Ultrasound-guided central venous catheterization

Philips tutorial

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sense and simplicity

Table of contents

1 Introduction

Central venous catheterization (CVC) is an important procedure in the practice of emergency medicine and critical care. CVC allows for multiple critical actions to be performed: these include the administration of intravenous fluids, blood products and vasoactive medications, as well as the insertion of specialized devices such as pulmonary artery catheters and transvenous cardiac pacing wires. CVC may also be the lone option in cases where standard peripheral access cannot be obtained.

With the increasing availability of bedside ultrasound, emergency medicine and critical care physicians have incorporated this new technology to reduce error and increase procedural success. Over the past two decades, numerous studies have demonstrated that ultrasound guidance during central venous catheterization can increase success rates and decrease complications.[1] The Agency for Healthcare Research and Quality (AHRQ), the Institute of Medicine (IOM) and the National Institute for Health and Clinical Excellence (NICE) have all endorsed ultrasound guided central venous catheterization (UGCVC) as a recommended practice.

Given the importance of CVC and the robust data on the utility of ultrasound guidance for reducing complications and procedural failure, it is paramount that emergency medicine and critical care physicians become proficient with UGCVC.

2 Clinical case

A 74 year old female with a past medical history of atrial fibrillation and warfarin use is brought to the emergency department (ED) for generalized weakness. The patient is noted to have abnormal vital signs when she arrives in the ED. Her blood pressure is 90/40 mmHg, heart rate is 110/minute and temperature is 38.4 C. The nurse is unable to obtain peripheral vascular access in the patient after multiple attempts. Central venous vascular access would be an ideal choice for this patient.

You remember the recent recommendations not to use the femoral vein due to the high rate of infection and thrombosis.[1] You decide against the subclavian vein given its relative non-compressibility in a patient who is presumed to be coagulopathic due to warfarin use. You, therefore, choose the internal jugular vein as the most appropriate site for central venous catheterization and you plan to use real-time ultrasound guidance to increase success and reduce procedural complications.

3 Anatomy

The internal jugular vein is a direct continuation of the sigmoid sinus and exits the skull through the jugular foramen just anteromedial to the mastoid process. It joins the subclavian vein deep and just lateral to the head of the clavicle. The surface projection of the internal jugular vein runs from the earlobe to the medial clavicle between the sternal and clavicular heads of the sternocleidomastoid muscle. The internal jugular vein increases in diameter as it descends. It is joined by tributary veins in the upper neck, making it easier to cannulate below the level of the cricoid cartilage.

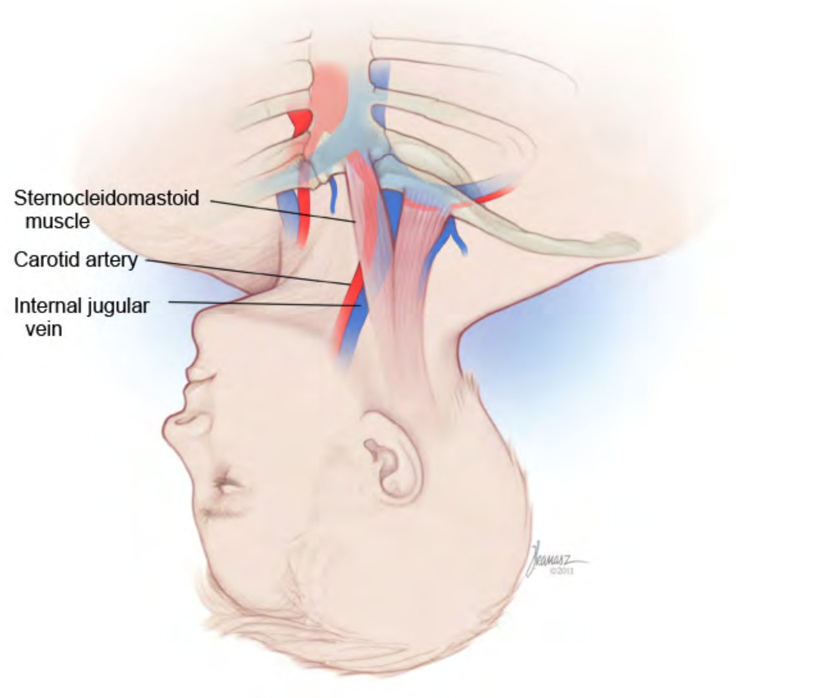

Figure 1 Relevant anatomy of the neck.

