# Practical Guide to EMERGENCY ULTRASOUND

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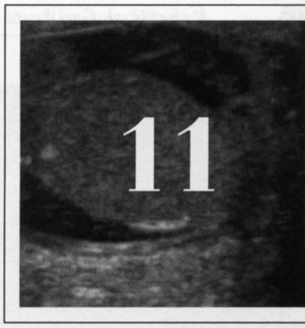
LIPPINCOTT WILLIAMS & WILKINS




# Lower Extremity Venous Studies

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## Introduction

The possibility of a lower extremity deep venous thrombosis (DVT) is a frequent clinical concern in emergency medicine, arising in patients with varied presentations, from painless leg swelling to impending cardiopulmonary arrest. DVT and pulmonary embolus (PE) can be difficult to diagnose and carry significant morbidity and mortality. Physical exam findings have a low sensitivity for the detection of DVT (1). Historical factors can aid in risk stratification, but not ultimate diagnosis (2). Although there are numerous diagnostic possibilities for patients in whom a DVT is suspected, venous compression ultrasonography is the most practical test for the emergency department (ED) setting.

In many institutions, consultative vascular studies are not available outside of regular business hours (3). Given this lack of availability, many clinical decision rules combining risk factor assessment and the use of a quantitative D-dimer assay have been proposed (4). These protocols decrease the need for vascular studies in low-risk patients, but still leave many patients requiring a service that is often not available. When a DVT is suspected, emergency physicians are often faced with three options: admit the patient, hold the patient in the ED awaiting the availability of venous studies, or discharge the patient after anticoagulation in the ED with arrangement for an outpatient study as soon as possible. This is especially troublesome for patients without primary care physicians, patients presenting early in the weekend, or patients without reliable follow-up. In response to these many concerns, emergency physicians began performing their own bedside examinations of the lower extremity venous system to evaluate for the presence of DVT. Although traditional venous compression ultrasonography is thorough and time-consuming, a limited approach that is more practical for emergency medicine practice can be applied. Poppiti et al. demonstrated that limited venous ultrasound can be done with a dramatic reduction in the usual time required for a complete consultative exam, taking 5.5 minutes for a targeted emergency ultrasound compared with 37 minutes for the complete vascular exam of the lower extremity (5,6). It has been shown that emergency physicians can accurately detect DVT on focused ultrasound (3,7–10). Limited emergency ultrasound is thus both accurate and fast enough to be practical for typical emergency medicine practice (3,8).

## Clinical Applications

Lower extremity venous compression ultrasonography is indicated any time there is a suspicion of a lower extremity DVT. In terms of clinical presentation, leg pain, leg swelling, or symptoms concerning for PE may prompt a clinician to proceed with the exam. There are no absolute contraindications to this noninvasive exam.

## Image Acquisition

The bedside exam has primary and secondary components. The primary component visualizes the venous structures and detects gray-scale compressibility. The literature suggests that only the primary component can be adequately relied upon for confirming the presence or absence of a DVT (11,12). Lack of compressibility defines a DVT. The secondary component involves the use of Doppler to evaluate for abnormalities in flow. The Doppler exam is an adjunct measure of lesser importance. Note that the diagnosis of DVT does not rest with direct visualization of thrombus within the lumen.

### Primary Component

Lower extremity studies are best performed with a high-resolution linear transducer with a frequency of 5.0 to 7.0 MHz. Use of higher frequency will give images with better resolution, but lower frequency may be needed in larger patients. Depth should be adjusted based on the physical characteristics of the patient. There are several options for patient positioning, the choice of which will vary with the patient's clinical condition, body habitus, and physician choice. Generally, the patient is supine. If the patient's hemodynamic status will allow it, placing the patient in 35° to 40° of reverse Trendelenburg (head up) will increase venous distention and aid in visualization. Also, the patient's leg can be slightly flexed at the knee and hip and the hip externally rotated to ease visualization of the vessels (Figs. 11.1, 11.2).

