around 8% at the present date in CVC in the ultrasound-guided era(2). Common indications for CVC placement include challenging intravenous access, infusion of high osmolarity agents, insertion of transvenous cardiac pacing devices, and CVP monitoring(3). Consequently, efforts have been made to develop safer techniques aimed at reducing complications associated with CVC. The present article focused on providing a comprehensive review of contemporary literature pertaining to CVC techniques and optimal strategies for managing complications arising during CVC procedures.

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Indications and contraindications for CVC

There are reasonable indications to insert a central venous catheter. First, the indication for CVC in the past was for measuring CVP, a pressure that can be measured at the superior vena cava connected to the right atrium. The benefit of CVP measurement lies in evaluating intravascular volume, as it could represent left ventricular end-diastolic volume in cases of normal valvular function. CVP is a static index that represents intramural pressure and does not fully reflect transmural pressure that actually represents preload, especially in mechanical ventilated patients(4). However, contemporary literature indicates that the sensitivity and specificity of CVP in predicting fluid responsiveness is quite lower than other dynamic indexes(5). Second, CVC is utilized for infusing irritant medications that either damage smaller peripheral veins or would be destructive to local tissue if a peripheral intravenous access failed and the medication extravasated during infusion such as chemotherapy, vasoactive agents, total parenteral nutrition (TPN), and other medications that irritate peripheral veins such as acyclovir, penicillin, and potassium chloride(6). Third, CVC is employed in cases where peripheral intravenous access is difficult to obtain. Fourth, central lines are used for temporary hemodialysis line insertion. Fifth, central lines are employed in procedures involving the insertion of equipment into large central veins, such as transvenous cardiac pacing, aspiration of air emboli, or placement of an inferior vena cava filter, pulmonary artery catheter for mixed venous oxygen saturation measurement, among others.

The absolute contraindications include central vein stenosis, central vein thrombosis, and infection at the puncture site on the patient's skin. There are several relative contraindications for CVC, such as coagulopathy or thrombocytopenia. However, studies have shown that ultrasound-guided CVC in coagulopathic patients under emergency conditions did not result in significant differences in serious or life-threatening complications(7). The risk of bleeding during CVC in coagulopathic patients, defined by a reduced platelet count of 50,000 or less and/or an elevated international normalized ratio (INR) of 1.5 or greater, was not associated with prophylactic platelet or fresh frozen plasma transfusion before the procedure. Additionally, the severity of coagulopathy did not predict the risk of bleeding(8). The American Association of Blood Banks recommends prophylactic transfusion in patients with a platelet count of 20,000 or less before elective CVC(9). The Association of Anesthetists of Great Britain and Ireland suggests that CVC in coagulopathic patients should be performed by experienced operators. If the platelet count was 50,000 or less, the activated partial thromboplastin time is greater than 1.3 times normal, and/or the INR is greater than 1.8, reversal of coagulopathic abnormalities should be considered. Operators should carefully weigh the risks and benefits of transfusion versus bleeding complications(10). In addition, ipsilateral pneumothorax is regarded as a relative contraindication for CVC. Iatrogenic pneumothorax may be intolerable for patients experiencing severe respiratory distress. However, to avoid good lung harm in patients with unilateral illness, CVC on the affected side of the lung should be taken into consideration.

Sites for central venous catheter placement

Internal jugular vein

The internal jugular vein is easily accessible as the vein lies superficially to the skin and directly drains into the superior vena cava. Additionally, the apex of the right lung is lower than the left side, making the right internal jugular vein easily accessible from the head of the bed. Furthermore, it is easier to access for right-hand dominant operators. However, patients may experience discomfort when the catheter is inserted, and accessing this site may be more challenging in patients with hypovolemia or obesity. In the case of the left internal jugular vein, there is a risk of accidentally injuring the thoracic duct. Additionally, catheter kinking may occur at the junction of the left internal jugular vein draining into the superior vena cava and the junction where the internal jugular vein drains into the innominate vein. The anatomical landmark of the internal jugular vein is situated below the apex of Sedillot's triangle, with the base of this triangle being the clavicle. The sternocleidomastoid sternal head and clavicular head form the sides of this triangle. The depth of the internal jugular vein is usually not deeper than 1.5 cm. If the needle penetrated deeper than 2 cm, there is a risk of arterial puncture or pneumothorax.

