Sonographic Evaluation of Upper Extremity Deep Venous Thrombosis

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Objective. The purpose of this presentation is to review the techniques of performing an upper extremity Doppler examination, in addition to illustrating the sonographic appearances of acute and chronic upper extremity deep venous thrombosis (UEDVT). ***Methods.*** The risk factors and complications of UEDVT are discussed, and the anatomy of the upper extremity deep venous system as well as examination techniques are described. Cases of acute and chronic deep venous thrombosis were also chosen to illustrate the spectrum of sonographic appearances. ***Results.*** Color Doppler sonography is accurate in the diagnosis of UEDVT. However, in cases of equivocal Doppler findings, or when the sonographic findings are normal but clinical suspicion for central venous thrombosis is high, magnetic resonance or contrast venography is necessary for further evaluation. ***Conclusions.*** Color Doppler sonography is a rapid and noninvasive technique in the evaluation of venous disease in the upper extremity and is the modality of choice in screening for UEDVT. ***Key words:*** Doppler sonography; upper extremity; venous thrombosis.

Abbreviations
MR, magnetic resonance; PICC, peripherally inserted central catheter; UEDVT, upper extremity deep venous thrombosis

Received October 18, 2004, from the Department of Radiology, West Los Angeles Veterans Administration Medical Center, Los Angeles, California USA (E.E.C.); Department of Radiology, University of California Los Angeles School of Medicine, Los Angeles, California USA (P.T.Z.); and Department of Radiology, University of Southern California, Keck School of Medicine, University of Southern California University Hospital, Los Angeles, California USA (E.G.G.). Revision requested December 8, 2004. Revised manuscript accepted for publication February 3, 2005.

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The prevalence of upper extremity deep venous thrombosis (UEDVT) is growing because of several predisposing factors associated with the disease, most notably, the increasing use of indwelling central venous catheters. In 6 different studies, 28% to 61% of patients with UEDVT had some form of indwelling catheter.[1–6] Similarly, in another recent study,[7] UEDVT developed in 12% of the patients after the placement of implantable central venous catheters, and Allen et al[8] found an approximately 23% thrombosis rate after initial placement of peripherally inserted central catheters (PICCs). Patients with malignancy are also predisposed to the development of UEDVT secondary to alterations in coagulation factors, low-grade disseminated intravascular coagulation initiated by tumor cells, or stasis due to compression by a tumor. Furthermore, these patients frequently receive central venous catheterization as well as radiation, which further increases the risk for UEDVT. Multiple other predisposing factors include "effort" thrombosis in otherwise healthy persons (Paget-

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Schroetter syndrome), inherited thrombophilic disorders, other acquired hypercoagulable states (such as pregnancy and oral contraceptive use), prior thrombosis or surgery, trauma, sepsis, venous stasis, and thoracic outlet obstruction related to anatomic anomalies.[9–11]

Pulmonary embolism is an important and sometimes fatal complication of UEDVT. The prevalence of pulmonary embolism secondary to UEDVT is not precisely known but may be comparable with that of iliofemoral deep venous thrombosis. Hingorani et al[12] found a prevalence rate of pulmonary embolism of 17% from UEDVT compared with 8% from lower extremity deep venous thrombosis. In 9 studies involving 406 patients with UEDVT, pulmonary embolism was observed in approximately 13% of these patients.[10] Other complications of UEDVT include post-thrombotic syndrome, superior vena cava syndrome, septic thrombophlebitis, and, rarely, venous gangrene.

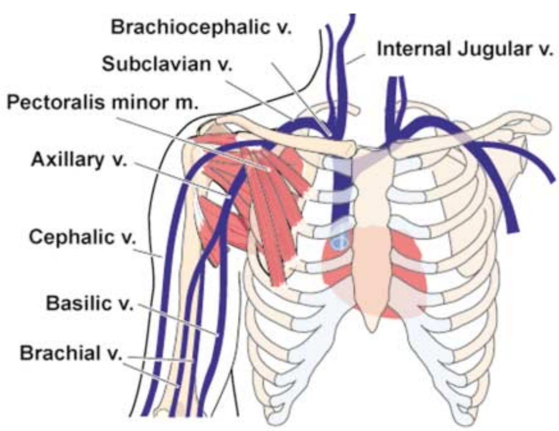
The clinical features of acute UEDVT include swelling, discoloration, or both, pain, and tenderness to palpation of the affected limb. However, these symptoms are nonspecific, and fewer than half of these patients will have imaging evidence of UEDVT.[10] Therefore, it is important to confirm or exclude the diagnosis with objective testing.

Doppler examination is the screening technique of choice, whereas contrast venography remains the standard in the evaluation of UEDVT. Doppler examination is also often used to locate intact venous access sites in patients who are about to undergo central venous catheter insertion. Six different prospective studies have found that color Doppler sonographic imaging is accurate in the diagnosis of UEDVT, with sensitivity ranging from 78% to 100% and specificity of 82% to 100%.[5,13–17] Most studies agree that false-positive results are rare. False-negative results may occur with small nonobstructive thrombi that cannot be directly assessed with compression techniques because of overlying bones. Additionally, centrally situated veins, including the medial segment of the subclavian vein, the brachiocephalic vein, and their confluence with the superior vena cava, may be difficult to visualize in some patients. Furthermore, differentiation between a normal vein and a large collateral in a patient with chronic venous thrombosis may sometimes be difficult. Therefore, contrast or magnetic resonance (MR) venography is used in select cases in which sonographic findings are equivocal or when clinical suspicion for UEDVT is high despite negative sonographic findings.