Begin the exam in the region of the common femoral vein, in the transverse plane just distal to the inguinal ligament (Fig. 11.3). Gel should be applied to the transducer or along the course of the vessel. The transverse view is first used to locate the vessel and to evaluate for compression. Once a good transverse view of both the common femoral vein and artery is obtained (Fig. 11.4), apply direct pressure. In a normal exam, complete coaptation of the vein occurs with pressure (Figs. 11.5, 11.6). In cases in which the vein does not appear to completely compress, there are two main possibilities: 1) presence of a clot, or 2) inadequate pressure on the transducer. Adequate pressure has been applied to the vein when one can observe the artery being deformed by the pressure (Fig. 11.7). Next, proceed distally and medially, following the course of the vessel (Fig. 11.2). In general, visualization of the common femoral vein should continue in 1-centimeter increments until the vein descends into the adductor canal, generally about two thirds down the thigh.

Now begin evaluation of the popliteal region. If possible, have the patient dangle his/her leg off the bed to improve access to the region (Figs. 11.1b, 11.8). Apply gel to the transducer or the skin surface at the popliteal fossa (Fig. 11.9). Visualize the popliteal artery and vein in the transverse view, noting that the vein is more superficial than the artery (Fig. 11.10). The rhyme "the vein comes to the top in the pop" may be helpful to remember this. Then proceed with compression in 1-centimeter increments throughout the popliteal fossa. The popliteal vein requires significantly less pressure than the common femoral vein, and in some patients even the pressure from the transducer on the skin may be enough to collapse the vessel.

### Secondary Component

The use of Doppler, while confusing at first, can provide additional useful information. Doppler measures the frequency shift from approaching and/or receding red blood cells. This can aid the emergency physician by identifying which structures have flow (blood

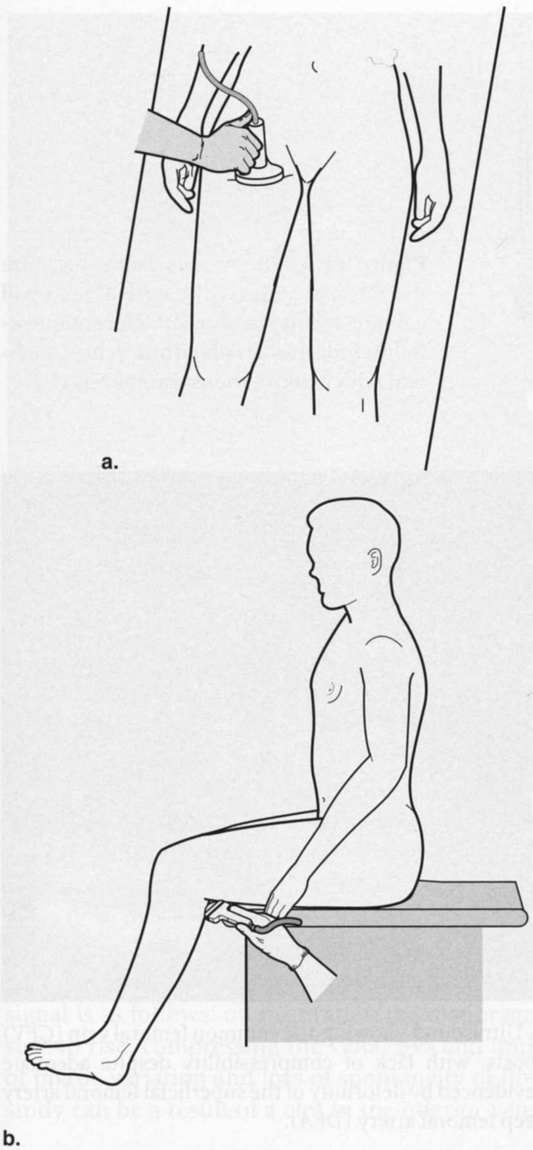


*Figure 11.1.* Guide to Image Acquisition. Begin with the patient semi-recumbent, with hip externally rotated and leg slightly flexed (A). Scan in a transverse orientation, beginning just distal to the inguinal ligament. Identify the common femoral vein, then scan distally to view the junction of the common femoral, deep femoral, and superficial femoral vessels. To view the popliteal vein, begin with the patient sitting with leg dangling (B). Scan in the popliteal fossa and identify the popliteal vein in transverse view.

*Figure 11.2.* Position for the venous examination of the lower extremity. The leg is externally rotated and flexed at the knee. The line represents the surface landmark of the femoral vein.

*Figure 11.3.* The venous study of the lower extremity begins with the femoral vessels.