3 Anatomy

The position of the internal jugular vein in relation to the common carotid artery within the carotid sheath can vary considerably between individuals. The traditional assumption that the internal jugular vein is always located lateral to the carotid artery has been debunked in ultrasonographic studies.

Figure 2 Short axis view – the internal jugular vein is lateral (screen right) to the carotid artery in this patient.

Depending on individual anatomic variation, patient positioning and the location at which the internal jugular vein is imaged, overlap of the carotid artery can vary from 0%-100%. The internal jugular vein can even lie medial to the carotid artery, making blind needle puncture nearly impossible and extremely dangerous.

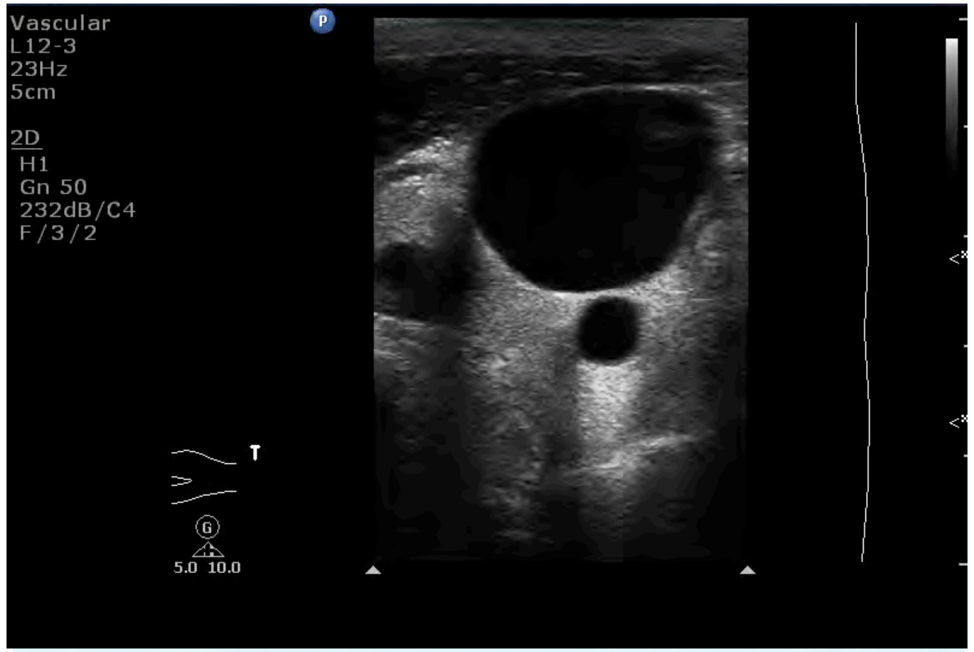

Figure 3 Short axis view – the internal jugular vein directly overlies the carotid artery in this patient.

3 Anatomy

In addition, the internal jugular vein varies in size as much as it does in location. In the same individual, the internal jugular vein can vary considerably in size and location when comparing the right and left sides, and the proximal and distal locations.[2-4] Mey et al. showed that an internal jugular vein size of less than 0.7 cm may be an independent risk factor for unsuccessful CVC.[5]

The internal jugular vein is collapsible and, therefore, its diameter is dependent on volume status and patient position. In hypovolemic patients the vein is easily compressible and will collapse with gentle external pressure from the transducer or from a palpating finger or even a large-diameter needle indenting the skin (Video 1). In the absence of a direct mass effect compressing the vein, placing the patient in the Trendelenburg position or having the patient perform the Valsalva maneuver will distend the vein making it easier to locate and cannulate (Video 2).

Video 1 Video demonstrating collapse of the internal jugular vein with gentle external pressure from the transducer.