Technique and Normal Anatomy

The venous anatomy of the neck, thoracic inlet, and arm is illustrated in Figure 1. The routine examination includes interrogation of the internal jugular, brachiocephalic, subclavian, axillary, brachial, and basilic veins of the symptomatic upper extremity. Evaluation of the cephalic vein at its confluence with the subclavian vein should also be performed, although this may be difficult to visualize in some patients. The radial and ulnar veins may be interrogated when there are specific symptoms referable to these regions. Additionally, duplex Doppler sonography of the contralateral asymptomatic limb is performed because waveform asymmetry may indicate more central obstruction that is difficult to visualize directly. In accessible veins, a compression technique should always be used because noncompressibility is the most sensitive and specific sign of venous thrombosis. Compression is performed in the transverse plane because the transducer may slide off the vessel in the longitudinal axis, potentially resulting in a false-negative finding. Color Doppler imaging becomes useful when overlying bones prevent direct compression. Furthermore, color as well as spectral Doppler sonography is essential in the evaluation of focal stenoses. Of note, Doppler

Figure 1. Anatomy of the venous system of the neck, thoracic inlet, and arm.



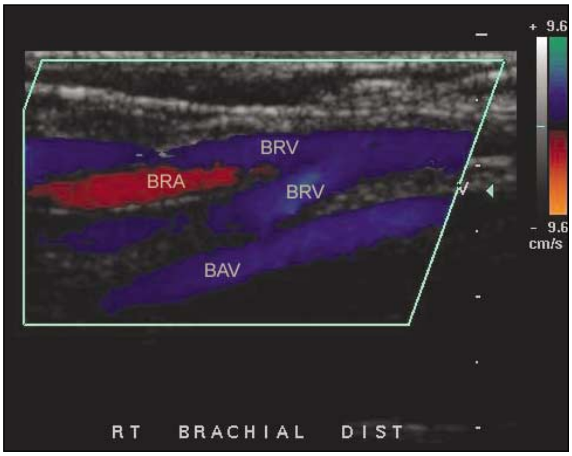


Figure 2. Longitudinal color Doppler image from a healthy volunteer shows the brachial artery (BRA) and veins (BRV) as well as the more superficial adjacent basilic vein (BAV). Note that the image was obtained from the lateral aspect of the upper arm; therefore, the brachial vessels are closer to the transducer. The brachial veins are often paired and are immediately adjacent to the artery.

insonation should be performed along the longitudinal axis of the vein with a Doppler angle of 60° or less.

The patient should be placed in the supine position with the arm to be examined comfortably extended to approximately 60° from the chest. Hyperextension should be avoided in that it may inhibit normal flow and may affect waveform shape and amplitude. By placing the transducer lightly over the mid portion of the inner aspect of the upper arm in a transverse orientation, the single brachial artery can be identified in the mid upper arm and used as a landmark. The artery can be differentiated from the veins by its direction and spectral pattern. The brachial veins, which are often paired, are closely applied to the artery (Figure 2). The basilic vein lies more superficially and is typically single. Although the basilic vein is technically part of the superficial system, it is often larger than the brachial veins and may have a considerable clot burden. Therefore, thrombosis in this vessel should be considered clinically important. Once the veins of the arm are interrogated, the vessels can be followed centrally into the axillary vein, which lies beneath the pectoralis minor. By angling the transducer cephalad and moving medially beneath the clavicle, the subclavian vein can be delineated until the area of the first rib or the head of the clavicle. When viewed from beneath the clavicle, the vein lies superficial and caudal to the adjacent artery. After this portion of the study is complete, the ipsilateral jugular vein should be interrogated with the patient's head slightly rotated away from the side of examination. The evaluation described thus far is best performed using a 5- or 7.5-MHz linear array transducer. Curved array transducers may be useful in the axillary areas or in larger individuals because of

Figure 3. Color Doppler image from a healthy volunteer shows the junction of the left subclavian (SV) and internal jugular veins (IJ), with visualization of the brachiocephalic vein (BCV). The image was obtained with a small-footprint transducer, in this case a curved array C8-5.

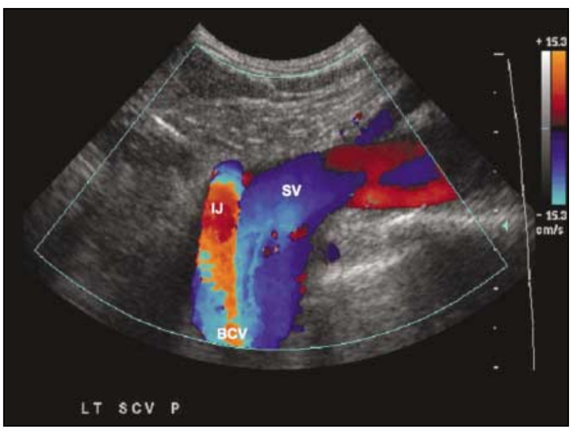
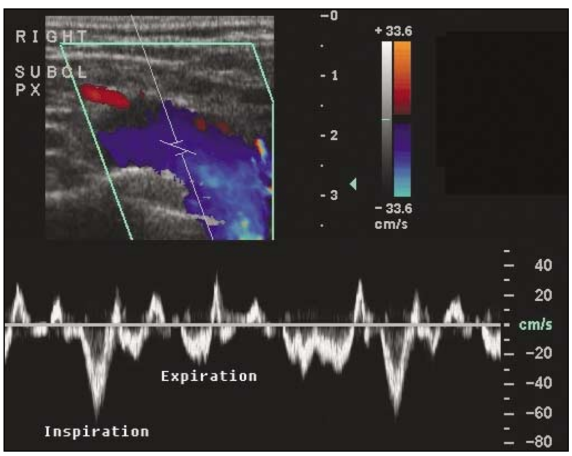


