Objectives

On completion of this lesson, you should be able to:

1. Describe the indications for ultrasound-guided central venous access.
2. Explain the contraindications for ultrasound-guided central venous access.
3. Discuss the potential risks and adverse events that occur with central venous access.
4. List the different anatomic sites for ultrasound-guided placement and indications for each site.
5. Describe the technique of ultrasound-guided central line placement at each anatomic site.
6. Discuss how the use of ultrasound has improved the practice of obtaining central venous access.

From the EM Model

19.0 Procedures and Skills Integral to the Practice of Emergency Medicine
19.2 Resuscitation

Establishing reliable venous access in the emergency department is important for management of critical patients. Peripheral access is more commonly used, but if this cannot be established or if the patient is critically ill, a central line must be placed to facilitate invasive monitoring and/or administration of vasoactive drugs. Over 5 million central venous catheters are placed in the United States every year. The use of ultrasonography is an important technological aid in establishing rapid central venous access.

Doppler ultrasonography was first used to assist central line placement in 1984. Many improvements have been made since this first use of ultrasound guidance. Currently, it is considered standard of care when placing central venous catheters. In 2001, an Agency for Healthcare Research and Quality (AHRQ) report and a policy statement from the American College of Emergency Physicians (ACEP) both made recommendations advocating the use of ultrasonography for central venous access. Furthermore, in 2002, the National Institute for Clinical Excellence (NICE) guidelines recommended the use of ultrasonography to minimize complications associated with central line placement.

Multiple studies have shown that ultrasound guidance in central venous catheterization is superior to the landmark technique. Furthermore, the need for central venous catheterization has decreased as ultrasound guidance use has improved clinicians’ ability to access peripheral veins.

Case Presentations

Case One
A 68-year-old man is transported to the emergency department after a high-speed rollover motor vehicle crash. The patient was the restrained driver of the car and required prolonged extrication. The patient was placed in a cervical collar and onto a backboard. There was an obvious deformity of his left thigh. Initial vital signs in the field were blood pressure 100/55, heart rate 115, respiratory rate 28, and pulse oximetry 93% on room air. The patient does not recall the crash and is confused. EMS requests trauma activation, and they attempt to start two large-bore intravenous lines in the patient but were unable to do so. The patient’s blood pressure is now 95/43.

Case Two
A 50-year-old woman presents complaining of chest pain and a productive cough. The patient has diabetes and is on hemodialysis three times a week because of renal failure. She was discharged from an extended-care facility 1 month ago.
**Critical Decisions**

- What are the indications for ultrasound-guided central venous access?
- What are the contraindications to central venous access?
- What are the potential risks associated with each anatomic site used for central venous access?
- When should a specific ultrasound-guided central line be placed?
- How do you place a central line under dynamic ultrasound guidance at each anatomic site?
- How has the use of ultrasound guidance improved establishment of central venous access?

CRITICAL DECISION

**What are the indications for ultrasound-guided central venous access?**

When compared to an external landmark approach for central line placement, ultrasound-guided central venous catheterization has fewer complications and is more effective in time and first-attempt success. The indications for central venous access are the same whether ultrasound guidance is used or not, as follows: the need for invasive hemodynamic monitoring, the need to administer intravenous vasoactive drugs or other therapeutic agents and nutrition, the need for hemodialysis, the need for a cardiac pacemaker, and the inability to obtain peripheral venous access. There are significant clinical advantages for vascular access via ultrasound guidance (Table 1), and thus ultrasound guidance is indicated in nearly every situation in which central venous catheterization is being performed.

Furthermore, ultrasound guidance is paramount in cases in which definitive access is needed in patients with increased risk for significant complications from multiple vascular attempts. For example, patients with supratherapeutic anticoagulation, hemophilia, disseminated intravascular coagulation, and thrombocytopenia are at increased risk of complications from multiple vascular access attempts. Minimizing attempts is important for the safety and comfort of the patient.

