CHAPTER 34

Lower Extremity Deep Venous Thrombosis

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KEY POINTS

- Providers can accurately detect lower extremity deep venous thrombosis with point-of-care ultrasound after limited training.
- Compression ultrasound exams are as accurate as traditional duplex and triplex vascular ultrasound exams.
- Compression ultrasound exam at only two sites, the common femoral vein and popliteal vein, permits rapid and accurate assessment of deep venous thrombosis.

Background

Venous thromboembolic disease (VTE) is a common cause of morbidity and mortality in hospitalized patients and is especially prevalent in critically ill patients.1–3 Approximately 70% to 90% of patients with an identified source of pulmonary embolism (PE) have a proximal lower extremity deep venous thrombosis (DVT). Conversely, 40% to 50% of patients with a proximal DVT have a concurrent pulmonary embolism at presentation, and similarly, in only 50% of patients presenting with a PE can a DVT be found.4–6

Point-of-care ultrasound is readily available as a diagnostic tool for VTE. Both emergency medicine and critical care medicine literature have demonstrated that after brief, focused training sessions, physicians and other health care providers can perform lower extremity compression ultrasonography exams rapidly and with high diagnostic accuracy to detect DVT.7–13 A meta-analysis of 16 studies showed that point-of-care ultrasound can accurately diagnose lower extremity DVTs with a pooled sensitivity of 96% and specificity of 97%.14

Traditional vascular studies, the duplex and triplex exams, use a combination of two-dimensional (2D) imaging with compression along with the use of color and/or spectral Doppler ultrasound. More recent studies have demonstrated that 2D compression ultrasound exams alone yield similar accuracy as traditional duplex or triplex vascular studies.9,11,15–17 Furthermore, reporting of duplex or triplex exams is often delayed due to limitations in the availability of radiology services. Delays in obtaining such test results can compromise the

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Vascular System

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Lateral perforator veins are usually seen just distal to the division of the CFA. Distal to the lateral perforator veins, the CFV divides into a deep femoral vein (DFV) posteriorly and femoral vein (FV) anteriorly. The FV, traditionally referred to as the femoral vein, is actually a deep vein. Thus, current guidelines recommend calling it the femoral vein to avoid confusion. The FV is visualized with ultrasound until it dives deep into the adductor canal (Hunter’s canal) in the distal thigh. In the popliteal fossa, the popliteal vein (PV) overlies the popliteal artery until the vein trifurcates in the distal fossa into the anterior and posterior tibial and peroneal veins.

**Image Acquisition**

A high-frequency (5–12 MHz) linear transducer is best suited for the evaluation of lower extremity vasculature because it provides high resolution of superficial structures. Vessels typically appear as well-defined, circular, anechoic structures that are contiguous when tracked proximally and distally. A key step in compression ultrasonography is differentiating veins from arteries. Even though no single feature is entirely specific, arteries are generally rounder, thicker walled, pulsatile, and smaller than accompanying veins. Most important, veins are normally fully compressible under light pressure, whereas arteries require substantial pressure to compress. Color flow Doppler can help differentiate arteries from veins when the above features are equivocal, when vessels are deeper in the leg, or when evaluating obese or edematous patients. When utilizing color flow Doppler, one should preferentially tilt the transducer face towards the heart. Using the default Doppler settings, venous blood flow will appear blue as the direction of flow is away from transducer. Normally, color fills the entire venous lumen, and manual compression of the distal leg will cause a transient increase in flow (augmentation) seen as a burst of color within the vein.

A compression ultrasound exam is ideally performed with the patient supine and the leg externally rotated with the knee slightly flexed. The ultrasound machine should be placed ipsilateral, distal to the site of examination with the screen directly facing the provider. The transducer is placed in a transverse orientation at the most proximal point above the inguinal ligament where the external iliac vessels can care of acutely ill patients.9 Thus, the importance of avoiding such delays, along with the minimal training needed to accurately perform the exam, has made point-of-care lower extremity compression ultrasonography an essential skill for health care providers.

