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Review Article

A Review of Central Vein Catheter for Hemodialysis: Insertion Sites and Techniques

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ABSTRACT

Chronic kidney disease (CKD) is a global epidemic, being increasingly prevalent in both developed and developing countries, including Indonesia. Hemodialysis (HD) is the primary renal replacement therapy, along with peritoneal dialysis and kidney transplantation. The effectiveness of HD relies on well-functioning vascular access, such as central vein catheters (CVCs). These catheters are classified by their duration of use: short-term, medium-term, and long-term. They are also distinguished by insertion type (central or peripheral), insertion site (jugular, subclavian, femoral), and number of lumens (single, double, triple). The preferred site for insertion is the internal jugular vein, followed by the femoral vein and the subclavian vein. Techniques for CVC insertion include the central approach, the posterior approach, and others. This article reviews the role of CVC for vascular access in HD. Specifically, various CVC insertion sites and techniques will be examined. The authors will also discuss the available research on the application of CVC as vascular access for HD in Indonesia.
Keywords: Chronic kidney disease, hemodialysis, central venous catheter, techniques, insertion sites.

Introduction

Chronic kidney disease (CKD) has emerged as a worldwide epidemic, with its incidence rising across both developed and developing nations. In Indonesia, CKD affects 12.5% of the adult population. Most CKD patients die from cardiovascular complications. Only a small percentage reach the terminal stage, requiring kidney replacement treatment. It is estimated that 100,000 patients require kidney replacement treatment in Indonesia.[1]

In most countries globally, hemodialysis (HD) remains the primary renal replacement therapy, alongside peritoneal dialysis and kidney transplantation. Over 2 million patients around the world are currently receiving HD treatment. In Indonesia, almost 150,000 people.[1] Effective HD requires adequately functioning vascular access. The optimal access should permit the use of two needles, enable a 300 ml/minute blood flow rate, be resistant to thrombosis and infection, and have minimal side effects.[2-4] This access may be an arteriovenous fistula (AVF), a graft, or a central venous catheter (CVC).[1]

AVF is preferred for HD vascular access due to the higher incidence of complications such as infection and thrombosis associated with grafts and CVC.[5] However, it takes at least 6 weeks for the AVF to be usable, and sometimes additional surgical intervention is required for the AVF to mature and be usable.[6, 7] For those with heart failure, chronic lung disease, or steal syndrome, AVF may not be the best option since it can result in intense pain and peripheral ischemia. On the other hand, grafts can be used for cannulation approximately 2-3 weeks after

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being implanted. However, grafts are generally not the preferred option for vascular access in hemodialysis patients.[8, 9] Therefore, CVC, whether temporary or permanent CVC, can be considered as vascular access for HD patients with such conditions.

This article reviews the role of CVC as a vascular access in HD. Specifically, various CVC insertion sites and techniques will be examined. The authors will also discuss the available research on the application of CVC as vascular access for HD in Indonesia.

Central Vein Catheter (CVC)

CVC insertion is a frequently performed procedure carried out in approximately 8% of hospitalized patients. It is also indicated in various treatments, such as plasmapheresis, HD, placement of defibrillator devices, and other procedures. The patient's anatomy and the indications for the CVC insertion, among other factors, determine the insertion sites and the number of lumens on the catheter.[10, 11]

The CVC is an appropriate option for vascular access when urgent or emergent HD is needed, such as in acute conditions or when other accesses are unfit. Due to its multiple insertion sites, the CVC is highly accessible and flexible. Furthermore, it provides swift access for HD as no maturation is necessary.[12] CVCs are typically categorized by 1) duration of use: short-term, medium-term, and long-term; 2) insertion method: central or peripheral; 3) insertion site: jugular, subclavian, femoral, and brachial; and 4) a number of lumens: single-lumen and multi-lumen.[13]