Figure 4. Doppler spectra of the right subclavian vein from a healthy volunteer, which is characterized by 2 phasic variations in amplitude. The action of the right atrium is reflected back into the vessel and manifests as a choppy and sometimes biphasic flow pattern, otherwise known as cardiac pulsatility. Also notice the respiratory phasicity reflected in this spectral waveform; considerable flow is seen with inspiration, whereas there is decrease in flow during expiration. Of note, there is increased pulsatility of the upper extremity spectral waveforms when compared with those of the lower extremity veins because of their proximity to the heart.



better depth penetration. Furthermore, it also provides a larger field of view, therefore allowing visualization of longer segments of the deep venous system.

Centrally situated veins, including the medial segment of the subclavian vein, the brachiocephalic vein, and their confluence with the superior vena cava, may be difficult if not impossible to image in some patients. Evaluation of these areas requires a supraclavicular or suprasternal approach and may necessitate the use of a sector or phased array transducer with a small footprint to facilitate imaging in these tight areas surrounded by bone (Figure 3). The technique described thus far may also be performed in the reverse sequence, namely, starting with interrogation of the internal jugular vein, continuing caudally toward the brachiocephalic and medial subclavian veins, and moving laterally to evaluate the remaining subclavian as well as the axillary veins. The arm veins would be last examined with this approach.

Knowledge of the normal spectral waveform in the upper extremity vein is essential in the examination of these veins (Figure 4). The spectral Doppler signals are characterized by 2 phasic variations in amplitude. Cardiac pulsatility manifests as a choppy and sometimes biphasic flow