3 Anatomy

Video 2 Video demonstrating the internal jugular vein distending when the patient performs the Valsalva maneuver.

The right internal jugular vein is generally preferred when compared to the left internal jugular vein as the site of central venous catheterization. The right internal jugular vein provides a nearly direct route to the superior vena cava. The dome of the right lung is somewhat lower than that of the left lung, thus theoretically decreasing the chance of inadvertently introducing an iatrogenic pneumothorax. Additionally, the thoracic duct is relatively large and lies high in the left chest. For these reasons the right internal jugular approach to central venous catheterization is generally preferred, although the left internal jugular vein may prove more attractive in any given individual due to anatomic variation or other factors such as thrombosis of the right internal jugular vein.

These facts form a strong argument for ultrasonographic guidance during internal jugular vein central line placement, as the potential for complications from blind access is considerable.

4 Ultrasound technique

Ensure that the ultrasound monitor is clearly visible so that the physician can visualize the area of skin puncture as well as the ultrasound monitor without requiring significant neck movement (Figure 4).

Figure 4 Ensure that the ultrasound system is clearly visible so that the physician can visualize the area of skin puncture and the ultrasound monitor without requiring significant neck movement.

Most physicians use a high-frequency linear transducer for central vascular access as it provides optimal imaging of superficial structures. For vasculature deeper than the limits of a high-frequency linear transducer, a low-frequency curvilinear transducer can be used. The authors recommend that deep intravascular lines requiring the use of a low-frequency curvilinear transducer be performed by clinicians who have considerable experience with ultrasound-guided CVC.

Prior to sterile preparation for the procedure, an initial screening ultrasound scan of the internal jugular vein should be performed bilaterally.

- Place the transducer on the skin in the transverse orientation in relation to the vein. The authors recommend that the transducer orientation marker is oriented to the clinician's left to synchronize the anatomic orientation of the patient and the ultrasound monitor (Figure 5).
- The screening scan should be started at the angle of the mandible and continued along the full course of the vein down into the supraclavicular fossa.
- Make note of the percentage of arterial overlap and the size of the internal jugular vein.

4 Ultrasound technique

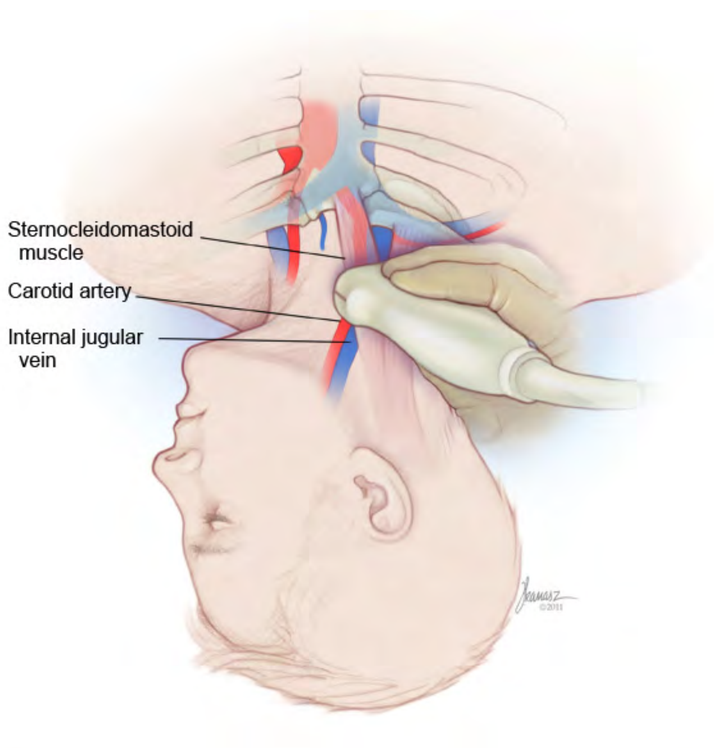

Figure 5 High frequency linear transducer in a transverse orientation. Note the transducer orientation marker on the transducer.

Based on this screening exam, choose the side and location that will optimize your chance for uncomplicated central venous access.