Catheters for HD usually have 2 lumens attached to 2 portals, one red and the other blue. The red portal indicates that the lumen is connected to the artery; hence, it draws blood from the body. Meanwhile, the blue portal suggests that the lumen is connected to the vein; thus, it returns blood from the HD machine back to the patient's body.[14]

Compared to catheters used for CVC in general, those used for HD have a larger diameter to produce greater flow velocity. This is in accordance with Poiseuille's law, which posits that a catheter's flow rate is influenced by its resistance to flow and is directly proportional to the length of the catheter and inversely proportional to its diameter. It is also affected by viscosity, which causes a higher resistance.[14]

Landmark and Methods of CVC Insertion

The choice of where to place a central vein catheter depends on several factors: the operator's proficiency, the patient's anatomy (such as existing venous blockages or lymphedema), potential risks like clotting issues or pulmonary disease, and specific needs related to the condition of patient and the length of time the catheter will be needed.[15-19]

The ideal insertion site should be clean and free from contamination. Contaminated areas include areas in proximity to tracheostomies or open surgical wounds, and burned or infected skin.[15] Furthermore, catheterization of sites that have experienced local anatomical alterations (such as healed clavicle fractures), scarring from previous accesses, or where there is already a central venous catheter or other implanted devices (like pacemakers or internal defibrillators) increases the likelihood of complications including failure, misplacement, dysrhythmias, and other issues. Whenever possible, alternative sites should be considered to minimize these risks.[6, 17] The presence of substantial lung disease affecting one side should warrant inserting the CVC on the contralateral side.[13]

The internal jugular vein, femoral vein, and subclavian vein are commonly selected sites for placing a CVC. Ultrasonography plays a crucial role in this process. It facilitates prompt and precise identification of the veins while also yielding information such as venous pressure and thrombus presence.[20] The benefits and drawbacks of each site are elaborated in Table 1.[13]

Table 1. Advantages and disadvantages of venous access based on insertion location.

Approach	Advantages	Disadvantages
External jugular	• Superficial vessel that is often visible • Coagulopathy not prohibitive • Minimal risk of pneumothorax (especially with US guidance) • Head-of-table access • Prominent in older adult patients • Rapid venous access	• Not ideal for prolonged venous access • Poor landmarks in patients with obesity • High rate of malposition • Catheter may be difficult to thread
Internal jugular	• Minimal risk of pneumothorax (especially with US guidance) • Head-of-table access • Procedure-related bleeding amenable to direct pressure • Lower failure rate with novice operator • Excellent target using US guidance	• Not ideal for prolonged access • Risk of carotid artery puncture • Uncomfortable • Dressings and catheter difficult to maintain • Thoracic duct injury possible on left • Poor landmarks in patients with obesity/edematous patients • Potential access and maintenance issues with concomitant tracheostomy • Vein prone to collapse with hypovolemia • Difficult access during emergencies when airway control being established
Subclavian	• Easier to maintain dressings • More comfortable for patient • Better landmarks in patients with obesity • Accessible when airway control is being established • Associated with lower incidence of catheter-related infection*[1]	• Increased risk of pneumothorax • Procedure-related bleeding less amenable to direct pressure • Decreased success rate with inexperience • Longer path from skin to vessel • Catheter malposition more common (especially right SCV) • Interference with chest compressions • Risk for stenosis/occlusion, which impacts future hemodialysis arteriovenous access
Femoral	• Rapid access with high success rate • Does not interfere with CPR • Does not interfere with intubation • No risk of pneumothorax • Trendelenburg position not necessary during insertion	• Delayed circulation of drugs during CPR • Prevents patient mobilization • Difficult to keep site sterile • Difficult for PA catheter insertion • Increased risk of iliofemoral thrombosis

US: ultrasound; SCV: subclavian vein; CPR: cardiopulmonary resuscitation; PA: pulmonary artery.
*From Parienti, infection rates: subclavian 0.5%; jugular 1.4%; femoral 1.2%.