The American Society of Anesthesiologists (ASA) proposed guidelines on central venous access in 2020, suggesting the use of real-time ultrasound guidance for internal jugular venous access to increase success rates and decrease the risk of arterial puncture, hematoma, and pneumohemothorax(11). However, anesthesiologists should also be proficient in landmark techniques. The preferred landmark technique involves tilting the table in a head-down position, if there are no contraindications, and turning the patient's head to the opposite side by no more than 45° to prevent the carotid artery from directly overlaying the internal jugular vein and causing arterial puncture(12). Another landmark technique, the paracarotid approach, entails drawing an imaginary line 5 cm from the clavicle at the same level as the cricoid cartilage, then turning the patient's head to the opposite side by no more than 20°. Gently palpating the carotid artery pulse will help locate the internal jugular vein, which lies just lateral to this site by less than 1 cm. However, this technique requires proficiency in CVC and does not demonstrate superior outcomes compared to other approaches(13).

Subclavian vein

The subclavian vein connects with the axillary vein and joins with the internal jugular vein before draining into the superior vena cava. This site offers the advantage of being easy to clean and is associated with fewer bloodstream infections and thrombotic events compared to other sites. However, it carries the risk of arterial injury and pneumothorax during the procedure, and it cannot be compressed in case of hemorrhage or hematoma(14). Additionally, there is a high risk of vascular obstruction, making vascular access for dialysis more difficult. This site is commonly used in neurological patients who have concerns about impeding cerebral blood flow with internal jugular vein catheterization(15). In cases of severe hypovolemia, the internal jugular vein may collapse even in the Trendelenburg position. CVC may be easier to access in this situation because the subclavian vein is surrounded by connective tissue near the clavicle and is anchored by the fascia of the subclavius muscle and the costoclavicular ligament, making it less prone to collapse(16).

Femoral vein

The femoral vein is often selected as the site for CVC in situations involving multiple traumas, where patients may present with neck collars or even cardiac arrest requiring cardiopulmonary resuscitation and chest compressions. These scenarios make CVC challenging. Femoral vein catheterization may also be necessary in cases of thrombotic events in the upper extremities. However, caution must be exercised regarding the puncture site, which lies below the inguinal ligament. Puncturing above the inguinal ligament may lead to injury to the external iliac vein and result in retroperitoneal hematoma, which is difficult to compress. Despite its utility in certain situations, the femoral vein carries a higher incidence of catheter-related bloodstream infections (CRBSI) and thrombotic events due to immobilization of the punctured limb. Therefore, it is not the primary site to consider for catheterization(17).

Basilic vein and cephalic vein

The peripheral inserted central catheters (PICCs) are a form of central venous catheter that is inserted in the superficial veins surrounding antecubital fossa. This area has superficial veins called basilic and cephalic veins. Cephalic veins are smaller than basilic veins and can be convoluted. Catheterization of the PICCs is now suggested in the basilic veins of the upper arms. Catheters placed in the elbow may rub against the skin during elbow movement, resulting in thrombophlebitis. Furthermore, it easily produces thrombus in the small basilic veins below the elbow.

Preparation

Vital signs monitoring such as blood pressure, pulse oximetry, and continuous electrocardiogram should be placed on patients who undergo CVC. Preparation according to the practice guidelines for central venous access in 2020 by the ASA, they recommend(11).

Figure 1. A sterile body drape is depicted, indicating the preparation for central venous catheterization planned for the right internal jugular vein.

The asterisk (*) denotes the sterile field at the right internal vein

- Perform CVC in an environment that permits the use of aseptic techniques.
- Ensure that a standardized equipment set is available for central venous access.
- Use a checklist or a protocol for placement and maintenance for central venous access.
- Use an assistant during placement of central venous catheter.

Infectious control during central venous catheterization

Antibiotic prophylaxis

There is currently no evidence to support the use of antibiotics to prevent CRBSI. However, studies show that antibiotics combined with anticoagulants, which are injected into the catheter lumen, can reduce the incidence of gram-positive bacterial infections in patients with cancer, immunocompromised hosts, or patients who use central venous catheter for long-term hemodialysis(18). Therefore, this method should be considered for use in high-risk infection groups to prevent drug resistance(19).

Sterile technique bundle

The CVC care bundle recommends hand hygiene using alcohol-based surgical hand rub, allowing it to dry, or performing a surgical scrub for two minutes. This process involves removing debris underneath fingernails and cleaning hands and forearms using antimicrobial soap and water. Maximum barrier precautions during insertion include wearing a non-sterile hat, mask, and eye protection, as well as sterile gloves and gowns. If there is excessive hair at the puncture site, razors should not be used due to the risk of breaking the skin and introducing infection[20]. Additionally, the puncture skin sites should be cleaned with soap and water if soil is visible, and the sterile site should be prepared immediately before catheterization. A sterile body drape is used to create a wide sterile field and protect all procedure equipment as aseptic, as shown in Figure 1. If ultrasound is used to guide CVC, a long sterile cover is suggested to be placed over the ultrasound probe. In case of an emergency puncture and the punctured site may not be fully prepared with sterile conditions, the catheter should be replaced within 24 hours or as soon as possible[21]. Moreover, an insertion checklist should be used to ensure an aseptic procedure at every step throughout the procedure.