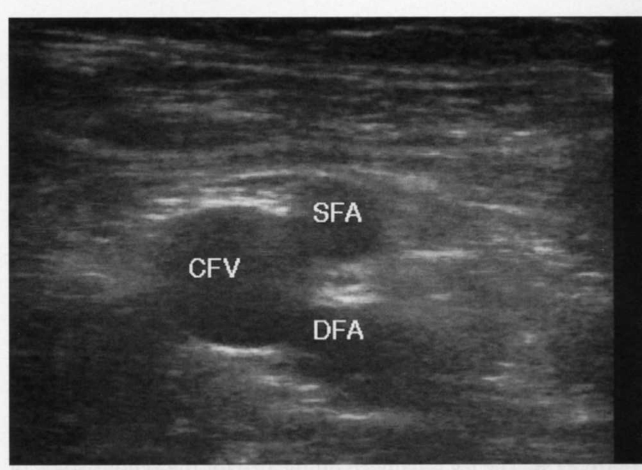


*Figure 11.4.* Transverse view of the left femoral region showing the common femoral vein (*CFV*), superficial femoral artery (*SFA*), and the deep femoral artery (*DFA*).

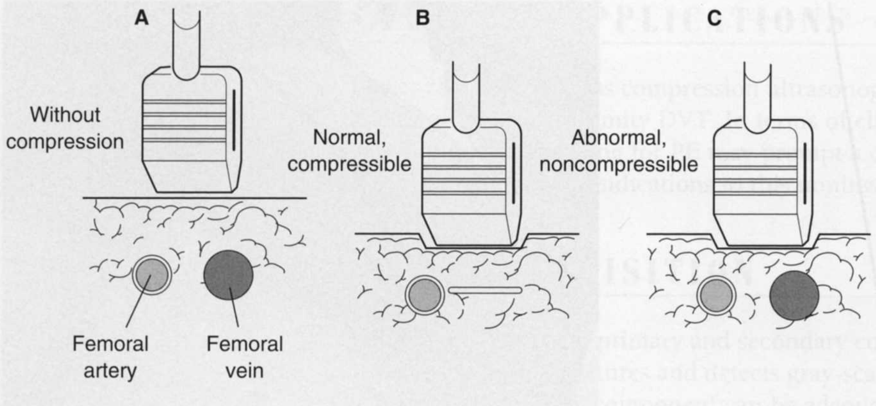


***Figure 11.5.*** The venous exam. Visualize the relevant vein (A). A normal vein will compress with pressure (B). Noncompressibility indicates an abnormal vein, consistent with a deep venous thrombosis (C).

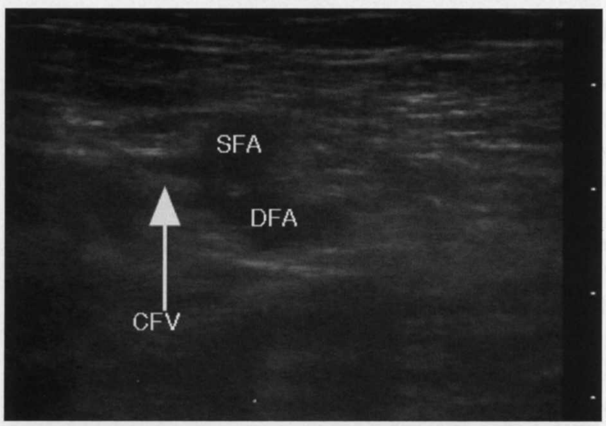


***Figure 11.6.*** Ultrasound showing normal compression of the left common femoral vein (CFV). (Superficial femoral artery: SFA; Deep Femoral Antery: DFA.)

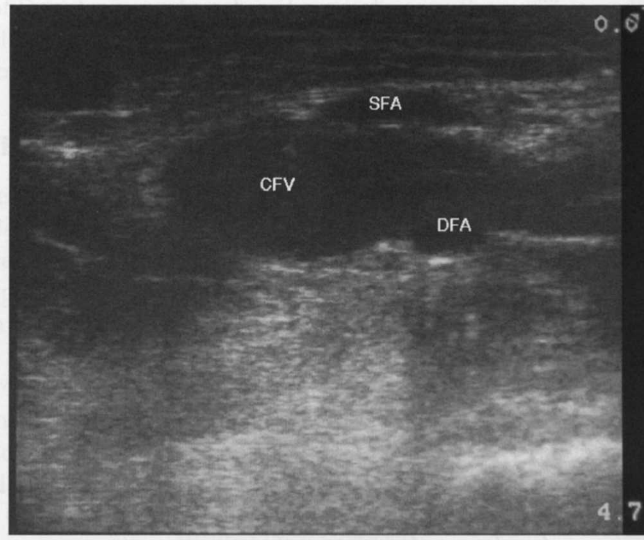


***Figure 11.7.*** Ultrasound showing the common femoral vein (*CFV*) with thrombosis, with lack of compressibility despite adequate pressure, as evidenced by deformity of the superficial femoral artery (*SFA*) and deep femoral artery (*DFA*).