Internal Jugular Vein

The internal jugular vein extends from the sigmoid sinus as it exits the jugular foramen at the base of the skull. Positioned within the carotid sheath alongside the carotid artery and vagal nerve (Figure 1), these veins typically show asymmetry in size between the left and right sides in patients, with a notable diameter disparity in over one-third of cases. The internal jugular vein's diameter tends to as it progresses downward into the chest.[21-23]

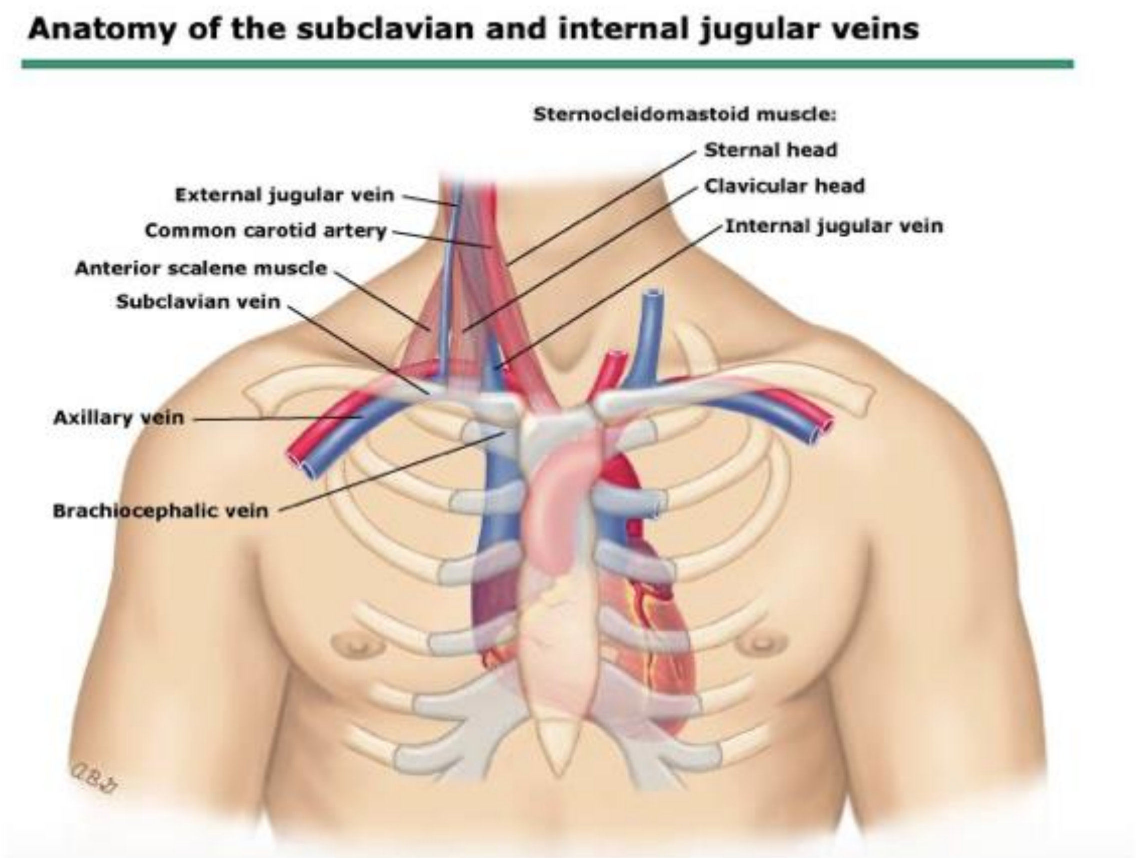

Figure 1. Anatomy of the internal jugular vein and subclavian vein[13]

The internal jugular vein exits the skull towards the internal carotid artery. As it reaches the level of the cricoid cartilage, it runs beneath the sternocleidomastoid muscle, and further down, it lies between the two heads of this muscle at the neck's base. Around this area, the veins are positioned superficially, between 1 and 1.5 cm beneath the skin surface. Eventually, behind the medial end of the clavicle, the internal jugular vein merges with the subclavian vein to form the brachiocephalic vein.[24]