Antiseptic selection

The recommended antiseptic for application and drying before skin puncture is 2% chlorhexidine gluconate in 70% alcohol. A study by Pages et al. compared the risk of central venous catheter-related infections across various antiseptics, including 5% povidone-iodine in alcohol, 2% chlorhexidine in alcohol, less than 1% chlorhexidine in alcohol, and 10% povidone-iodine in water. They found that using 2% chlorhexidine in alcohol for one-step cutaneous disinfection of the central venous catheter insertion site and maintenance catheter care was associated with a reduced risk of central venous catheter-related infection. The adverse effects observed with all antiseptics were not significantly different[22]. In cases involving infants or patients allergic to chlorhexidine, povidone-iodine in alcohol is considered as an alternative[23].

Antibiotics-coated central venous catheter

A meta-analysis study demonstrated the effectiveness of catheters impregnated with chlorhexidine/silver sulfadiazine, or other antibiotics such as vancomycin, miconazole/rifampicin, or minocycline, among others. The findings revealed that chlorhexidine/silver sulfadiazine, and antibiotics-coated catheters were associated with a lower number of CRBSI compared to standard catheters. Specifically, chlorhexidine/silver sulfadiazine-coated catheters exhibited fewer cases of microbial colonization. However, they did not significantly reduce CRBSI when compared with silver ion-impregnated central venous catheters. It is noteworthy that all CVCs in the studies included in this meta-analysis were conducted under infectious control bundles[24].

Central venous catheter fixation and dressing

Studies have compared suture techniques, securement devices, and dressing types for central venous catheters in terms of catheter securement failure and bacterial colonization or infection rates. A systematic review revealed that medication-impregnated dressings, such as chlorhexidine gluconate or silver, were associated with fewer cases of CRBSI compared to other dressing types for central venous catheters[25]. In instances of excessive bleeding, oozing, or diaphoresis at the insertion site, a sterile gauze dressing is preferred until resolution of the condition[23]. Transparent semipermeable membranes impregnated with chlorhexidine dressing should be changed every five to seven days. Additionally, studies have investigated innovative central venous catheter fixation techniques. One study demonstrated that sutures combined with a chlorhexidine disc and integrated securement dressing resulted in a lower incidence rate of central venous catheter failure, including dislodgement and infection[26]. Another study compared the use of topical tissue adhesive with standard care involving gauze and transparent dressing. The findings indicated that applying topical tissue adhesive over the catheter insertion site can reduce the incidence of immediate postoperative pericatheter blood oozing[27].

Mechanical injury prevention during central venous catheterization

The mechanical complications during CVC can be minimized and started from the easiest step, the site selection and position during procedure. The American Society of Anesthesiologist practice guideline recommends choosing the upper body insertion site to minimize the risk of thrombotic complications relative to the femoral site[11]. The internal jugular vein should be selected to avoid pneumothorax requiring chest-tube insertion compared with subclavian vein[14]. During the procedure, the patient should be placed in supine position with insertion slightly below the level of heart or the Trendelenburg position because the venous engorgement will be more obvious, and it will be easier for the clinician to access the vein. This position provides advantages such as reducing the air entrainment in the circulation and minimizing the risk of air embolism during the procedure. The head of the patient should be turned opposite to the insertion site, but not more than 45° because it led the carotid artery stay directly above the internal