***Figure 11.8.*** The leg is dangled off the bed for the venous study of the popliteal vessels.

***Figure 11.9.*** Probe placement for the examination of the popliteal vessels.

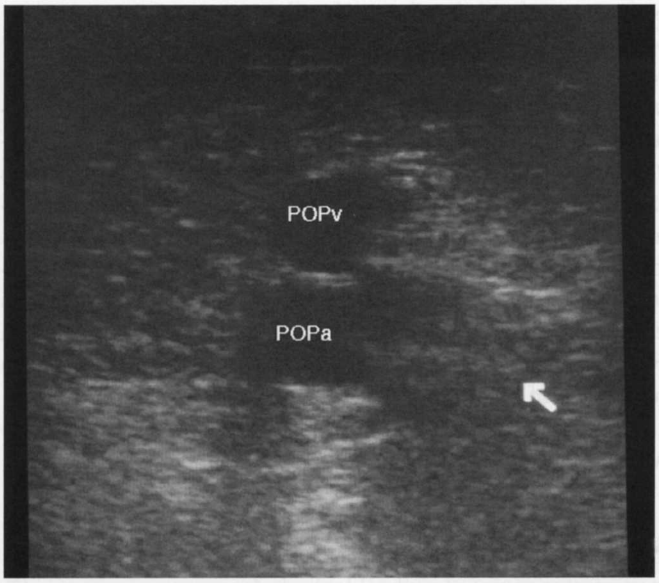


***Figure 11.10.*** Ultrasound of the popliteal area in transverse orientation. (POPa, popliteal artery; POPv, popliteal vein).

vessels) and which do not (cysts or fluid-filled organs). Veins have a characteristic color flow pattern in a normal individual. Loss of this pattern may suggest occlusion at a site directly beneath the transducer, or more proximally. There are three aspects to the Doppler exam for DVT: augmentation, spontaneity, and phasic variation. Augmentation occurs when the examiner or an assistant uses their hand to squeeze the calf while the Doppler signal is being taken. In the normal individual a blush of color fills the vein (augments); a filling defect is observed in patients with DVT (Fig. 11.11). Spontaneity is the detection of flow in the larger vessels that should occur without squeezing the calf. Variation of the venous flow that occurs during the respiratory cycle is termed phasic variation. In the normal study, the Doppler signal of the lower extremity veins increases during expiration and decreases during inspiration. The mechanism of this seemingly counterintuitive Doppler signal is as follows: on inspiration the diaphragm descends causing intra-abdominal pressure to rise, compressing the vena cava and impeding venous outflow from the legs. Loss of phasic variation and loss of spontaneity of flow in the face of a negative compressibility study can be a result of a clot in the inferior vena cava (IVC).

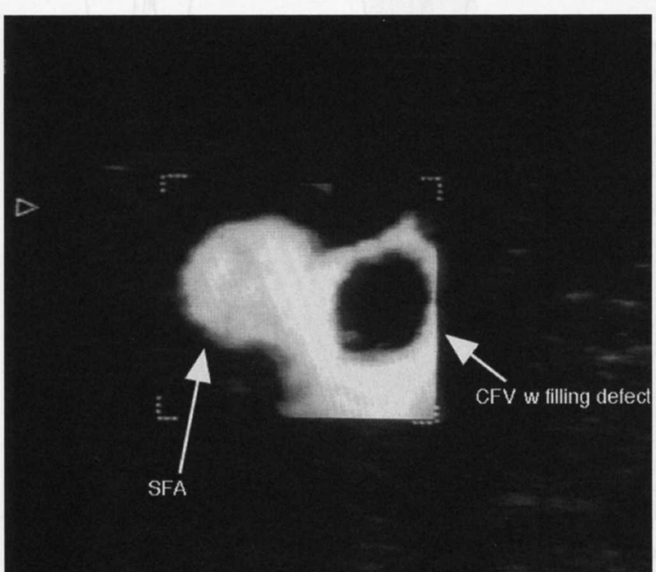


***Figure 11.11.*** A filling defect is seen during augmentation. (CFV, common femoral vein; SFA, superficial femoral artery.) (See color insert.)