The external jugular vein is a visible superficial neck vein (Figure 2) that runs across the sternocleidomastoid muscle. It connects with the anterior subclavian vein or can be situated just outside the anterior scalene muscle. Typically, the external jugular vein has a diameter exceeding 10 mm, and its size inversely correlates with that of the internal jugular vein.[25]

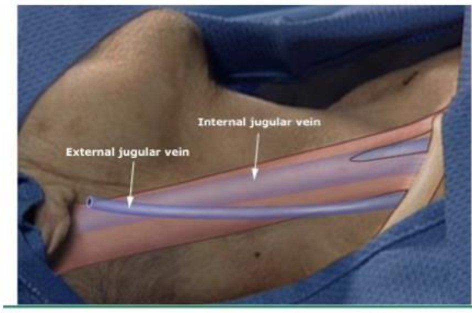

Figure 2. Anatomy of internal jugular vein and external jugular vein[13]

For several reasons, the preferred site for CVC insertion is the internal jugular vein (Figure 3). First, it is a prominent superficial vein that can be readily visualized using ultrasound. Second, this vein provides a direct pathway to the right atrium or superior vena cava, ensuring rapid blood flow. Third, its lower section lies behind a triangular area formed by the junction of the sternomastoid and clavicle muscles, which serves as a landmark for CVC placement.[12] The right internal jugular vein is favored due to lower malposition risks. However, the left side internal jugular vein may be chosen when extensive scarring or venous thrombosis is present on the right side.[13]

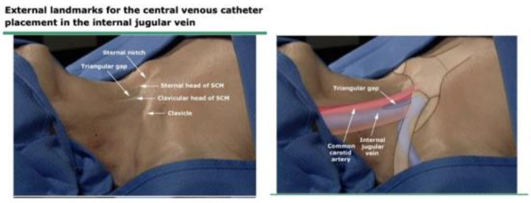

Figure 3. Landmark of CVC insertion through the internal jugular vein[13]

Normally, this vein is located anterolateral to the internal jugular artery, but in some cases, it is located anterior or even medial to the artery.[26] For this reason, ultrasonography is very useful in such cases.[27]

Proper patient positioning involves tilting the head about 10 degrees to insert a CVC. This helps locate the vein effectively and lowers the risk of air embolism.[28] To ensure safety during the procedure, it is advisable to keep the patient's head in a neutral position. As this vein runs closely above the carotid artery, there is a significant risk of accidental puncture into the artery. Minimal rotation of the patient's head towards the side where cannulation is being performed may be required. However, excessive rotation should be avoided since it can compress the vein, potentially reducing its diameter.[29] Moreover, head rotation can cause the vein to shift sideways, further complicating locating it.[30]

Two methods are distinguished by whether the needle is visible during vein entry. One involves using ultrasound, positioning the probe along the long or short axes. Currently, the short axis view from the side has proven effective, making it the preferred method for cannulating the internal jugular vein.[31] The alternative method is direct insertion, also known as the Seldinger technique. This method involves using a guide wire alongside the needle. After the vein is accessed, a guide wire is carefully inserted, and the needle is withdrawn. It's crucial to avoid advancing the wire excessively to prevent irritation of the right atrium and potential arrhythmias. Subsequently, before introducing the catheter, the dilator must be cautiously passed over the guide wire to minimize venous trauma.[32] The Seldinger technique has three approaches: the central approach, the posterior approach, and the anterior approach.[13]

Central Approach

The most utilized method is a central approach to the internal jugular vein (Figure 4). The needle insertion site is identified at the triangular apex created by the sternocleidomastoid muscle, located approximately 5 cm above the clavicle.[13] Table 2 details the steps in performing the central approach for internal jugular vein catheterization.