CRITICAL DECISION

**What are the contraindications to central venous access?**

General contraindications for central line placement remain the same whether the landmark approach or ultrasound guidance is used. These include infection of the placement site and suspected pathologic conditions affecting the veins such as deep vein thrombosis. Patients who have had previous injury to their vasculature, have small veins, or are morbidly obese require increased caution when central lines are placed. Careful consideration is needed in determining which insertion site is to be used. Trauma and distortion of landmarks require that further care be used in attempting to place central lines, and alternative sites should be considered if possible. The subclavian site should be avoided in patients who have severe hypoxemia since pneumothorax is more likely to occur and is less likely to be tolerated by these patients. Ultrasonography is a noninvasive, nonionizing form of imaging that is safe for use in patients of all ages and in pregnant women. There are no absolute

**Table 1.**

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confirms vessel location and patency prior to central venous cannulation</td>
<td></td>
</tr>
<tr>
<td>Assists in real-time cannulation under direct ultrasound visualization</td>
<td></td>
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<tr>
<td>Minimizes the number of attempts to gain vascular access</td>
<td></td>
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<tr>
<td>Decreases time to successful central venous catheterization</td>
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</tr>
<tr>
<td>Reduces complications during placement of the central venous catheter</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2.**

<table>
<thead>
<tr>
<th>Artery</th>
<th>Vein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thicker walls</td>
<td>Thinner walls</td>
</tr>
<tr>
<td>More round in shape</td>
<td>More oval in shape</td>
</tr>
<tr>
<td>Not easily compressible</td>
<td>Easily compressible</td>
</tr>
<tr>
<td>Demonstrates arterial pulsatility</td>
<td>Lacks arterial pulsatility/demonstrates venous phasicity</td>
</tr>
</tbody>
</table>
contraindications regarding the actual use of ultrasound during central venous placement.12

**CRITICAL DECISION**

What are the potential risks associated with each anatomic site used for central venous access?

Three main categories of risk are associated with central venous access—mechanical, infectious, and thrombotic complications.

**Mechanical Complications**

There are many potential mechanical complications during central venous access; damage to any structure in proximity to the target vessel is possible, and complications with the guidewire and catheter can occur. The most common mechanical complications in central line placement are arterial puncture, hematoma, and pneumothorax.1 A 2003 review article recommends avoiding femoral vein catheterization, noting that it has the highest mechanical risk for arterial puncture and hematoma (including retroperitoneal hematoma) out of the three sites used in central venous catheter placement.1 A Cochrane review, however, in 2012, only including randomized controlled trials found either similar or decreased mechanical complications at the femoral site.13 Overall, internal jugular and subclavian lines have similar rates of mechanical complications. However, the subclavian site is closer to the lung and is a noncompressible site. Therefore, subclavian lines have increased risk for pneumothorax and for hemorrhage requiring blood transfusion or surgery. The use of dynamic ultrasound guidance reduces the overall rate of mechanical complications at all sites.14

**Infectious Complications**

Infectious complications associated with venous access have several different mechanisms, as follows: infection at the catheter site followed by migration of the pathogen along the external catheter surface; contamination of the catheter hub that leads to intraluminal catheter colonization; and hematogenous seeding of the catheter.1 In a recent metaanalysis,15 no definitive difference in catheter-related bloodstream infections was seen at the three sites. There is debate on the analysis of the data and its conclusions, specifically its exclusion of two “statistical outliers” that showed increases in catheter-related bloodstream infections at the femoral site compared with the subclavian site. A 2012 Cochrane review,13 based on the Merrer 2001 randomized controlled trial16 prefers the subclavian to the femoral site because of higher rate of catheter colonization (1.2 infections per 1,000 catheter-days versus 4.5 infections per 1,000 with femoral catheterization; \(P = 0.07\)). This did not equate with a statistical increase in catheter-related bloodstream infections. A subgroup analysis in one study suggests a higher risk of infection with femoral line placement in obese patients.17 Overall, it appears that the more recent the study, the lower the rate of infectious complications. This suggests we have made advances in sterile technique and improved aseptic care of central venous catheters. Therefore, no matter which site is chosen, maximal sterile-barrier

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**Table 3.** Ultrasound-guided internal jugular vein approaches

