Clinician Update

Duplex Ultrasound in the Diagnosis of Lower-Extremity Deep Venous Thrombosis

Heather L. Gornik MD, MHS; Aditya M. Sharma, MD

Case Presentation
A 26-year-old woman presented with progressive swelling and pain of the left leg within 2 months after switching to a different oral contraceptive preparation. On examination, she had marked edema and erythema of the leg from the calf to the thigh with significant tenderness to palpation. Pedal pulses were intact. The right leg was normal. Lower-extremity venous duplex ultrasound (VDUS) with B-mode compression maneuvers and Doppler evaluation was performed, and she was found to have an acute deep venous thrombosis (DVT) of the left leg that extended from the common iliac vein into the left calf (Figure 1A–1E).

Components of the VDUS Examination to Assess for DVT
VDUS combines 2 components to assess for DVT: B-mode or gray-scale imaging with transducer compression maneuvers and Doppler evaluation consisting of color-flow Doppler imaging and spectral Doppler waveform analysis. The technique of compression B-mode ultrasonography for the diagnosis of DVT was first described by technologist Steve Talbot in 1982 and has subsequently been refined to become the diagnostic standard. B-mode imaging is used while the lower-extremity veins are compressed along their length with the ultrasound probe and for direct visualization of intraluminal thrombus. A patent, thrombus-free vein will demonstrate complete vein wall coaptation with compression by the transducer (Figure 2). Loss of compressibility of the vein is the most reliable indicator of the presence of thrombus within the vein. In addition to loss of compressibility, an acutely thrombosed vein is commonly dilated with a diameter greater than that of the adjacent artery. Intraluminal echoes consistent with thrombus may be imaged. Color-flow Doppler is helpful to assess for residual flow within a thrombosed venous segment (ie, nonocclusive DVT) and for confirming patency of venous segments that are not accessible for compression maneuvers (eg, the iliacal veins). The pulsed Doppler spectral waveform from a normal, widely patent lower extremity demonstrates spontaneous and respirophasic flow (Figure 3A). Alteration of this expected waveform (ie, monophasic flow) raises suspicion of venous obstruction proximal to the level of interrogation (Figure 3B), and additional imaging may be required to definitively establish the diagnosis of DVT. In addition to assessment of respirophasicity, distal augmentation maneuvers (such as compressing the calf) are performed during spectral Doppler evaluation to further demonstrate patency of the veins. While the distal augmentation maneuver is performed, there should be a sharp “spike” of augmented anterograde venous flow (Figure 3A). Blunted or absent flow augmentation suggests venous obstruction distal to the level being interrogated. Retrograde flow in the venous system after a distal augmentation maneuver indicates venous valvular incompetence, which may be a manifestation of prior DVT and the postthrombotic syndrome (Figure 3C). A complete VDUS of the lower extremities includes evaluation from the inguinal ligament (distal external iliac or common femoral veins) into the calf. The accuracy of VDUS compared with venography for the diagnosis of proximal and calf DVT has been well established.

From the Department of Cardiovascular Medicine, Section of Vascular Medicine, Cleveland Clinic Heart and Vascular Institute, Cleveland, OH (H.L.G.); and Cardiovascular Medicine Division, University of Virginia, Charlottesville (A.M.S.).
Correspondence to Heather L. Gornik, MD, MHS, Medical Director, Non-Invasive Vascular Laboratory, Cleveland Clinic Heart and Vascular Institute, 9500 Euclid Ave, Desk J3-5, Cleveland, OH 44195. E-mail gornikh@ccf.org (Circulation. 2014;129:917-921.)
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Assessing the Acuity of DVT

Thrombus is typically referred to as acute (within the first 2 weeks after the thrombus forms), subacute (>2 weeks and potentially up to 6 months after thrombus forms), or chronic (usually >6 months old). Acuity of the DVT is assessed by the appearance of the thrombus on B-mode imaging (eg, hypoechoic, isoechoic, or hyperechoic), vein lumen size, vein wall appearance, venous compressibility, function of the venous valves, and presence of collateral circulation. The classic ultrasound characteristics of acute, subacute, and chronic DVT are shown in the Table, although in many cases, there is overlap of findings, and aging the acuity of thrombus is not possible. In such cases, “DVT of indeterminate age” should be reported. Murphy and Cronan previously demonstrated that dilated vein diameter is the most accurate parameter in aging the acuity of DVT.

Controversies in VDUS

Repeat Ultrasound and Residual Vein Thrombus After Completion of Therapy

More than half of patients with proximal DVT have residual vein thrombosis seen on VDUS 6 months to 1 year after diagnosis and completion of therapy. Indeed, the presence of residual DVT has been shown to be a risk factor for recurrent venous thromboembolism. However, residual vein thrombosis is not yet established as a marker to assess the duration of anticoagulation therapy beyond clinical factors such as the circumstances of the DVT (ie, provoked or unprovoked event), presence of ongoing risk factors, and follow-up D-dimer levels. Regardless, obtaining a repeat VDUS 6 months to 1 year after treatment for proximal DVT is clinically useful because it establishes a new baseline for future comparison in the case of recurrent ipsilateral limb symptoms, when differentiating recurrent DVT from the postthrombotic syndrome can be challenging.