This chapter focuses on 2D ultrasonography to detect proximal lower extremity DVT. Distal lower extremity DVTs are not discussed because of their low embolic potential and the lower accuracy of compression ultrasound to detect DVTs below the knee, even by expert sonographers.18–20

**Anatomy**

The proximal lower extremity deep venous system consists of the external iliac, common femoral, deep femoral, femoral, and popliteal veins (Fig. 34.1). Deep veins are accompanied by an adjacent artery. The external iliac vessels are named common femoral vessels distal to the inguinal ligament. Arteries are typically lateral to veins in the thigh. The greater saphenous vein (GSV) is the first venous branch of the common femoral vein (CFV) located anteromedially in the upper thigh. Next, the adjacent common femoral artery (CFA) divides into the deep and superficial femoral arteries.

![Figure 34.1 Vascular Anatomy of the Right Lower Extremity.](image-url)
Continuing distally, the CFA branches into superficial and deep branches before the CFV branches into the femoral vein (FV) and the deep femoral vein (DFV). Along the CFV, lateral perforator veins are usually seen coursing laterally between the superficial and deep femoral arteries (Video 34.5). Distal to the lateral perforators, the CFV divides into the DFV and FV (Video 34.6).

Data have shown high diagnostic utility of a limited two- or three-point compression ultrasound exam in patients who have physical still be identified without obscuration from overlying bowel gas.

Compressions should be applied every 1 to 2 cm along the lower extremity veins. While sliding the transducer distally along the CFV, identify and compress each of the main branch points (Figs. 34.2 and 34.3). Start by compressing the CFV proximal to the GSV branch (Video 34.1) and then the CFV-GSV anastomosis (Video 34.2). The proximal portion of the GSV should be examined as thrombus here has high risk of extending into the CFV (Videos 34.3 and 34.4). Continuing distally, the CFA branches into superficial and deep branches before the CFV branches into the femoral vein (FV) and the deep femoral vein (DFV). Along the CFV, lateral perforator veins are usually seen coursing laterally between the superficial and deep femoral arteries (Video 34.5). Distal to the lateral perforators, the CFV divides into the DFV and FV (Video 34.6).

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Figure 34.3  Lower Extremity Compression Ultrasound Exam. Transducer position and corresponding precompression (left) and postcompression (right) ultrasound images are shown at different levels. (A) Common femoral vein–greater saphenous vein (CFV–GSV) level. (B) CFV–lateral perforator (LP) vein level, distal to the bifurcation of the common femoral artery (CFA) into superficial femoral artery (SFA) and deep femoral artery (DFA). (C) Bifurcation of the common femoral vein into femoral (FV) and deep femoral veins (DFV). (D) The femoral vein is deep to the SFA from the mid- to distal thigh.
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The transducer should be held gently to avoid inadvertently collapsing the PV. If an adequate seal between the transducer and skin cannot be attained in the popliteal fossa without applying excessive pressure, consider using a narrower linear transducer or applying copious gel. The PV is typically superficial or lateral to the artery in the center of the popliteal fossa (Video 34.10). If only small veins are visualized, the transducer is positioned too distal and should be slid proximally toward the posterior thigh. Compressions are performed sequentially to the trifurcation of the PV into anterior and posterior tibial and peroneal veins.

Normal and Pathologic Findings

Normal veins should fully compress; opposing walls should touch with application of exam findings or symptoms of a DVT (calf pain, tenderness, edema, or redness). A limited compression ultrasound exam must evaluate at a minimum: the CFV-GSV level, the bifurcation of the CFV into DFV and FV, and the PV level. The distal course of the FV is not examined in a limited two- or three-point exam. However, given the relative ease and rapidity of performing compression ultrasonography, we recommend performing compressions distally from the CFV along the FV in select patients with high suspicion for lower extremity DVT. Studies have shown that thrombi can be isolated to the FV and not involve a branch point. Compressions are continued every 1 to 2 cm along the proximal (Video 34.7), middle (Video 34.8), and distal FV (Video 34.9) until the vein dives deep into the adductor canal (Hunter’s canal) in the distal thigh.

Figure 34.4 Transducer position in popliteal fossa (A) with corresponding precompression and postcompression ultrasound images (B). PA, Popliteal artery; PV, popliteal vein.

Normal and Pathologic Findings

Normal veins should fully compress; opposing walls should touch with application of compressions during the ultrasound exam. The PV is typically superficial or lateral to the artery in the center of the popliteal fossa. Compressions are performed sequentially to the trifurcation of the PV into anterior and posterior tibial and peroneal veins.
Figure 34.5  Common Femoral Vein Deep Venous Thrombosis. Noncompression of the common femoral vein (CFV) is revealed by the precompression (left) and postcompression (right) images demonstrating a deep venous thrombosis (DVT). CFA, Common femoral artery.