Data for the internal jugular vein show that veins with a diameter less than 7 mm, veins that collapse completely with inspiration, or veins that overlap 100% with the carotid artery may be associated with higher complication rates for novice providers.[6,7] If pathologic findings are present (i.e. visible thrombosis, mass with venous compression), then another site should be chosen.

Broadly anesthetize the skin prior to sterilization. Injecting after cleansing the skin with alcohol but prior to full sterile preparation will let the anesthesia take effect during full sterile preparation and, therefore, potentially increasing patient comfort.

Next, prepare and drape the site in the normal sterile fashion for the procedure. The transducer should be covered with a sterile sheath and placed on the sterile field. This can be done with or without assistance (Videos 3 and 4).

4 Ultrasound technique

Video 3 Technique for applying a sterile probe sheath when an assistant is available.

Video 4 Technique for applying a sterile probe sheath when an assistant is unavailable.

4 Ultrasound technique

Although an assistant can hold the ultrasound transducer (two-operator technique), the authors recommend becoming comfortable with the single operator technique (non-dominant hand holds transducer, dominant hand holds syringe) as it increases physician independence, decreases personnel procedural burden and removes the potential for second operator fluid-or-needle exposure. Data are limited comparing single versus two-operator techniques with no proven difference in success rates or complication rates to date.[6]

Ultrasound data for the internal jugular vein show that when using traditional anatomic landmarks, the needle is more likely to traverse the common carotid artery the farther the head is turned from midline during the procedure.[8,9] Therefore, we recommend limiting head rotation when attempting central access of the internal jugular vein.

The main benefit of ultrasound-guided CVC is to help introduce the needle at an appropriate trajectory to avoid injury to critical anatomic structures. The target vein should be imaged and placed in the center of the ultrasound field.

For clinicians who are new to ultrasound guided central venous access, the transverse orientation of the linear transducer is recommended. This view will allow the operator to visualize the target vein and surrounding critical structures throughout the procedure. However, the disadvantage of this technique is that only the short axis of the needle (not the entire needle) is visualized at one time. The majority of studies to date have used this imaging plane (Figure 6).