## Consultative Technique Contrasted with Limited Emergency Ultrasound

Traditionally, lower extremity venous Doppler studies performed by the department of radiology or vascular laboratories visualize the entire deep venous system in the affected extremity, a process that can be very time-consuming. This comprehensive method involves compressing the deep venous system of the leg in 1-centimeter increments starting proximally at the level of the common femoral vein and proceeding down through the superficial femoral canal. This is followed by an evaluation of the popliteal system, extending distally to the level of the trifurcation in the upper calf. In contrast, emergency physicians perform a limited examination involving evaluation of vein compressibility at the common femoral and popliteal veins (Fig. 11.1). This limited evaluation of the deep venous system has been shown to be adequate because of the rarity with which clots are isolated to the superficial femoral canal. Pezzullo reviewed 146 scans that were positive for DVT and concluded that only 1% of clots were isolated to the superficial femoral canal (6,11,13).

## Normal Ultrasound Anatomy and Landmarks

The deep veins of the lower extremity include the popliteal, deep femoral, superficial femoral, and common femoral veins. It is worth noting that despite its name, the superficial femoral vein is in fact part of the deep system, not the superficial system. To avoid confusion, it is sometimes simply referred to as the femoral vein. (Fig. 11.12). The popliteal vein is formed by the merger of the anterior and posterior tibial veins with the peroneal

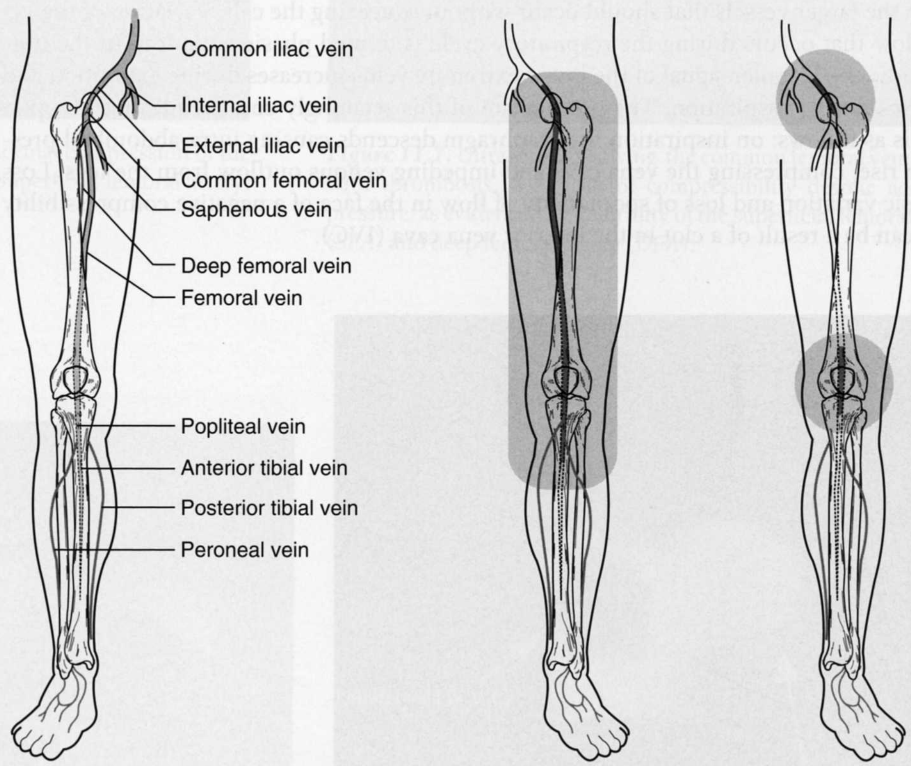


***Figure 11.12.*** The venous system of the lower extremity (A). The entire system is visualized by traditional studies (B). The more focused exam for emergency ultrasound targets the inguinal and popliteal regions (C).

vein. Continuing proximally, the popliteal vein becomes the superficial femoral vein in the distal thigh. The superficial femoral vein joins the deep femoral vein to form the common femoral vein, which becomes the external iliac vein at the level of the inguinal ligament. At the level of the inguinal ligament, the great saphenous vein (a superficial vein) merges with the common femoral vein. In relation to the companion arteries, the popliteal vein is superficial to the artery. The common femoral vein lies medial to the artery only in the region immediately surrounding the inguinal ligament. The vein abruptly runs posterior to the artery distal to the inguinal region.