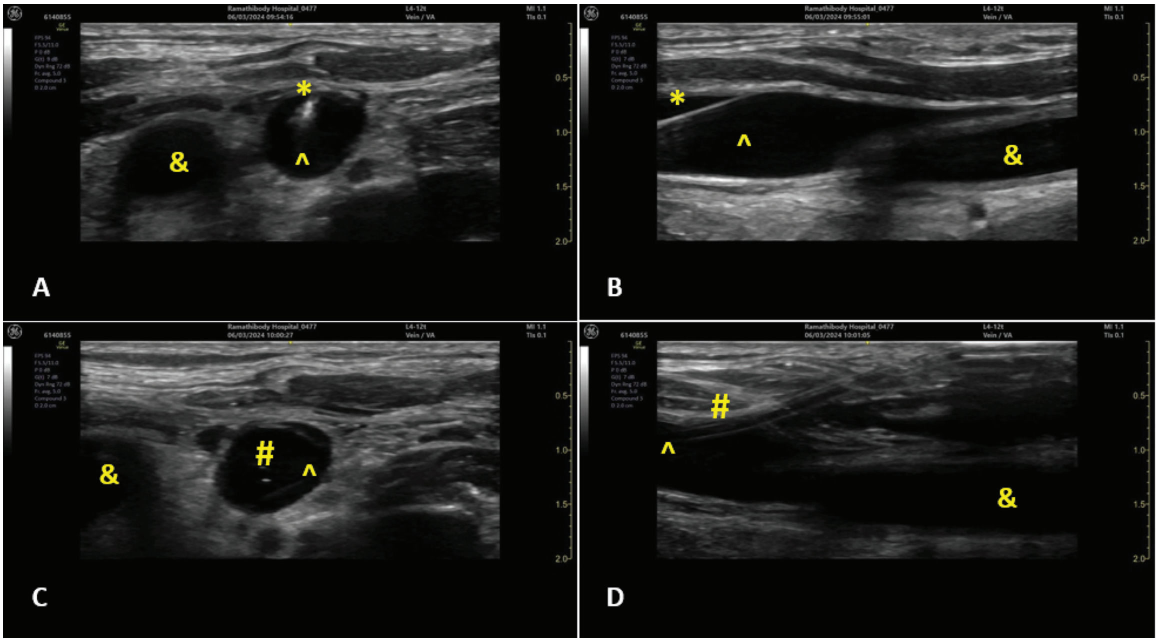

Figure 2. Depicts the confirmation of needle, wire, and catheter placement using ultrasound imaging. Panel A illustrates the placement of the wire in the internal jugular vein as observed in the sagittal view sonography, while Panel B displays the wire placement in the same vein from a longitudinal view. Panel C showcases the catheter placement within the internal jugular vein, as visualized in the sagittal view sonography, and Panel D exhibits the catheter placement in the internal jugular vein from a longitudinal view.

* Wire, # Catheter, ^ Internal jugular vein, & Carotid artery

jugular vein and increases the risk of arterial puncture[28].

Real-time ultrasound-guided CVC is the preferred method for central venous access. A study illustrated the advantages of ultrasound-guided CVC, including a reduced procedural time, enhanced success rate, and decreased occurrence of major complications[29]. Additionally, real-time ultrasound-guided internal jugular vein catheterization offers greater benefits compared to the landmark technique in several aspects, such as fewer attempts and reduced incidence of CRBSI[30]. Comparing the use of ultrasound exclusively in the prepuncture period with respiratory jugular vasodilation as a landmark for vein location in mechanically ventilated patients, the study found that prepuncture ultrasound was not superior in terms of success rate, access rate, or incidence of arterial puncture, although it proved useful in cases where respiratory jugular venodilation was unidentified[31]. Furthermore, prepuncture ultrasound is valuable for assessing vein patency and size before puncture. There are two approaches for real-time ultrasound-guided internal jugular vein catheterization, the short axis and long axis. Both approaches demonstrated similar success rates in terms of catheterization time, although the long axis approach appeared to result in fewer incidences of arterial injury and puncture of the posterior wall of the internal jugular vein[32]. However, static ultrasound should be performed before skin preparation to verify the size and patency of the internal jugular vein. Static ultrasound may be beneficial in identifying the landmark for anatomical puncture during subclavian or femoral vein catheterization.

Ensuring catheter confirmation throughout the procedure is a crucial technique to mitigate vascular injury, as depicted in Figure 2. Relying solely on blood color observation or the absence of pulsatile flow is deemed unreliable for confirming venous catheter placement. In contemporary practice, transthoracic ultrasound is advocated for verifying venous placement at each stage of the needle, wire, and catheter insertion within the venous system. Additionally, prompt acquisition of a chest radiograph post-procedure is recommended to ascertain the final position of the catheter tip and venous system placement. Upon completion of the procedure, thorough inspection of the removed guidewire within the procedural field is imperative to ensure the absence of any retained guidewire within the patient's venous system.

Management of arterial injury from central venous catheterization

If a small needle or guidewire inadvertently punctures an artery, prompt removal of the needle or guidewire is imperative. Subsequently, manual compression may be applied, particularly if the artery can be easily compressed. Conversely, in instances where a large bore central venous catheter, equal to or larger than 7 Frenches, unintentionally advances into the carotid artery, leaving the catheter or dilator in place is advisable. Immediate repair of the injured artery is warranted, utilizing surgical techniques or endovascular interventions such as balloon angioplasty, percutaneous closure devices, or covered stent placement. In complex cases, open surgery may be necessary. Removal of the catheter and application of pressure compression can precipitate severe complications including hematoma, upper airway obstruction, hemothorax, ischemic stroke, pseudoaneurysm, or arteriovenous fistula. Following arterial repair procedures, patients should undergo close serial neurological examinations to monitor their recovery progress.