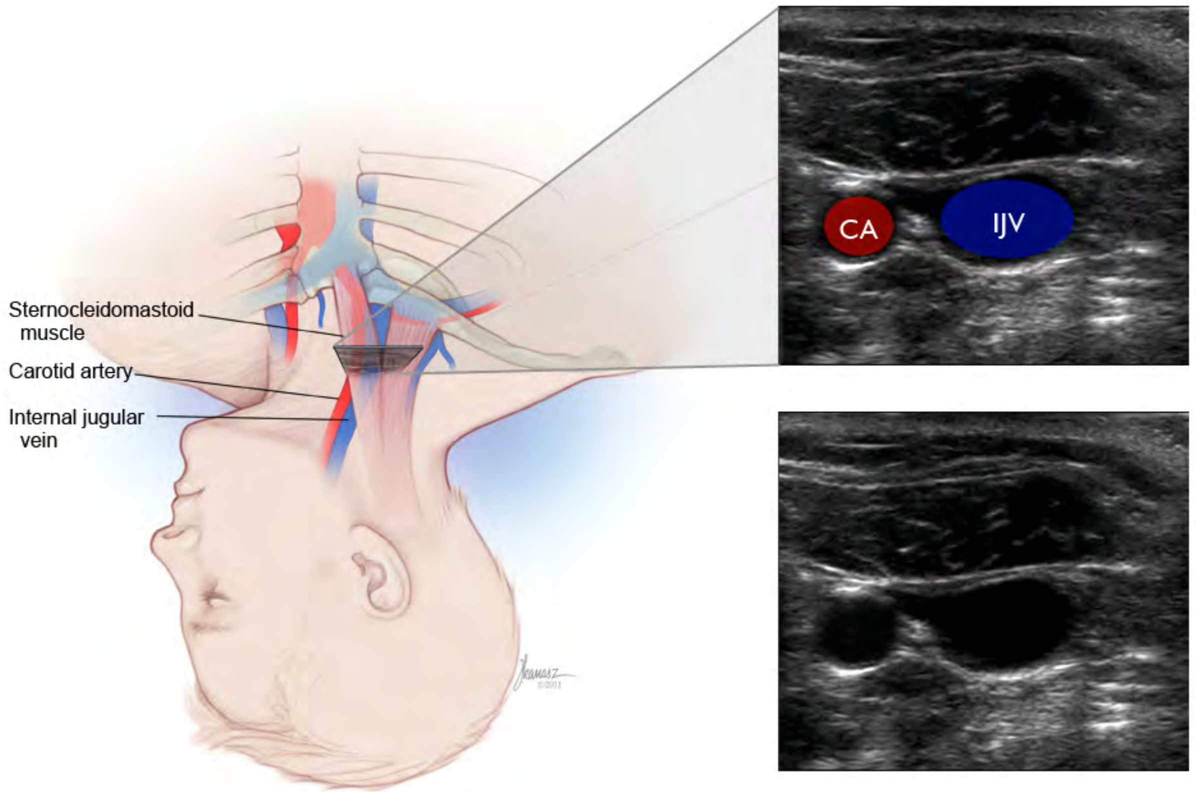

Figure 6 Illustration demonstrating plane of imaging and ultrasound image obtained utilizing a transverse view. Note the position of the internal jugular vein, the carotid artery and the overlying sternocleidomastoid muscle.

4 Ultrasound technique

However, in cases when a high degree of internal jugular vein and carotid artery overlap is present, we recommend the in-plane approach (also known as the longitudinal approach) to minimize error (carotid artery puncture). The longitudinal imaging plane technique can be more technically demanding and does not consistently allow for visualization of the surrounding critical structures during the procedure. Each provider must weigh the advantages and disadvantages of these approaches in conjunction with their own experience and select which will be used.

When puncturing the skin, angle the needle at 40 to 60 degrees from the plane of the skin and 1 cm proximal to the center of the ultrasound transducer. The physician should note a depression of the skin and superficial soft tissues overlying the target vein on the ultrasound image. This soft tissue depression should be located directly over the target vein if the needle is positioned properly (Figure 7 and Figure 8).

Figure 7 Photo demonstrating needle angle at 40 to 60 degrees from the plane of the skin and 1 cm proximal to the center of the ultrasound transducer.

4 Ultrasound technique

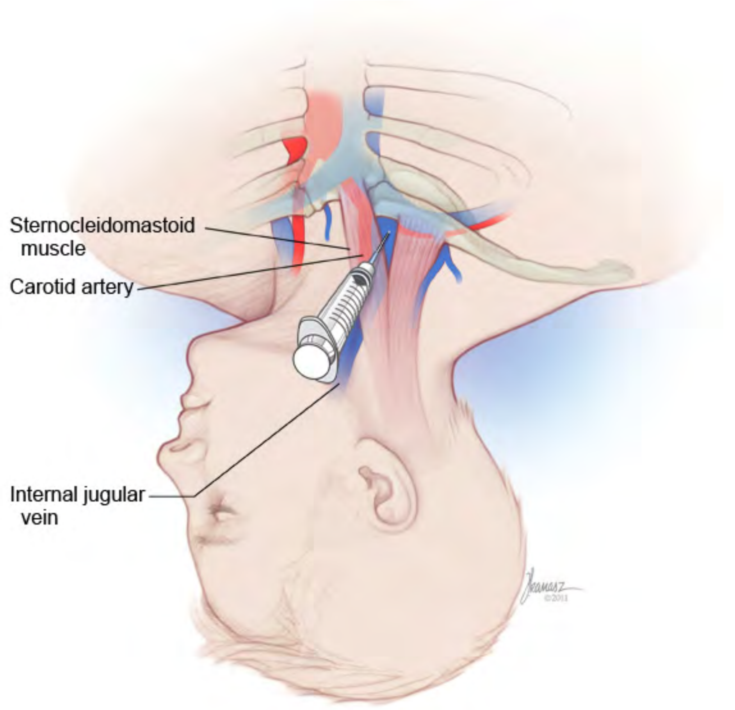

Figure 8 Illustration demonstrating the position of the syringe and angle of the needle.