Lower-Extremity VDUS in the Evaluation of Patients With Suspected Pulmonary Embolism

VDUS may be used as an adjunct to more definitive imaging modalities in the evaluation of patients with suspected pulmonary embolism (PE). One question frequently asked is whether to perform VDUS before chest computed tomography among patients presenting with symptoms of PE, perhaps eliminating the need for chest computed tomography among those with DVT who will require anticoagulation. In general, this practice is discouraged because fewer than half of patients with PE will have residual...
DVT on VDUS (ie, the majority of thrombus has already embolized to the lungs). In addition, patients with DVT may have other causes of dyspnea and pleurodynia besides PE such as pneumonia or pleural effusion. Thus, VDUS should not be used solely for the assessment for PE. Diagnostic testing algorithms for PE have been developed that include pretest probability assessment, D-dimer testing, and VDUS to eliminate the need for computed tomography.

Figure 2. B-mode imaging of the veins with compression maneuvers, expected normal findings. A, Duplicating femoral veins in the thigh (V) next to superficial femoral artery (A). B, Both femoral veins compress completely with pressure of the ultrasound transducer. Only the superficial femoral artery (A) is seen. C, Calf vein imaging. Shown are the paired posterior tibial veins (PTV) and artery and the 2 peroneal veins (Pero V) and artery. D, During the compression maneuver, the calf veins compress completely, and only the arteries are visualized (A). Acoustic shadowing from the fibula can be seen (arrowhead).

Figure 3. Spectral Doppler waveform analysis of the lower-extremity veins. A, Spontaneous and respirophasic flow with normal response to an augmentation maneuver and aliasing of the pulsed Doppler signal (arrow). B, Monophasic venous flow suggesting venous obstruction proximal to this segment. EIV indicates external iliac vein. C, Retrograde flow in the popliteal vein (POP V) after an augmentation maneuver (arrow), consistent with valvular incompetence in a patient with a history of deep venous thrombosis and the postthrombotic syndrome.
Table. Distinguishing Ultrasound Features of Acute, Subacute, and Chronic DVT*

<table>
<thead>
<tr>
<th>Features</th>
<th>Acute</th>
<th>Subacute</th>
<th>Chronic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attachment of thrombus to vein wall</td>
<td>Loosely attached</td>
<td>Firmly attached</td>
<td>Firmly attached</td>
</tr>
<tr>
<td>Thrombus echogenicity</td>
<td>Hypoechoic or isoechoic</td>
<td>Variable (more echoic than acute DVT)</td>
<td>Hyperechoic (appears as a bright fibrous web or scar attached to the vein wall and protruding into the lumen)</td>
</tr>
<tr>
<td>Presence of free-floating or mobile thrombus tail</td>
<td>May be present</td>
<td>Generally absent</td>
<td>Absent</td>
</tr>
<tr>
<td>Vein wall appearance</td>
<td>Variable</td>
<td>Variable</td>
<td>Venous wall thickening and scarring</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Calcium deposition may be seen (phlebolith)</td>
</tr>
<tr>
<td>Vein lumen</td>
<td>Distended</td>
<td>Starts to retract to normal size</td>
<td>Smaller than normal size (atrophic)</td>
</tr>
<tr>
<td>Compressibility</td>
<td>Slightly deformable, “spongy”</td>
<td>More compressible than acute</td>
<td>Partly noncompressible, likely partially recanalized</td>
</tr>
<tr>
<td>Collateralization</td>
<td>Generally absent</td>
<td>May be present</td>
<td>May be present</td>
</tr>
<tr>
<td>Venous valve function</td>
<td>Usually competent</td>
<td>May be competent or incompetent (reflux present)</td>
<td>Often incompetent (reflux present)</td>
</tr>
</tbody>
</table>

*In some cases, there is overlap of ultrasound features, in which case the DVT should be reported as being of indeterminate age.

DVT indicates deep venous thrombosis.

Tomographic angiography among low-risk patients.16

**Pitfalls of Venous Ultrasound for Diagnosis of DVT**

**Duplicate Veins**

Duplication of the femoral or popliteal veins is commonly encountered during VDUS and venography.17,18 Unrecognized venous duplication can lead to misdiagnosis of DVT when the thrombus-free vein of a pair is identified and the vein with thrombus is missed. To minimize this error, it is important to note venous duplication on the written report. In 1 study, 15% of duplicated or triplicated veins were missed on repeat evaluations.18

**Misnomer of the Superficial Femoral Vein**

The superficial femoral vein is actually a deep vein that is the continuation of the popliteal vein that joins the profunda femoral vein to form the common femoral vein. Thrombosis in this deep vein warrants treatment with anticoagulation similar to any DVT. Given the potential for diagnostic and treatment errors related to the use of this term, the International Interdisciplinary Consensus Committee on Venous Anatomic Terminology concluded in 2001 that the term superficial femoral vein should not be used.19 Accreditation organizations strongly recommend against using this term, and this venous segment is now referred to as the femoral vein.2,20

**Conclusions**

VDUS using B-mode imaging with compression maneuvers and color and spectral Doppler evaluation is now the standard diagnostic modality for suspected lower-extremity DVT. Loss of compressibility of a venous segment, often with associated Doppler abnormalities, identifies DVT with a high degree of accuracy, and no additional testing is needed to initiate treatment. Negative whole-leg VDUS has a very high negative predictive value for suspected lower-extremity DVT, and no further testing is required to withhold anticoagulation. Whole-leg VDUS, including calf vein assessment, is the diagnostic standard.

**Case Resolution**

The patient was immediately started on subcutaneous low-molecular-weight heparin and was ultimately referred for catheter-directed thrombolysis, given the extensive iliofemoral DVT and her severe symptoms.

**Disclosures**

Dr Gornik is a noncompensated (volunteer) member of the Board of Directors of the Intersocietal Accreditation Commission–Vascular Testing Division representing the American College of Cardiology. Dr Sharma reports no conflicts.

**References**

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