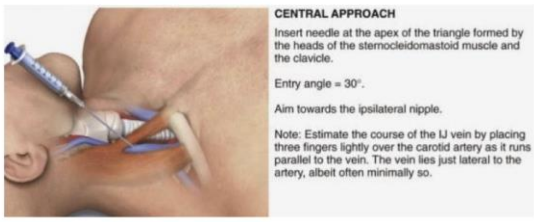

Figure 4. Central approach[13]

Table 2. Steps in performing the central approach technique

1. Insert the needle adjacent to the carotid pulse at a relative 30 to 45-degree angle to the skin. 2. Guide the needle laterally in the sagittal plane toward the nipple on the same side. This path typically runs along or beneath the lateral edge of the sternocleidomastoid muscle. 3. Approaching the jugular vein from medial to lateral may lower the risk of pneumothorax and accidental puncture of the carotid artery. 4. If blood cannot be aspirated within 2.5 cm of depth, slowly withdraw the needle while maintaining continuous negative pressure and check for blood aspiration. 5. If the initial needle insertion is unsuccessful, promptly withdraw the needle to the skin surface and redirect it 10 degrees medially.

Posterior Approach

Table 3 details the steps in performing the posterior approach for internal jugular vein catheterization. To enhance the visibility of the insertion site and potentially improve the success rate of access using the posterior approach (Figure 5), one should turn the head towards the opposite side.[13]

Table 3. Steps in performing the posterior approach technique

1.	Place the needle along the back edge of the sternocleidomastoid muscle where its middle and lower sections meet. This spot lies about 5 cm above the clavicle and is typically identifiable by the presence of the external jugular vein.
2.	Begin inserting the needle beneath the posterior sternocleidomastoid muscle and proceed in an anteromedial direction toward the sternal notch.
3.	Any further adjustment in needle direction should be carried out in a methodical manner, progressing from the outer to the inner needle position

Anterior Approach

Table 4 details the steps in performing the anterior approach for internal jugular vein catheterization. Using the anterior technique, one approaches the internal jugular vein from the point where it enters anterior to the sternal head of the sternocleidomastoid muscle (Figure 6).[13]

Table 4. Steps in performing the anterior approach technique

1.	Feel the carotid artery.
2.	Place the needle 5 cm above the sternum, precisely at the midpoint of the front edge of the sternocleidomastoid muscle.
3.	Guide the needle outward toward the carotid pulse along a trajectory aimed towards the same side's nipple.

Figure 6. Anterior approach[13]

A catheter inserted through the right jugular vein typically measures approximately 15 cm, while insertion through the left internal jugular vein measures about 17 cm. In the case of a temporary CVC, it is crucial that the tip is positioned outside the right atrium, a placement that should be confirmed during the procedure using electrocardiography or through a post-procedure chest X-ray prior to commencing hemodialysis. In contrast, for a cuffed tunneled catheter, one end of the CVC must reach the right atrium, while the other end should be positioned 1 cm above and outside the right atrium.[12]

Femoral Vein

The primary deep vein in the lower limbs, the femoral vein (Figure 7) travels through the thigh and then becomes superficial in the femoral triangle. It passes under the inguinal ligament and continues into the pelvis as the external iliac vein. Below the inguinal ligament, at the level where the femoral nerve is situated, lie the hip joint and the psoas muscle.

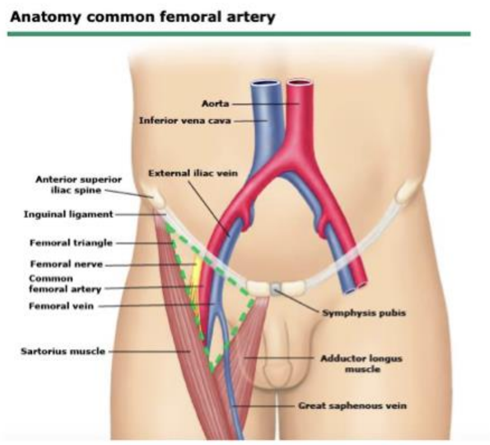

Figure 7. Femoral vein anatomy[13]

In the femoral triangle, the femoral sheath shields the common femoral vein, positioned medially relative to the femoral artery. It receives blood from the anterior saphenous vein and the great saphenous vein. These veins are sometimes mistaken for femoral veins and unintentionally used for cannulation during CVC placement. The femoral artery serves as a landmark to guide needle insertion. The mid-inguinal point lies between the anterior superior iliac spine and the pubic tubercle.