There is limited anatomic variation in this area. Approximately one third of the population will have a duplicated popliteal vein. Additionally, although the common femoral vein is classically taught to be medial to the artery, there is some variability in its position relative to the artery. In some situations it may be necessary to confirm a venous structure. This is done by placing spectral flow Doppler onto the vein to observe for venous waveforms.

## Pathology

The most common pathological finding in lower extremity venous studies is noncompression of the vessel. Noncompression is the inability to completely compress the vessel with proper pressure (enough to slightly deform the artery) after ensuring good position (Fig. 11.7). It is important to remember that only complete compression of the vessel rules out DVT, and only the lack of total compression is a hard finding for DVT. Although findings such as direct visualization of clot or the absence of flow may suggest a DVT, only compression findings stand alone as rule-out/rule-in criteria.

## Artifacts and Pitfalls

1. In general, clot echogenicity increases with the age of the clot. However, this is highly variable and therefore not clinically reliable. The direct visualization of clot in the lumen of the vessel is potentially misleading for three reasons. First, the flow of blood can occasionally be echogenic and therefore mimic the presence of a clot. Second, artifact can often appear as echogenic material in the vessel lumen and be mistaken for a clot (Fig. 11.13). This is especially true in larger patients. Finally, the nonvisualization of a clot does not rule out DVT because clots themselves may lack echogenicity altogether.


A B

*Figure 11.13.* The common femoral vein (*CFV*) demonstrates artifact resembling thrombus. GS, great saphenous vein (A). Same CFV demonstrating full compression (B).

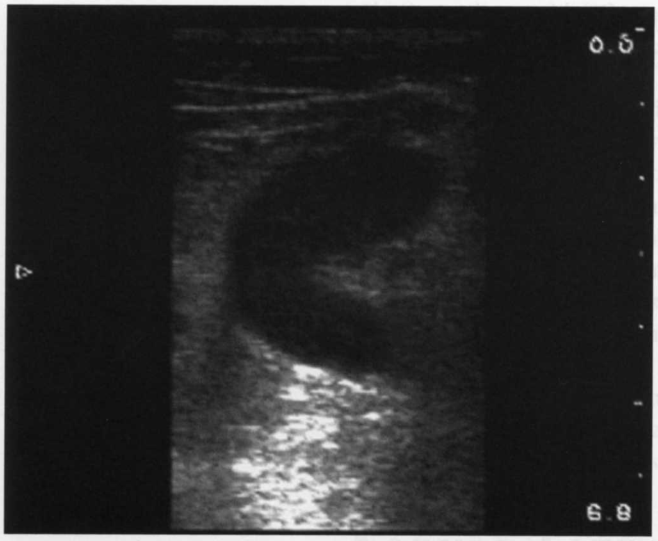


*Figure 11.14.* Image of Baker's cyst in the popliteal fossa.

2. Cysts will sometimes be encountered in the popliteal region. The most common cyst seen during lower extremity scanning is a Baker's cyst in the popliteal fossa (Fig. 11.14). Following the Baker's cyst in a longitudinal plane will typically reveal its confluency with the joint space. It may be helpful in equivocal cases to help differentiate a cyst from a vessel by using Doppler.
3. In addition to misinterpretation of images, pitfalls in bedside venous ultrasonography include challenging subjects and lack of understanding of the limits of bedside ultrasonography. Subjects who are obese or have significant edema are more difficult to image. In these patients, it is often necessary to use lower frequencies (3.5- to 5.0-MHz range) for tissue penetration, which decreases the image quality.
4. It is important to understand the limits of bedside ultrasonography. The focused exam is not a complete vascular study in which every vessel is interrogated along its entire course. Focused venous ultrasound is not a good choice to evaluate for isolated calf DVT. Several studies suggest that calf vein DVTs can propagate to more proximal locations. Hollerweger et al. showed that the embolic frequency for isolated calf vein thrombosis and muscular calf vein thrombosis was 48% and 50%, respectively (14). In a patient for whom there exists a moderate to high clinical suspicion for DVT with a negative focused ultrasound exam, it is advisable to obtain confirmatory studies in a timeframe in keeping with the level of clinical suspicion, in three to five days.
5. A few common technical problems may be encountered. If the vein is not visualized, pressure from the transducer may be collapsing the vein. Consider lessening the transducer pressure. If that does not help, reposition the patient and check landmarks. If the vein doesn't compress but no clot is seen, consider repositioning the patient and/or the transducer to apply pressure from a different angle.