Management of other complications related to central venous catheterization

Lymphatic injuries associated with CVC are infrequent. Chylothorax and chylopericardium are caused by lymphatic injuries. Because of the placement of the thoracic duct, the left-sided internal jugular vein or subclavian vein for central venous access appears to be more likely to produce lymphatic injury than the right-sided internal jugular vein. Nitric oxide, thoracoscopic fibrin glue, and percutaneous coiling are the options for managing lymphatic injuries. If lymphatic injuries are severe, TPN or low-fat enteral nutrition should be considered first, followed by invasive repair[33].

Nerve injuries are infrequent during CVC. However, incidental trauma or perineural hematoma can cause injury to the recurrent laryngeal nerve, sympathetic chain, brachial plexus, and phrenic nerve. Nerve injuries caused by CVC can take 6 to 12 months to recover[34].

Air embolism can also occur during central venous catheter insertion, especially when the patient is inspired and creates negative intrathoracic pressure. This can lead to fatal complications in patients with atrial or ventricular septal defects or patent foramen ovale, which can transmit air emboli into the left-sided of the heart and transfer to the systemic circulation. If a patient develops hypoxemia during the procedure and air embolism is suspected to be an insult, the patient should be treated with a high concentration of oxygen and turned to stay in the left lateral decubitus position. This position locks the air into the right atrium and prevents further air embolism from transferring to the pulmonary artery. Small volumes of air emboli can self-limit. In this case, the patient should receive supplemental oxygen therapy to facilitate air absorption. There are reports about using hyperbaric oxygen therapy to help air reabsorption[35,36].

Catheter-related venous thrombosis can occur at a higher incidence rate in some sites, such as the femoral vein and basilic vein or cephalic vein for PICC, especially for the long-term use of central venous catheter. General management when thrombosis occurs includes lifting the area of thrombosis above the other organs, rest, cold packs, systemic or topical therapy with anti-inflammatory drugs for pain relief. For catheter management, the clinicians should consider catheter removal if the catheter is not necessary to use. There is no routine recommendation to remove the catheter once thrombosis is diagnosed. If the clinicians consider the catheter necessary for the patients, the catheter can be retained in the patients with a full dose of anticoagulant or at least thromboprophylaxis should be prescribed until the catheter is considered to be removed. If the clinicians consider that the catheter should be removed, a full dose of anticoagulant therapy or at least thromboprophylaxis dose should be initiated three to five days before catheter removal to prevent accidental thrombus mobilization. The recommendation for the duration of the full dose of anticoagulant therapy is at least three months after the thrombotic events were diagnosed if the catheter was removed. If the catheter remains in the patient, a full dose of anticoagulant or thromboprophylaxis is recommended to be continued for at least three months after the full dose of anticoagulant and continued until catheter removal. Thrombolytic therapy may be considered in patients with severe symptoms, thrombus involving the subclavian vein and axillary vein, and symptoms persisting for more than 72 hours. The patients who are candidates for thrombolytic therapy have low bleeding risk, good functional status, and a life expectancy of more than one year. Mechanical thrombectomy and other surgical procedures to remove thrombus should be considered if the patients have persistent symptoms after anticoagulant therapy and thrombolytic therapy. Cava filters may be considered in patients who have absolute contraindications to anticoagulant therapy. The clinicians should note that this procedure has no effect on thrombosis progression, it just prevents the thrombus progression to pulmonary emboli[37].

Conclusion

Studies investigated methods aimed at reducing complications throughout each stage of central venous catheter insertion. These stages encompass skin preparation, catheter selection, insertion techniques, and the management of mechanical complications. Acquiring comprehensive knowledge of these aspects is essential to iteratively refine procedural protocols and potentially mitigate inherent complications in subsequent applications.

What is already known on this topic?

CVC has long been beneficial in medical practice, especially when peripheral venous access is difficult. This procedure should be done under fully sterile techniques. However, complications such as pneumothorax or arterial injury can still occur.

What does this study add?

Currently, the use of real-time ultrasound-guided CVC is recommended to significantly reduce mechanical complications. Moreover, selecting optimal venous sites, catheter types, appropriate disinfectants, and dressing types contribute to preventing catheter-related infections. However, if mechanical injuries occur, following proper step-by-step protocols for repair can minimize potential severe complications.

Conflicts of interest

The authors declare no conflict of interest.

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