The femoral vein is an alternative site for placing a temporary CVC in hospitalized patients, often chosen when there's a reduced risk of bleeding and no need for immediate post-placement radiological confirmation. Nonetheless, an X-ray verification may be beneficial to ensure proper CVC position. Confirmatory x-ray should show no twisting of the tube and that its tip has not entered unintended veins like the lumbar vein or its branches.[12]

For insertion at the femoral vein, the patient lies on their back with the thigh moved outward and rotated externally. The entry point for the needle into the femoral vein is positioned just under the inguinal ligament (around 2 cm below) and towards the inside of the femoral artery (Figure 8). The needle typically goes about 2–4 cm deep and is inserted at an angle of 10–15°. The femoral vein can also be accessed using the Seldinger technique.[12]

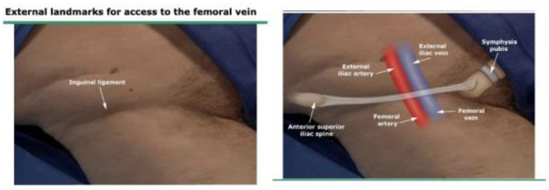

Figure 8. Landmark for CVC insertion via femoral vein[13]

The Valsalva maneuver widens the femoral vein's diameter. Ideally, when inserting the distal tip of a CVC via the iliac vein, it should be positioned optimally in the right atrium or the inferior vena cava. However, typical catheters (20 cm long) frequently only access the iliac vein, resulting in heightened blood recirculation at this tip location. It is important to note that using a longer catheter would increase resistance to blood flow even more.[12]

Subclavian Vein

For subclavian cannulation, the clavicle is the primary reference point (Figure 9). The sternal head appears elongated in an S-shape (double curve horizontally) when moving outward from the suprasternal notch: the middle two-thirds forms the convex anterior portion, while the outer third forms the concave anterior portion.[13]

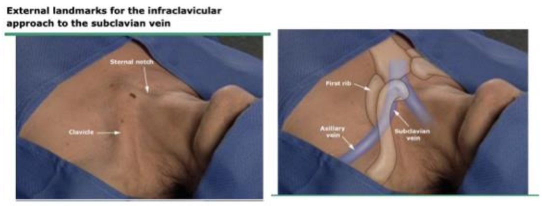

Figure 9. Landmarks for CVC insertion via subclavian vein[13]

The subclavian vein originates as a direct extension of the axillary vein, commencing at the outer edge of the first rib. It arches posteriorly behind the medial clavicle and descends towards the internal jugular vein, which merges to form the brachiocephalic vein behind the sternoclavicular joint. Alongside the subclavian vein runs the subclavian artery, positioned superiorly and posteriorly to the vein, with the anterior scalene muscle separating the two.[13]

Inserting a catheter into the subclavian vein is seen as a less preferred option due to the significant risk of developing subclavian thrombosis. This procedure aims to puncture the upper part of the subclavian vein where it meets the internal jugular vein. Accurately identifying the clavisternomastoid angle, formed by the junction of the lateral aspect of the sternocleidomastoid muscle and the clavicle, is crucial for successful access. Elevating the patient's head actively can enhance visibility of this landmark.