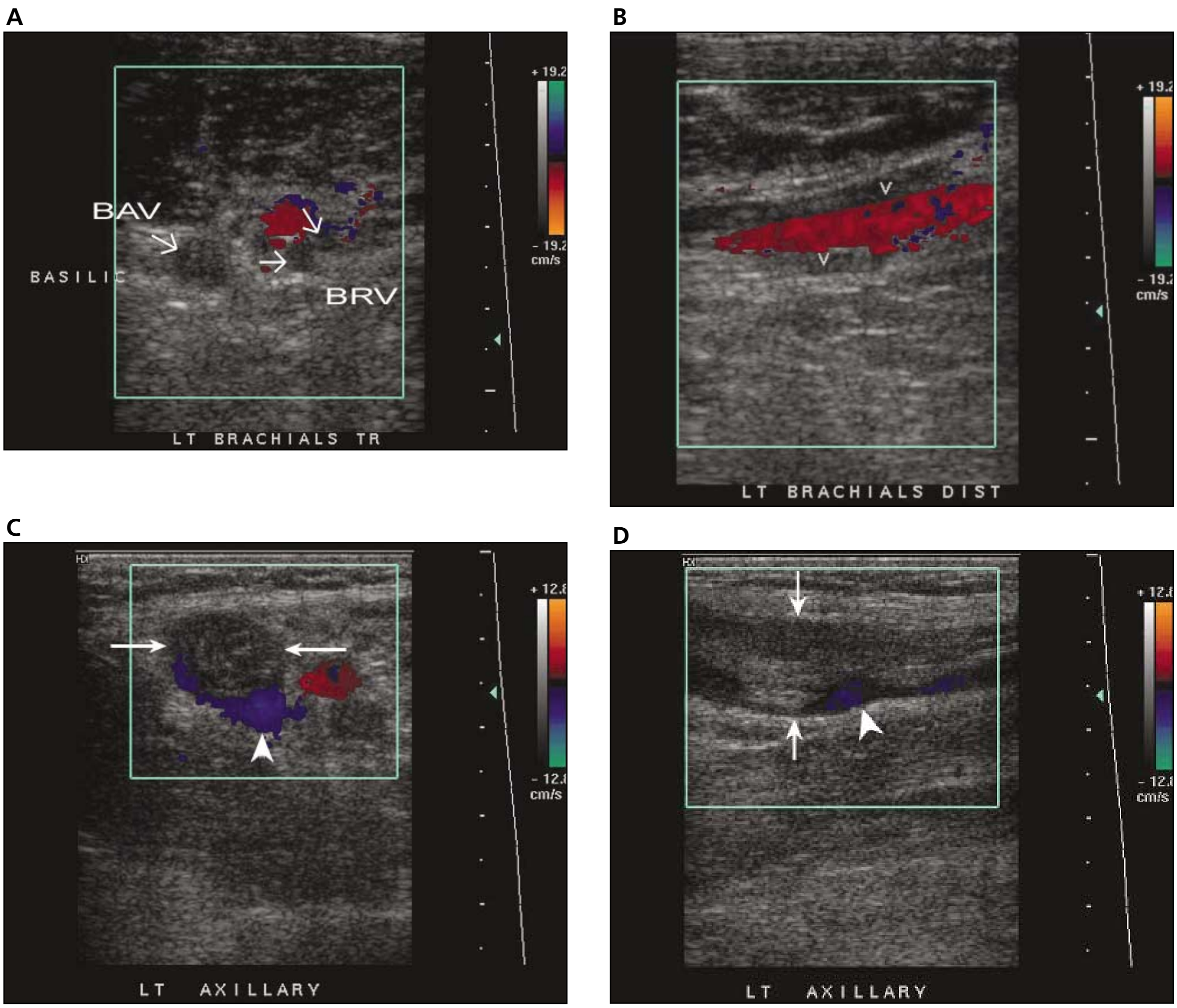


Figure 5. Images from a 65-year-old man with an indwelling PICC terminating within the superior vena cava in whom a left upper extremity thrombus subsequently developed. **A** and **B**, Transverse and longitudinal color images show the thrombus within the left brachial and basilic veins. Note paired, thrombosed brachial veins (BRV) adjacent to artery, as well as the more superficial location of the basilic vein (BAV). **C** and **D**, Transverse and longitudinal color images of the axillary vein show an expansile, hypoechoic thrombus (arrows), which implies an acute process. Note peripheral flow around the clot (arrowhead) (continued).

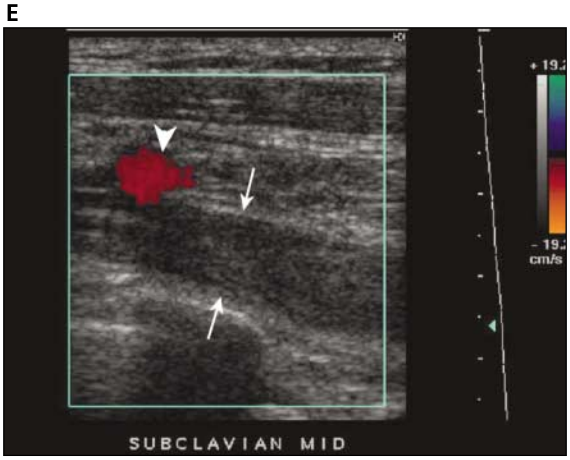
pattern.[14] There is peak forward flow during mid diastole, whereas the flow slows or reverses as the tricuspid valve closes. Respiratory variation may also be fairly pronounced in the upper extremity veins, with increased flow during inspiration and decreased flow on expiration. With end inspiration or expiration, little flow may be seen in some healthy patients. This should not be mistaken for blockage or an anechoic thrombus.

Acute Deep Venous Thrombosis

The thrombosed vein is visualized as an enlarged and tubular structure filled with a thrombus of variable echogenicity. On color Doppler sonography, flow is absent in the area of the thrombus, or the thrombus is outlined by color (Figures 5 and 6). Collaterals are often visualized as prominent venous structures in the soft tissues surrounding the thrombosed main vein (Figure 5F). Spectral analysis may also be useful in the evaluation of central thromboses in which the clot may be difficult to identify. Conversion of the normal biphasic pattern into a nonpulsatile signal (similar to portal venous flow) is strongly suggestive of central venous impairment (Figure 5G), such as thrombosis, stenosis, or extrinsic compression by an adjacent mass. In cases in which a diagnosis of central thrombus is considered on the basis of dampening of the spectral waveform, comparison should be made with the opposite side to confirm that the pattern is only present on the symptomatic side (Figure 7). Patel et al[18] showed excellent results in diagnosing central obstruction by using this dampening effect. In their series, they carefully compared waveforms from one side to the other, helping overcome the limitations imposed by inherent variations in waveforms from patient to patient. They found that, although respiratory phasicity was often asymmetric in patients with unilateral venous occlusion, absent or reduced cardiac pulsatility was a more sensitive parameter. However, they cautioned that subtle dampening of pulsatility or phasicity may be difficult to

Figure 5. (continued) **E**, Longitudinal color image shows the thrombus within the left subclavian vein (arrows). Note the venous collateral adjacent to the thrombosed vein (arrowhead). **F**, Additional spectral image of the venous collateral shows nonpulsatile flow, as expected in a vessel distal to a blockage. **G**, Transverse color and spectral image shows a patent left internal jugular vein. The vessel compressed normally. However, the waveform is nonpulsatile, which is highly suggestive of a more central obstruction (ie, the brachiocephalic vein or superior vena cava).