<table>
<thead>
<tr>
<th>Landmark-based reference: The sternocleidomastoid muscle</th>
<th>Axis of transducer to vessel</th>
<th>Axis of needle to transducer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>Transverse</td>
<td>Short</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>Transverse</td>
<td>Short</td>
</tr>
<tr>
<td></td>
<td>Oblique</td>
<td>Long</td>
</tr>
<tr>
<td>Central</td>
<td>Transverse</td>
<td>Short</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td></td>
</tr>
</tbody>
</table>

*The more common approaches

**Table 4.** Ultrasound-guided subclavian vein approaches

<table>
<thead>
<tr>
<th>Landmark-based reference: The clavicle</th>
<th>Axis of transducer to vessel</th>
<th>Axis of needle to transducer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supraclavicular</td>
<td>Long</td>
<td></td>
</tr>
<tr>
<td>Infraclavicular</td>
<td>Transverse</td>
<td>Short</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td></td>
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</tbody>
</table>

*The more common approaches

**Table 5.** Ultrasound-guided femoral vein approaches

<table>
<thead>
<tr>
<th>Landmark-based reference: The inguinal ligament/crease</th>
<th>Axis of transducer to vessel</th>
<th>Axis of needle to transducer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse</td>
<td>Short</td>
<td></td>
</tr>
<tr>
<td>Long</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The more common approaches
precautions and aseptic technique are essential. This includes use of a mask, cap, sterile gown, sterile gloves, large sterile drape, and antimicrobial dressing at catheter insertion site. Use of a sterile transducer sleeve is also important in reducing risk of infection. No study has shown an association with increase of infection with ultrasound use.

**Thrombotic Complications**

Finally, patients who require central venous access are at high risk for catheter-related thrombosis. This risk is variable according to the site of insertion. Femoral venous catheters were found to have a significantly higher occurrence of thrombosis (21.5% of patients) in comparison to 1.9% of subclavian venous catheters ($P < .01$). In the 2012 Cochrane review, there was no difference in thrombotic complications between the subclavian and internal jugular sites. In an observational study previously, however, the internal jugular site had approximately four times the risk in comparison to the subclavian site. Thus, the subclavian site has the lowest risk of catheter-related thrombosis and should be considered if risk of thrombosis is a concern. An advantage of ultrasound guidance is that vessel patency and presence or absence of deep venous thrombosis can be ascertained prior to insertion.

**CRITICAL DECISION**

**When should a specific ultrasound-guided central line be placed?**

Once the decision has been made that central venous access is necessary, careful consideration must be given to which site is chosen. Even with the use of ultrasound guidance, a thorough understanding of the anatomy and the intricacies of the procedure are important in successful cannulation. If there is difficulty in identifying landmarks for one type of catheterization, another site should be considered. Assessing the patient’s history and body habitus are also important in determining an appropriate site. Previous failed catheterization attempts, skeletal deformity, scarring, altered anatomy congenitally or from previous or concurrent injury, or the patient’s ability to lie flat are important considerations.

In morbidly obese patients, internal jugular catheterization can be difficult since the landmarks are often obscured. Ultrasound guidance is useful in visualizing the vasculature, but oftentimes the short nature of and limited access to these patients’ necks increase the difficulty in placement. In this subgroup, there is an increased risk of catheter-related bloodstream infection at the femoral site.

Consider avoiding the subclavian site in patients with severe hypoxemia since the complication of pneumothorax is increased at this site. However, some would argue that if the patient already has a concurrent pneumothorax requiring chest tube placement, the subclavian site on that side should be chosen. In a coagulopathic patient, there is increased risk for bleeding requiring surgery or blood transfusions at the subclavian site as it is a noncompressible site and therefore should be avoided. But in a patient with increased concern for thrombosis, the subclavian site has the lowest incidence of thrombotic complications. Ultrasound guidance can be limited in subclavian line placement due to the clavicle. However, in a prospective randomized trial, ultrasound guidance at the subclavian site has been shown to decrease complications. The axillary vein may be used instead due to ease of placement and comfort to the patient.

The femoral insertion site should be avoided in patients with grossly contaminated inguinal regions due to the increased risk for development of catheter-related infections. The

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**Figure 1.**

Internal jugular vein

T=thyroid; CA=carotid artery; IJV=internal jugular vein; SCM=sternocleidomastoid muscle
femoral site can be very useful in acute resuscitation in a patient who is unable to lie flat during central line placement or when the chest or neck is not accessible for central line placement.