The Seldinger technique allows access through the subclavian vein. It can be performed using three methods: below the collarbone (infraclavicular), above the collarbone (supraclavicular), and through the armpit (axillary).[13]

Infraclavicular Approach

The infraclavicular approach to the subclavian vein necessitates three insertion points (Figure 10). The midpoint technique is frequently employed in this procedure, wherein the needle is positioned approximately 2 to 3 cm below the midpoint of the clavicle (around 1 to 2 cm lateral to the clavicle's curve) and aimed just behind the suprasternal notch.[33]

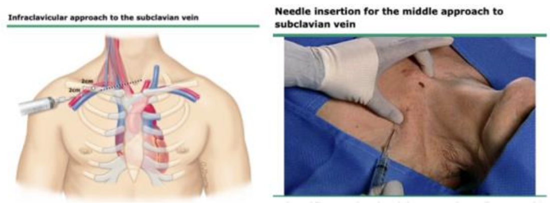

Figure 10. Infraclavicular approach[14]

The lateral needle insertion (outside the midclavicular line) leverages the thinner front section of the clavicle, making it easier to approach at the coronal level. This can enhance safety if the needle can access the vein. The medial insertion point lies along the inner third of the clavicle. To access the larger vein, the needle is directed towards the suprasternal notch. However, this method has a drawback: the steep angle required under the thick medial clavicle and through soft tissues like the costoclavicular ligament.

The needle may initially encounter the clavicle and could puncture the periosteum after breaking through the skin, potentially causing bone fragments to block the needle. To reach the lower edge of the clavicle, the needle should be gently advanced deeper. Throughout this process, it is crucial to keep the needle parallel to the clavicle (in the coronal plane) to pass beneath the bone and reduce the risk of puncturing the pleura. Once the needle reaches below the junction of the middle and medial thirds of the clavicle, it should enter the vein. Adjust by aiming the needle slightly upward during the subsequent insertion if the first attempt is unsuccessful.[33]

Supraclavicular approach

The supraclavicular approach targets puncturing the subclavian vein close to its confluence with the internal jugular vein. The sternocleidomastoid clavicular head region is the landmark for insertion in this technique. The subclavian vein lies at a depth of approximately 1 to 1.5 cm beneath the skin surface and is readily accessible with a needle. To access it, the needle is inserted 1 cm to the side of the outer edge of the sternocleidomastoid muscle and 1 cm behind the clavicle. It should be angled 45° relative to both the front-to-back and side-to-side planes, and at a 15° downward angle from the top-to-bottom plane, aiming towards the opposite nipple (Figure 11).[33] The needle enters an avascular plane by bisecting the angle formed by the clavicle, sternum, and mastoid process. It avoids the subclavian artery and the pleural dome, targeting the confluence of the subclavian vein and internal jugular vein. The right side is favored due to the lower position of the pleural dome, a more direct path to the superior vena cava, and the absence of the thoracic duct.[12]

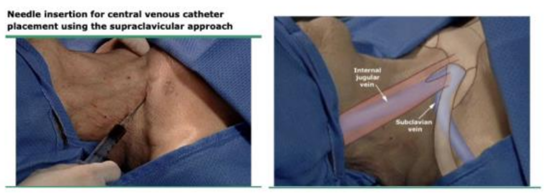

Figure 11. Supraclavicular approach[13]

Axillary approach

The axillary approach is rarely employed. It involves using ultrasonography to locate and access the vein where the subclavian vein meets the axillary vein. The Trendelenburg position is advised to reduce the chances of air embolism and may aid in venous dilation since the subclavian vein lacks superior fascial constraint. To mitigate complications, the needle should point downwards during insertion, and it is crucial to accurately identify the clavisternomastoid angle beforehand. However, this method is associated with increased risks of bleeding, pneumothorax, and thrombosis.[12]

Vascular Access Recommendation

According to KDOQI guidelines, selecting the appropriate location and type of long-term access significantly impacts survival rates and reduces complications. Ideally, vascular access should be distal and situated in the upper extremities. The preferred choice is an AVF, with AVG as a secondary option before considering CVC. CVCs should only be used as a final option when AVF and AVG are not feasible for the patient. The guidelines also stated that the preferred site for placing a dialysis catheter is the right internal jugular vein. However, other alternatives are the right external jugular vein, as well as both the left internal and external jugular veins, the subclavian vein, and the femoral vein. The subclavian vein is considered only when access through the upper extremities or other thoracic areas is not feasible.