E



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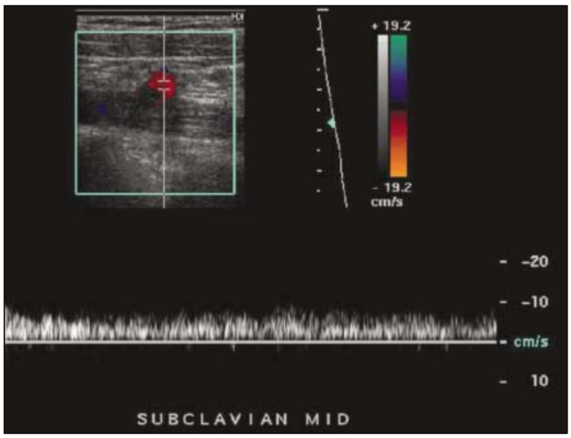

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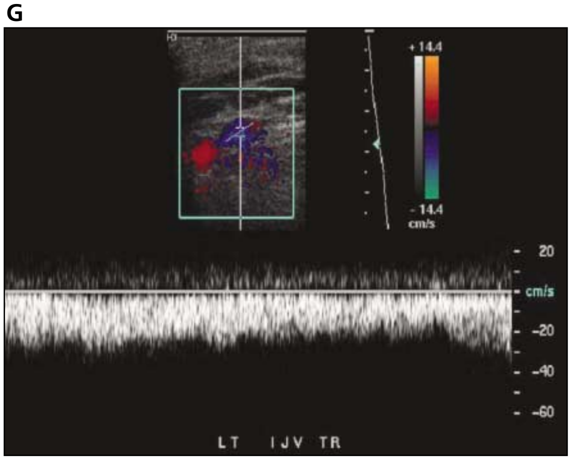
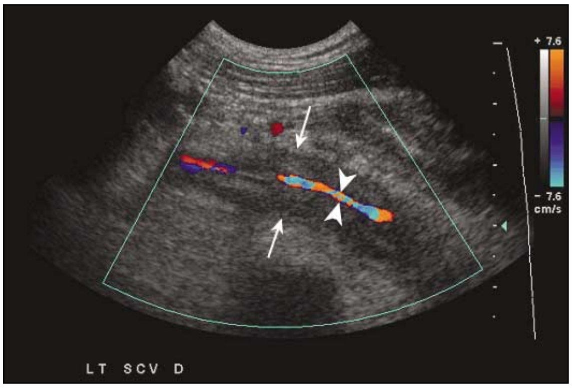


Figure 6. Images from a 53-year-old man with aplastic anemia and an indwelling PICC in whom a left subclavian venous thrombus developed. The PICC was removed just before this Doppler examination. **A**, Color Doppler image shows an enlarged subclavian vein containing a nonocclusive thrombus (arrows). Note the residual patent channel previously occupied by the PICC (arrowheads). **B**, Spectral Doppler image of the more peripheral left axillary vein shows a low-velocity, nonpulsatile waveform secondary to the thrombus within the subclavian vein. **C**, Another spectral image of the small patent lumen amidst the subclavian thrombus shows pulsatile turbulent flow. Of interest, pulsatility is often present in the narrowed channel, whereas the more peripheral vessel is nonpulsatile.

A



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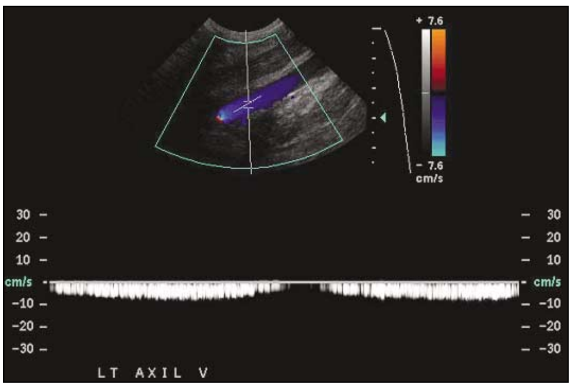

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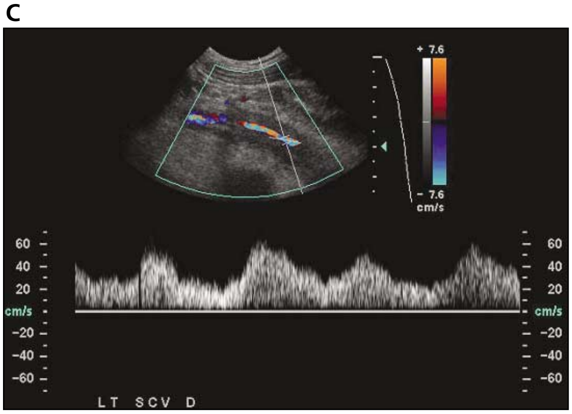


appreciate in cases of bilateral subclavian vein or superior vena cava occlusions. In situations of nondiagnostic or equivocal Doppler findings or when clinical signs are highly suggestive of UEDVT despite normal sonographic findings, MR or contrast venography is necessary for further evaluation.

Chronic Upper Extremity Venous Disease

Chronic venous disease may affect the upper extremity after an acute thrombotic event of any cause or in any patient with long-term catheterization. The diagnosis of chronic venous disease is considerably more challenging than acute venous disease because enlarged, thrombus-filled veins are not present. Frozen valve leaflets, synechia (Figure 8), and recanalized veins with internal channels in addition to small-caliber veins with noncompressible thickened walls and foci of echogenic thrombi may be seen. Furthermore, stenosis due to prior thrombosis is readily visible on color Doppler evaluation, as shown in Figure 9. Aliasing is frequently found in these areas, signifying a region of high-speed flow. Additionally, the flow in the narrowed segment (which may be due to stenosis, in which case no thrombus is visualized, or secondary to an adjacent clot, as shown in Figures 6C and 7D) is often markedly pulsatile, whereas the more peripheral waveform is dampened and nonphasic. The reason for the return of pulsatility in the narrowed segment is uncertain and to our knowledge has not been explained in the literature.