With the above considerations in mind, an understanding of the complications and complication rates associated with each anatomic site, and the expertise and comfort level of the provider, the specific site chosen for central venous access still remains a clinical decision.

**CRITICAL DECISION**

How do you place a central line under dynamic ultrasound guidance at each anatomic site?

There are two general approaches for ultrasound-guided line placement. The first is a static approach that is often used to confirm the predicted landmark-based anatomy. This approach is useful when the patient is unable to lie in the standard position for catheterization and the operator wishes to confirm vessel location. An advantage to this approach is that the operator is able to more easily use the ultrasound machine without requiring additional equipment such as a sterile transducer sleeve. The dynamic approach, on the other hand, allows the operator to control the needle entering the vessel under real-time visualization. It is the latter approach that is recommended in the AHRQ report. This method does require more preparation and assistance but is safer and may save time when landmarks are not evident in critically ill patients.

The general technique for dynamic ultrasound guidance requires the use of a high-frequency linear array transducer. Proper ultrasound machine settings should be employed to maximize temporal and spatial

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**Figure 2.**

Subclavian vein diagram

SCV=subclavian vein; SCA=subclavian artery
resolution. Once the anatomic site has been chosen, scanning the patient prior to placement of the sterile probe cover allows the operator to visualize the anatomy, evaluate for thrombosis, and determine the best approach for cannulation. The difference between the central artery and the central vein at each site should be recognized (Table 2). Color-flow Doppler can be used for further assessment, but this is not necessary. Most importantly, the structures should follow the expected anatomy particular to each site (eg, the femoral vein lying medial to the femoral artery).

Once this assessment has been done, the patient should be prepared for a sterile procedure following standard protocol. At this point, the transducer should be covered with a sterile sleeve and gel. After local anesthesia has been administered, the operator should place the transducer on the patient, visualize the initial insertion of the needle tip, and follow its path in real time with the ultrasound probe towards the vessel.

The transducer can either be placed in a longitudinal (long-axis), transverse (short-axis), or oblique orientation to the vessel. The needle can be inserted either in an in-plane (short-axis) or out-of-plane (long-axis) fashion. There are advantages and disadvantages to both. The long-axis orientation gives information on depth and slope, allowing the operator to visualize the needle in its entirety and its path without having to move the transducer. This orientation is technically more difficult to obtain as the transducer, needle, and vessel all have to be precisely aligned along the same axis. The short-axis orientation shows the relationships to other adjacent anatomy and is technically less difficult. This orientation does not allow the operator to easily differentiate the tip of the needle from any other part of the needle and therefore makes it difficult to assess depth. The operator must be careful to visualize the needle tip so as not to puncture the posterior wall of the vein or any structure that lies deep to it. In either orientation, the more perpendicular the needle is to the ultrasound beam the better the needle can be visualized. In addition, certain ultrasound machine settings and enabling needle visualization software may enhance visualization of the needle.

**Internal Jugular Vein Cannulation**
Anatomy: Figure 1
Approaches: Table 3
Technique: Video 1 (http://www.acep.org/CDEM_2014_Lesson_10-1)

**Subclavian Vein Cannulation**
Anatomy: Figure 2
Approaches: Table 4
Technique: Video 2, supraclavicular approach (http://www.acep.org/CDEM_2014_Lesson_10-2)
Video 3, infraclavicular approach (http://www.acep.org/CDEM_2014_Lesson_10-3)

**Femoral Vein Cannulation**
Anatomy: Figure 3
Approaches: Table 5
Technique: Video 4 (http://www.acep.org/CDEM_2014_Lesson_10-4)
CRITICAL DECISION

How has the use of ultrasound guidance improved establishment of venous access?

Since the reports from AHRQ and NICE, multiple reviews of the literature and several individual studies have looked at the implications of these statements in obtaining central venous access. One study primarily assessed associated complication rates as an outcome measure after the implementation of the NICE guidelines. This study showed that there is a significant reduction in complication rates after implementation of the NICE guidelines; pre- and post-implementation complication rates were 10.5% and 4.6%, respectively, with an absolute risk reduction of 5.9% (95% CI 0.5-11.3%).