KDOQI has issued several basic principles regarding dialysis catheters (Table 5). The use of ultrasound during dialysis catheter insertion and radiological confirmation of the catheter tip is endorsed by KDOQI.

Table 5. Basic principles of catheter use in dialysis

1. Long-term catheters, including tunneled and port catheters, require the catheter tip to be positioned in the right atrium, confirmed by fluoroscopy to ensure adequate flow.
2. Short-term catheters should be placed in the superior vena cava and confirmed by radiology or fluoroscopy before commencing hemodialysis.
3. Non-cuffed dialysis catheters are suitable only for hospitalized patients and should be used for less than one week.
4. A plan should be established to discontinue or transition from a short-term catheter to a long-term catheter within one week.
5. Long-term or port catheters should not be inserted at the same site as an arteriovenous fistula (AVF).
6. The femoral dialysis catheter should be sufficiently long to ensure adequate blood flow and minimize recirculation, aiming for an expected flow rate of 300 ml/min with a recommended catheter length of 24–31 cm.
7. Currently, no evidence shows the superiority of one catheter design over another. The selection of a dialysis catheter should be based on clinical experience, objectives, and cost considerations.
8. Dialysis port catheters can be used alongside long-term catheters as temporary access while awaiting permanent access solutions.

Application of CVC for HD in Indonesia

A 2021 study involving 151 CKD patients in Dr. Mohammad Hoesin, Palembang, Indonesia, found that the most prevalent HD vascular access was temporary vascular access (61%). Most patients with permanent vascular access had a brachiocephalic fistula (46.3%). Meanwhile, long-term double-lumen catheters were most frequently observed in those with temporary vascular access. The most used site in patients with short-term double-lumen catheters was the femoral vein. On the other hand, internal jugular vein access was seen in most patients with long-term double-lumen catheters.[34] Similarly, a 2019 research study of 150 subjects with stadium 4–5 CKD at Cipto Mangunkusumo National Hospital reported that CVC was more often inserted at the internal jugular vein.[35]

A cohort of 151 Indonesian patients undergoing HD in a period of 13 months had an infection rate of 37%, according to a retrospective cohort study by Widani and Suryandari. They concluded that the lengthy duration of catheterization, femoral insertion, and the presence of diabetes mellitus were risk factors for the incidence of infection in patients with double lumen catheter undergoing HD.[36] Ocsyavina and Patrianef reported a 7.53% incidence of central vein stenosis in 717 patients with CVC undergoing HD. They found that the subclavian insertion site (compared to the internal jugular) and previous multiple ipsilateral catheterization were associated with the incidence of central vein stenosis, with an odds ratio of 148.77 and 63.82, respectively.[35]

Conclusion

Vascular access is typically categorized into two types: permanent, such as AVF, and temporary, which involves inserting a central venous catheter. Central venous catheters are classified by the duration of use (short-term, medium-term, and long-term), insertion type (central or peripheral), insertion location (jugular, subclavian, femoral, and brachial), and number of lumens (single, double, or triple). Effective hemodialysis depends on having reliable vascular access. CVCs can provide rapid HD access and may be suitable for certain patients. Sufficient knowledge of anatomy and proper techniques are required to ensure a successful CVC insertion. Apt selection and maintenance of CVCs are crucial for reducing complications and improving patient outcomes in HD treatment. Addressing CKD's rising incidence requires advancing these vascular access techniques and ensuring their practical application.

Declarations

Competing interests

None declared.

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Author's Contribution

Idea/concept: JPS, AR. Design: JPS, AR. Control/supervision: JPS, AR. Data collection/processing: JPS, AR. Analysis/interpretation: JPS, AR. Literature review: JPS, AR. Writing the article: JPS, AR. Critical review: JPS, AR. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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