Not uncommonly, the only manifestation of chronic venous thrombosis is the inability to show a specific vessel in the expected anatomic location (Figure 10) because the vein is simply collapsed and fibrosed. Unfortunately, collateral veins may become so prominent in patients with chronic disease that they may be mistaken for the main vein, which is essentially absent. In patients thought to have chronic thrombosis, any deviation from the expected normal anatomy (Figure 11) or flow direction (Figure 12) should be viewed with suspicion. Identifying the vein and its adjacent artery is also an important clue to differentiating main veins from enlarged collaterals. Additionally, the loss of respiratory phasicity and, particularly, cardiac pulsatility by spectral analysis may be the only positive finding in patients with central venous obstruction who have other-

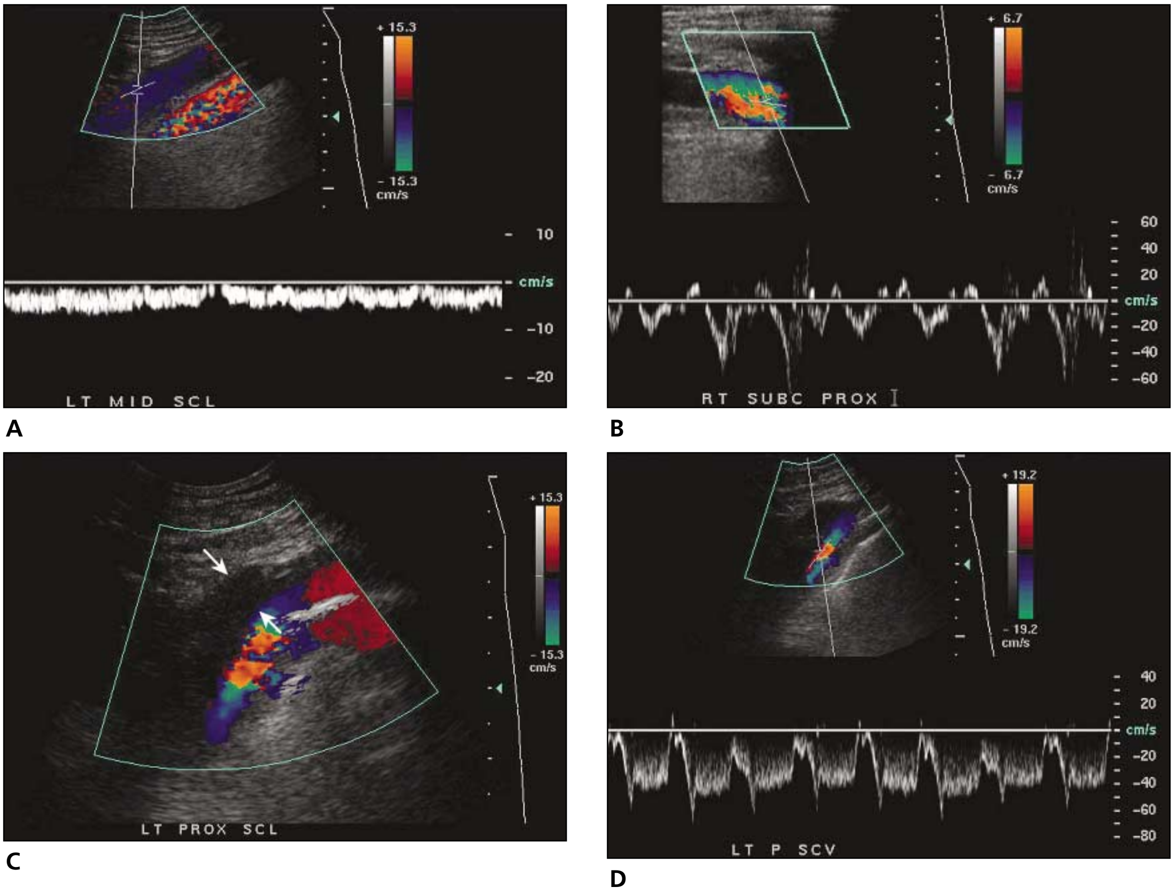


Figure 7. Images from a 41-year-old man after repair of a type A aortic dissection, complicated by fascial dehiscence, in whom left upper extremity swelling subsequently developed on postoperative day 21. **A**, Longitudinal color and spectral image of the left subclavian vein shows a dampened waveform, highly suggestive of central venous impairment. **B**, Images of the contralateral nonsymptomatic subclavian vein shows a normal pulsatile waveform. **C** and **D**, Scanning centrally identifies a partially occlusive thrombus within the medial subclavian vein (arrows). Note turbulent but pulsatile flow in the narrowed venous channel.

wise normal findings. However, a caveat of using this criterion is that sometimes these collateral vessels are large and extensive enough to provide adequate drainage, and the pulsatility and respiratory variations may be preserved.[11]

Another difficult task is the diagnosis of an acute thrombus superimposed on a chronic thrombus, which remains a problematic area. Although a hypoechoic and expansile thrombus implies an acute process, this is infrequently seen in clinical practice. Comparison with the initial examination may also be helpful to identify areas of new thrombosis that were previously absent. Unfortunately, clinical judgment and other modalities such as contrast venography may be necessary in those patients with suspected recurrent thrombi and in whom sonography is not helpful.