Because the use of ultrasound guidance has been definitively shown to decrease complication rates, ACEP has continued to publish policy statements about the use of ultrasound guidance in central venous access. The 2009 statement noted that Class I evidence (randomized, controlled trials are the gold standard) exists for ultrasound-assisted central venous cannulation. There are no negative data published on ultrasound-assisted central venous cannulation, giving it a Level I recommendation (convincingly, justifiable recommendation based on available scientific information alone).  

Not only has ultrasound guidance in central venous access decreased complication rates, but also it has been shown to decrease total number of attempts, increase first attempt success, decrease time to insertion, and decrease failure rate. This reduces the need to correct coagulation parameters of patients, given the feasibility of successful first pass cannulation. Nonetheless, the decision as to whether to reverse anticoagulation prior to obtaining central venous access should be made considering all clinical variables.

In patients with difficult peripheral venous access, the use of ultrasound has increased the success of placing peripheral intravenous lines. This obviates the need for the clinician to gain central venous access solely because peripheral access could not be obtained. Therefore, ultrasound guidance in peripheral venous access has decreased the need for central venous access and the complications associated with central venous catheter placement.

Case Resolutions

■ Case One

In the case of the trauma patient, peripheral intravenous access could not be obtained. Given the need for venous access and resuscitation of the patient, a subclavian line was placed; access was achieved on the first attempt using ultrasonography. The patient was losing significant blood within his thigh and had experienced blunt trauma to his abdomen. A traction splint was applied to the patient and a FAST examination performed, which was positive. The patient was given blood products and his blood pressure stabilized. The patient’s mental status remained unchanged in the trauma bay. The patient was sent for CT scans of his chest, abdomen, and pelvis, which revealed a grade 2 liver laceration. At this time, the patient’s vital signs remained unchanged, and the patient was admitted to the trauma service for monitoring and serial abdominal examinations. Orthopedic evaluation revealed a femoral shaft fracture requiring surgery, which was done the following day.

■ Case Two

In the case of the diabetic patient, her chest radiograph revealed a right-sided lower-lobe pneumonia. Her ECG showed some nonspecific T-wave inversions, and her initial blood results revealed a WBC count of 19,000/mcL with 10% bands and normal cardiac enzymes. The patient had an elevated lactate of 4.4 mEq/L. The patient’s chest pain was reproducible and worsened with

Pearls

• The use of ultrasound has significantly reduced complication rates in central venous line placement and is considered standard of care by ACEP (Level I recommendation) and the AHRQ.

• Use ultrasonography to assess multiple anatomic sites for patency of veins and ease of access prior to choosing the site for central venous cannulation.

• The longitudinal orientation of the transducer enables visualization of the needle in its entirety but is technically more challenging.

• The use of ultrasonography to facilitate peripheral venous access has reduced the need for central venous access in certain patients.

Pitfalls

• Assuming dynamic ultrasound guidance obviates the need for expert knowledge of anatomy and procedural technique in central venous access.

• Obtaining central venous access without dynamic ultrasound guidance as this has a higher complication rate.

• Not identifying a deep venous thrombosis at the site of central line placement prior to central venous cannulation.

• Not visualizing the needle tip during the short-axis approach.

• Failing to differentiate between an artery and a vein on ultrasound and cannulating the adjacent artery.
coughing. The patient was able to tolerate oral intake and was given acetaminophen. Peripheral venous access could not be established, and the patient’s blood pressure decreased to 86/40. The decision was made to obtain central venous access. Ultrasonography was used to guide placement of an internal jugular central venous catheter, and antibiotics and intravenous fluid resuscitation were initiated. She was admitted to the ICU for septic shock.

Summary

Establishing central venous access is important in treatment of critically ill patients and patients who acutely have exhausted peripheral access options. Emergency physicians must recognize the indications for and risks associated with central venous access. Understanding these indications and risks allows the emergency physician to choose an appropriate site for establishing central venous access. Ultrasonography has improved the safety, efficacy, and ease with which central venous access is obtained. Appropriate training and implementation of ultrasound-guided central line placement have decreased the risks associated with this procedure.

References