Things to keep in mind:

- The physician should be looking at the patient's skin and the needle during any adjustments in needle position.
- The authors recommend advancing the needle in small (<1 cm) increments.
- After each advance, the physician should check the ultrasound image to ensure the proper needle trajectory has been maintained.
- Being aware of the first sign of blood (the "flash") in the syringe will avoid the common mistake of posterior wall ("through and through") vessel puncture, as this may lead to puncture of the carotid artery if there is significant overlap of the internal jugular over the carotid (Video 5).
- If the needle tip appears to be located laterally or medially to the vessel, withdraw the needle to just below the skin surface, and then adjust the needle orientation accordingly.
- Having the transducer orientation marker towards the clinician's left makes this an intuitive process and avoids confusion regarding needle orientation.

4 Ultrasound technique

Video 5 Short-axis approach using dynamic ultrasound guidance for internal jugular vein catheterization demonstrating initial return of blood (flash) into the syringe.

When the needle is passed correctly, the needle tip will be seen on the ultrasound image to compress the anterior aspect or "indent" the target vein wall (Video 6). Once the wall is punctured the needle tip may be visualized within the lumen of the vein allowing for direct visual confirmation of needle placement within the target vein.

4 Ultrasound technique

Video 6 Video demonstrating depression of the superficial soft tissues and the anterior wall of the target vein on the ultrasound image. This soft tissue depression should be located directly over the target vein if the needle is positioned properly.

When blood flashback is obtained, the guide wire can be passed through the needle into the vein. A longitudinal image of the target vein should now be obtained distal to the puncture site while noting the guide wire location (Video 7). If the physician is confident the guide wire is located within the target vein the dilator can be used to prepare a path through the soft tissues for the catheter. Once the catheter is in place, the last step is to confirm placement of the catheter within the target vein.

4 Ultrasound technique

Video 7 Longitudinal image of the internal jugular vein demonstrating dynamic advancement of the guide-wire into the vein (note the J-tip at the leading edge of the guide-wire).

As stated on page 27, direct visualization of guide wire location within the vein can reassure the physician of proper subsequent venous placement of the catheter.[10] However, we recommend using central venous pressure measurements as the final confirmation of catheter placement prior to use. Chest radiography is traditionally used to exclude procedure-related complications, such as pneumothorax, yet some studies suggest that ultrasound may play a role in post-procedural assessment of patients after central venous catheter placement (CITE). The success rate for real-time ultrasound-guided access of the internal jugular vein is reported between 94-100%.[7,11-14]

5 Clinical pearls

- Examine both sides of the neck prior to sterile preparation to find the optimal location for internal vein puncture.
- Avoid extreme rotation of the neck, as it increases the degree of vessel overlap.
- If the internal jugular vein is collapsed, place the patient in mild Trendelenburg position, and determine if the patient is able to perform the Valsalva maneuver. Both of these techniques will increase vein size and may be useful in increasing cannulation success.
- When the optimal location is found, we recommend infiltrating the skin and soft tissue with local anesthetic well before the procedure is started in order to increase patient comfort.
- If there is complete internal jugular vein and carotid artery overlap, the physician should recognize the high risk of inadvertent carotid artery puncture. In these cases the authors recommend that experienced physicians attempt an in-plane (longitudinal) or oblique approach.
- Measure the depth of the internal jugular vein and then enter the skin the same distance back from the transducer. Ensure a needle entry angle of 45 to 60 degrees and observe the syringe for blood return rather than looking at the ultrasound image for needle entry into the target vessel.
- After threading the wire into the target vessel, use ultrasound to visualize proper venous placement of the guide wire. This can be performed either in-plane or out-of-plane. This should be performed before dilation and catheter placement to confirm venous placement.

6 Case resolution

Using ultrasound guidance, the internal jugular vein was punctured with first pass success and a triple lumen catheter was placed. The patient was diagnosed with urosepsis and the catheter was used for blood draws, fluid resuscitation and vasopressor administration.

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Additional resources

Additional resources related to emergency medicine and critical care ultrasound can be found on the following Philip's web site: **www.philips.com/CCEMeducation**

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