Figure 8. Longitudinal gray scale image from a 67-year-old man with myelodysplastic syndrome in whom a left axillary venous thrombus developed after placement of a PICC. The image, obtained after a period of anticoagulation, shows frozen valve leaflets (V) as well as echogenic synechiae (S) as sequelae of prior thrombosis.

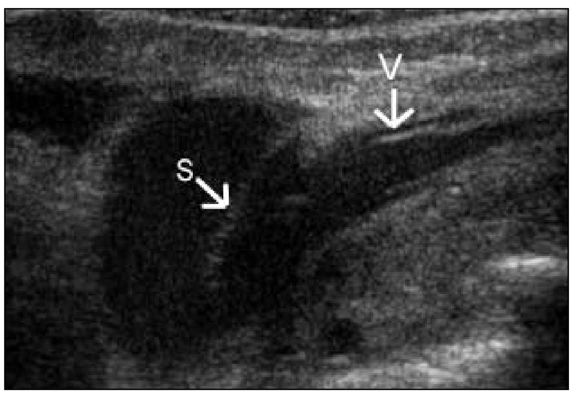
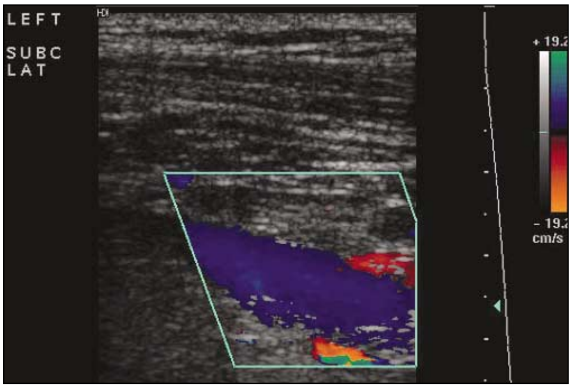


Figure 9. Images from a 70-year-old man with pancreatic carcinoma, after a Whipple procedure, in whom left upper extremity swelling subsequently developed after placement of a PICC line. **A** and **B**, Color Doppler images of the left lateral subclavian vein show no evidence of a thrombus. However, the spectral waveform shows dampened cardiac pulsatility, despite normal respiratory phasicity. **C**, Scanning more centrally reveals a consistently narrowed segment of the subclavian vein (arrows) as it joins with the internal jugular vein. Intense aliasing suggests a region of high-speed flow in the area of stenosis.

A



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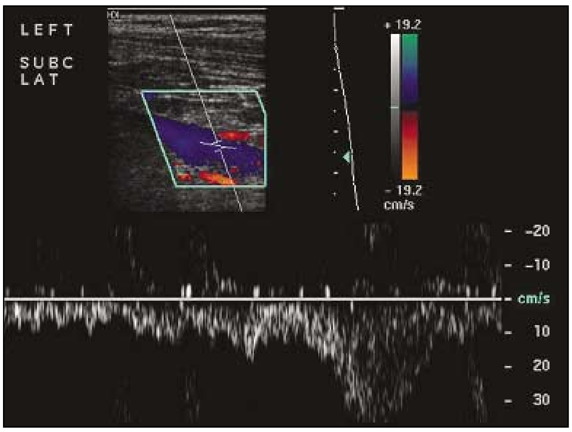

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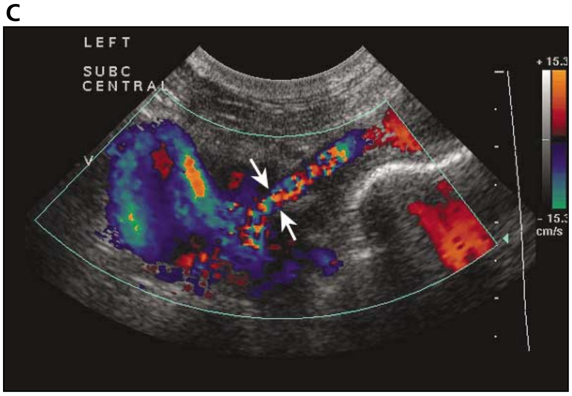
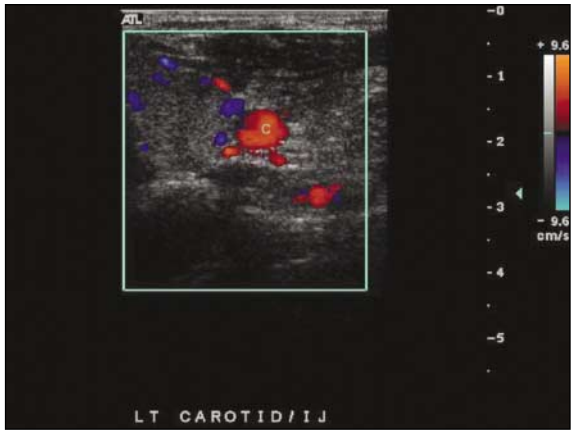


Figure 10. Transverse image through mid left neck from a 54-year-old woman with a history of left internal jugular catheter but no documented acute episode of thrombosis shows a normal common carotid artery (C) lateral to the thyroid. No jugular vein was identified. Note the large collaterals around the thyroid gland.