Figure 34.6  Popliteal Vein Deep Venous Thrombosis. Noncompression of the popliteal vein (PV) is revealed by the precompression (left) and postcompression (right) images demonstrating a deep venous thrombosis (DVT). PA, Popliteal artery.

less pressure than is required to compress the adjacent artery. Most deep venous thrombi usually develop around valve sinuses, especially at bifurcations, where decreased blood flow exists.\textsuperscript{25} Inability to completely compress the venous lumen is the main criterion for diagnosis of DVT using compression ultrasonography, even if thrombus is not visualized in the vein (Figs. 34.5 and 34.6). Lower extremity DVTs can be detected at any of the examination points: CFV (Video 34.11), CFV-GSV anastomosis (Video 34.12), CFV-lateral perforator vein anastomosis (Video 34.13), FV (Video 34.14), and PV (Video 34.15).

Providers should keep in mind that thrombosis is a spectrum. Early thrombus formation begins with venous stasis, usually seen as spontaneous echo contrast or “smoke” around valve leaflets, and fibrin deposition (Video 34.16). The sonographic appearance of venous thrombi varies based on age, extent, and location. Acute thrombi are gelatinous in consistency, appear anechoic or hypoechoic, and cause greater venous distention than chronic thrombi. Subacute and chronic thrombi are more echogenic due to fibrin deposition and can often be visualized without compression (Video 34.17). Chronic thrombi recanalize,
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• Providers should have a thorough understanding of lower extremity venous anatomy, including the main segments and branch points, before performing venous compression ultrasound exams.
• Lower extremity compressions should begin at the most proximal visualizable vein segment above the inguinal ligament (external iliac vein).

• Compression ultrasound should always be performed in a transverse orientation because compressions in a longitudinal orientation are prone to the operator sliding to one side of the vessel resulting in erroneous exam findings.
• Firm, rapid, downward compressions of veins should be used to reduce false-positive results. Conversely, forceful compressions should be avoided to reduce false-negative results. Adequate force is being applied if the adjacent artery is slightly compressed.
• After diagnosing a lower extremity deep venous thrombosis (DVT), serial compressions should be avoided in cases of acute, free-floating thrombus.
• Besides DVT, some veins may not compress due to operator error, depth of the vein, obesity, or edema. The depth of some lower extremity deep veins, such as the distal femoral vein, often precludes adequate compression. Compressing the vein at an angle, rather than perpendicularly, can also result in false positives.
CASE 34.1

CASE PRESENTATION
A 50-year-old man with a history of chronic obstructive pulmonary disease presents to the emergency department with a week-long history of purulent cough, dyspnea, and fever. Chest x-ray demonstrates bilateral infiltrates. He is admitted to the hospital for community-acquired pneumonia. On hospital day 2, he is transferred to the intensive care unit for septic shock and acute hypoxic respiratory failure. On hospital day 4, vasopressors are weaned off and the FiO$_2$ is reduced to 40%. During a spontaneous breathing trial, the patient suddenly becomes hypoxic and tachycardic. Despite re-initiating full ventilatory support, his FiO$_2$ requirement remains at 100% and tachycardia persists. The differential diagnosis includes mucus plugging with atelectasis, pneumothorax, and venous thromboembolism.

ULTRASOUND FINDINGS
Focused lung ultrasound and lower extremity compression ultrasound exams are performed. Lung ultrasound demonstrates bilateral lung sliding, ruling out the possibility of pneumothorax. Asymmetric areas of B-lines with thickened pleura are noted without signs of consolidation. Compression ultrasound of the right leg demonstrates noncompression of the right common femoral vein (CFV) at the level of the lateral perforator vein, although echogenic thrombus is not visualized within the vessel (Video 34.20). The right CFV reveals echogenic thrombus, shown here in a longitudinal view (Video 34.21). Noncompression of the venous lumens and identification of echogenic thrombus confirms a diagnosis of lower extremity deep venous thrombosis (DVT).

CASE RESOLUTION
The patient’s acute respiratory failure and lower extremity DVT suggested a high likelihood of pulmonary embolism. The patient was promptly started on unfractionated heparin. On hospital day 6, the patient was successfully extubated and bridged to warfarin therapy.