## Use of the Image in Clinical Decision Making

A focused lower extremity ultrasound exam will generate two data points for each vein: the ability to compress the vein, and Doppler findings. A normal exam will have complete compression of the vessel and a phasic Doppler signal that augments with distal compression. In an abnormal exam the vessel will either be able to be compressed partially, or not at all. The Doppler signal may be normal or abnormal. It is important to stress that the most important finding is the presence or absence of complete compression.

***Table 11.1: Wells criteria***

| *Wells explicit assessment* |
|---|
| ▪ Active cancer |
| ▪ Paralysis, paresis or recent plaster, or immobilization of lower limb |
| ▪ Recently bedridden for more than 3 days or major surgery in the past 4 weeks or more |
| ▪ Localized tenderness |
| ▪ Entire leg swollen |
| ▪ Calf swelling >3 cm compared with asymptomatic leg |
| ▪ Pitting edema |
| ▪ Collateral superficial veins |
| ▪ Alternative diagnosis as likely or greater than deep venous thrombosis |
| Each positive response is 1 point, except if an alternative diagnosis is as likely or greater than deep vein thrombosis DVT, where 2 points are deducted. |
| Low probability: 0 or fewer points |
| Moderate probability: 1 to 2 points |
| High probability: 3 or more points |

The question of whether or not a lower extremity DVT can be excluded by normal findings on a venous ultrasound was reviewed by the American College of Emergency Physicians Clinical Policies Subcommittee on Suspected Lower-Extremity Deep Venous Thrombosis (15). Its conclusion was that in patients with a low clinical probability for DVT, negative findings on a single venous ultrasound scan in symptomatic patients exclude proximal DVT and clinically significant distal DVT. However in patients with moderate to high pretest probability of DVT, serial ultrasound exams are needed. Furthermore, patients with a high suspicion of pelvic or IVC thrombosis may require additional imaging techniques such as contrast venography, computed tomography (CT), or magnetic resonance imaging (MRI). Pretest probability is assessed using the Wells criteria that take into account both historical features and physical exam findings to risk-stratify patients (Table 11.1) (16). Patients in whom there is a clinical suspicion of PE but who are either too unstable to leave the department for diagnostic testing, or in whom testing is not available in a timely fashion, can be evaluated at the bedside for DVT. In the appropriate clinical setting, a positive lower extremity study can strongly support the diagnosis of pulmonary embolism.

In many cases an emergency ultrasound can guide disposition and treatment decisions. When the vascular structures are adequately visualized but lack compressibility, the diagnosis of DVT is established and treatment is indicated. If the ultrasound examination is normal (vessels are visualized and compressible), disposition depends upon the pretest probability guided by Wells criteria. Low-risk patients with normal ultrasounds can be discharged home with no need for a repeat study. If patients have moderate to high probability, two options are available. Either an alternative test can be done (CT, MRI, or venogram), or arrangements made for a follow-up ultrasound in three to five days, assuming that the patient has access to care and is reliable. If any ultrasound is indeterminant, alternative testing will be necessary.

## Correlation with Other Imaging Modalities

Compression sonography remains the primary diagnostic modality in the evaluation of the lower extremity venous system. Additional modalities include contrast venography, CT, and MRI. Contrast venography is the gold standard for the diagnosis of DVT, especially for calf veins and upper extremity vessels. It is particularly helpful in differentiating between acute and chronic DVT. However, venography is invasive; painful; expensive; time-consuming; cannot be performed at the bedside; and places the patient at risk for phlebitis, hypersensitivity reactions, and even DVTs (17). For these reasons, it is typically used only when other tests are nondiagnostic or unavailable.

CT has been well studied in the literature and compared to ultrasonography and contrast venography (18,19). CT provides the ability to simultaneously evaluate for both PE and DVT. It is accurate; less operator-dependent; and not limited by casts, burns, open wounds, obesity, or severe pain. Also, CT enables one to visualize the opposite limb, IVC, superior vena cava, and heart. CT has the disadvantage of exposing the patient to radiation and risk of contrast reaction. In addition, it requires potentially unstable patients to be moved from the emergency department.