Conclusions

Color Doppler sonography is a rapid, accurate, and noninvasive technique in the evaluation of venous disease in the upper extremity and is the modality of choice in screening for UEDVT. However, MR or contrast venography may be necessary in select cases in which sonographic findings are nondiagnostic or equivocal or when clinical suspicion for UEDVT remains high despite normal Doppler findings.

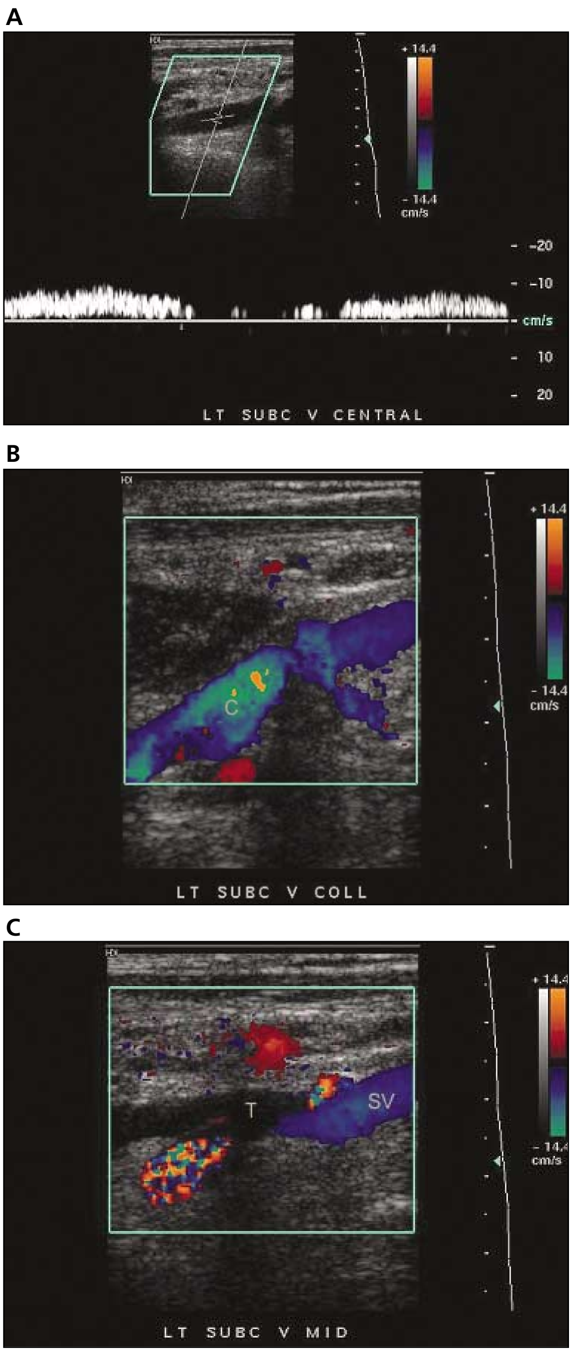


Figure 11. Images from a 29-year-old woman after a liver transplant, in whom post-transplant lymphoproliferative disease and left upper extremity swelling subsequently developed. **A**, Spectral waveforms from the central portion of the subclavian vein are markedly dampened and have low-velocity flow. This is strongly suggestive of a central thrombosis or stenosis. **B**, The subclavian vein was originally thought to be patent, but on reexamination by the radiologist, it was noted to follow a course away from the subclavian artery. Therefore, this vessel was determined to be a large collateral (C). **C**, Further scanning shows the patent subclavian vein (SV) more peripherally, whereas a thrombus (T) occupies the more central subclavian vein.

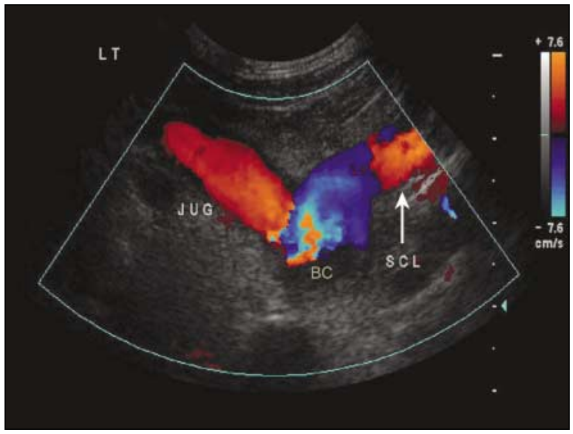


Figure 12. Color Doppler image from a 42-year-old man with a history of myelodysplastic syndrome and renal cell carcinoma who was admitted for sepsis and in whom upper extremity swelling subsequently developed after placement of a subclavian venous catheter. This image, from the area of the junction of the left subclavian vein (SCL) and internal jugular vein (JUG), reveals normally directed flow in the subclavian vein but reversal of flow in the internal jugular vein. This unusual physiologic characteristic is essentially diagnostic of brachiocephalic vein (BC) occlusion, which is partially visualized on this image. In this situation, the internal jugular vein serves as a collateral pathway to allow blood to drain from the arm to the opposite jugular venous system via collaterals in the mid and upper neck and around the thyroid.

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