Lower extremity compression ultrasound exams performed by providers with limited training are highly accurate when compared to duplex or triplex Doppler ultrasound exams. Similar diagnostic accuracy has been demonstrated in studies with patients in hospital wards, emergency departments, and intensive care units. Point-of-care lower extremity compression ultrasound exams allow providers to rapidly identify DVTs and promptly initiate anticoagulation.

CASE 34.2

CASE PRESENTATION
A 65-year-old man with end-stage renal disease, hypertension, and systolic heart failure is admitted to the intensive care unit (ICU) with respiratory failure and septic shock secondary to Pseudomonas pneumonia. Using ultrasound guidance, a right femoral central venous catheter is placed for vasopressor infusion. On ICU day 7, the nurse notes difficulty infusing medications via the central venous access and inability to withdraw blood. On physical examination, the right lower extremity is edematous and warm compared to the left leg. A point-of-care ultrasound is performed to evaluate the right leg.

ULTRASOUND FINDINGS
A lower extremity compression exam demonstrates a hypoechoic, noncompressible, right common femoral vein (CFV). The central venous catheter was noted within the vessel, but no clear thrombus is visualized (Video 34.22). Initially, anticoagulation is held due to concerns of gastrointestinal bleeding. A repeat exam of the right CFV a few days later demonstrates obvious hyperechoic thrombus formation and propagation of thrombosis distally (Video 34.23).

CASE RESOLUTION
The patient’s unilateral lower extremity swelling was concerning for deep vein thrombosis. Noncompression of the venous lumen, despite the inability to initially visualize a thrombus, prompted strong concern for catheter-related thrombosis. The catheter was carefully removed and therapeutic anticoagulation was initiated. Serial examinations ultimately demonstrated organization of thrombus.

Acute thrombosis has a gelatinous, hypoechoic consistency when visualized early in formation and becomes more hyperechoic with organization of the clot. The inability to completely compress the venous lumen is the main criterion for diagnosis of deep vein thrombosis.
Review Questions

1. What is the main diagnostic criterion for diagnosis of deep vein thrombosis?
   A. Visualization of hyperechoic thrombus within the venous lumen
   B. Distention of the venous lumen when compared to the arterial lumen
   C. Noncompression of the venous lumen
   D. Reduction of flow by color or pulsed-wave Doppler ultrasound
   Answer: C. The inability to completely compress the venous lumen is the main criterion for diagnosis of deep vein thrombosis. Visualization of thrombus is not required, and acute thrombi are usually anechoic. Although distention of the venous lumen supports a diagnosis of deep venous thrombosis, the venous lumen is normally larger than the arterial lumen. Doppler ultrasound is not required to diagnose deep venous thrombosis.

2. What is the characteristic echogenicity of a subacute or chronic thrombus?
   A. Anechoic
   B. Hypoechoic
   C. Isoechoic
   D. Hyperechoic
   Answer: D. Acute thrombi are gelatinous and anechoic or hypoechoic, while subacute and chronic thrombi are hyperechoic due to fibrin deposition within the clot.

3. Which of the following veins is not normally examined during a 2D compression ultrasonography exam of the lower extremity deep veins?
   A. Soleal vein
   B. Greater saphenous vein
   C. Femoral vein
   D. Popliteal vein
   Answer: A. Distal lower extremity DVTs (below the knee) have low embolic potential. Additionally, compression ultrasound has lower accuracy to detect DVTs below the knee. The common femoral, femoral, and popliteal vein, as well as their main branches, are the proximal lower extremity deep veins that are examined during a 2D compression ultrasound exam.

For examples 4–10, view each video, identify the site, and determine whether the lower extremity compression ultrasound exam is normal or abnormal.

4. Video 34.24 (Answer: E)
5. Video 34.25 (Answer: A)
6. Video 34.26 (Answer: G)
7. Video 34.27 (Answer: B)
8. Video 34.28 (Answer: F)
9. Video 34.29 (Answer: D)
10. Video 34.30 (Answer: C)
   A. Right common femoral vein–greater saphenous vein anastomosis that is PARTIALLY compressible
   B. Left common femoral vein–greater saphenous vein anastomosis that is FULLY compressible
   C. Popliteal vein that is NOT compressible
   D. Popliteal vein that is FULLY compressible
   E. Right common femoral vein–lateral perforator anastomosis that is FULLY compressible
   F. Right common femoral vein–lateral perforator anastomosis that is PARTIALLY compressible
   G. Femoral vein that is PARTIALLY compressible

References