MRI is an alternative seldom used by EDs. It has the ability to directly image the thrombi and visualize nonocclusive clots (17). MRI is also effective for imaging pelvic, IVC, and upper extremity vessels. It can help differentiate acute from chronic DVT's. As opposed to CT, there is no radiation, and the scan can be performed without contrast, making it useful for pregnant patients. However, an accurate study requires the active involvement of an experienced radiologist and resources that are often not available at all hours.

Venous ultrasound can aid in the evaluation of PE as well as DVT. In patients who are being evaluated for PE but are unable to undergo CT or ventilation perfusion scans, the presence of a DVT on ultrasound greatly simplifies the evaluation. This can be especially helpful in an unstable, hypotensive patient in whom the rapid diagnosis of a DVT may significantly alter management. Combining the use of bedside ultrasound for DVT and bedside cardiac ultrasound for right ventricular strain in patients unstable for CT or angiography may, in some cases, prove lifesaving (see Chapter 5) (20).

## Incidental Findings

Many patients in whom we consider the diagnosis of DVT actually have cellulitis causing their legs to be swollen. Lymph nodes, especially in the femoral region, can be mistaken for a vessel with intraluminal clot (Fig. 11.15). Lymph nodes can be differentiated from DVT's in two ways. First, lymph nodes are superficial structures located 2 to 3 cm from the skin surface, while the deep venous system is significantly more posterior, in the range of 4 to 5 cm from the skin surface. Second, enlarged lymph nodes are highly vascularized structures and therefore exhibit high Doppler signals in contrast to a venous clot.

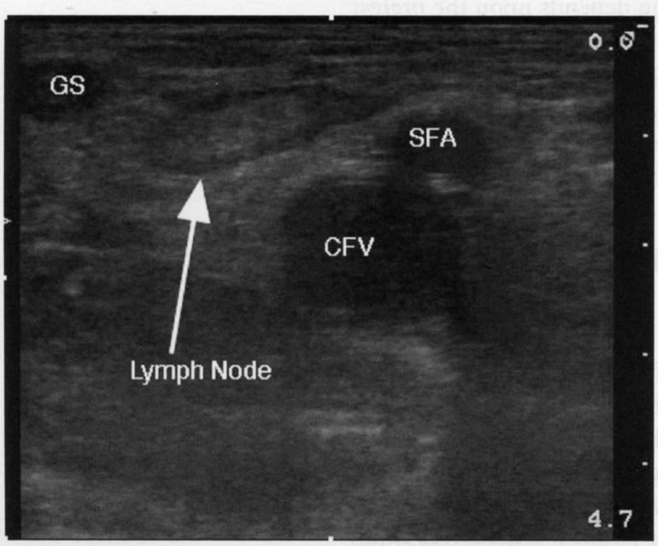


***Figure 11.15.*** A lymph node (arrow) can be mistaken for a vessel with intraluminal clot. (GS, greater saphenous vein; SFA, superficial femoral artery; CFV, common femoral vein)

## Clinical Case

A 65-year-old male presents at 7 PM on a Friday complaining of right leg swelling and pain, worst behind the knee, for 1 day. His past medical history includes congestive heart failure and significant osteoarthritis, and a recent hospitalization for subdural hematoma. His vital signs include a heart rate of 94 beats per minute, blood pressure of 147/82 mm Hg, respiratory rate 14 breaths per minute, oxygen saturation 95% on room air, and temperature 99.2 °F. On exam, his right knee is swollen and tender to palpation in the popliteal region. The swelling appears to extend distally, however he has 2+ edema bilaterally, making it difficult to compare. On direct measurement, the right calf measures 2.5 cm larger than the left. A focused bedside ultrasound showed a femoral and popliteal vein that compressed easily, with no visible echogenicity visible in the lumen. Doppler evaluation was normal. The patient was discharged home from the ED on an anti-inflammatory for presumed arthritis, and followed up for complete vascular evaluation on Thursday, to be followed by his primary physician.

The application of focused bedside ultrasound of the lower extremity saved this gentleman three to four days of unnecessary anticoagulation or Greenfield filter, and possibly unnecessary hospitalization.

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