3 Diagnostic Imaging for Veins

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Clinical Pearls

1. Ultrasound is the diagnostic modality of choice for the peripheral veins.
2. Deep vein thrombosis is diagnosed by the vein being enlarged and noncompressible and the absence of flow on color Doppler.
3. Pathological reflux is defined by flow away from the heart across a valve for more than 0.5 s.

Venous disorders include a wide range of acute and chronic conditions caused and influenced by a complex interaction of inherited, acquired, and environmental factors. The diagnostic workup for a venous patient should be individualized based on the specific pathology and state of the disease and aim to identify correctible pathology. Of all imaging modalities that are currently used for venous patients, diagnostic ultrasound became the most practical initial test. For many clinical situations, ultrasound can provide a definitive management answer, but for some additional modalities are needed. This chapter is intended to provide a basic review of these modalities and their most common applications.

Ultrasound Diagnosis of Acute DVT

Noninvasive nature and relatively low cost made ultrasound a dominant modality in the diagnosis of deep venous thrombosis (DVT). However, the ability of clinical decision rules, such as the Wells score, to identify patients with low probability of DVT and the addition of d-dimer assays increasing the accuracy of such identification approaching 100% made any imaging test less relevant for this category of patients. The false-positive rate of ultrasound scans is above 4% and the false-negative rate exceeds 10% [1]. The accuracy of ultrasound testing is especially low when the thrombus is fresh, affects a small segment of the vein, and is located above the inguinal ligament. Such diagnostic properties result in unnecessary treatment of some patients without a benefit of more reliable identification of patients with DVT when ultrasound is used as initial diagnostic step. Current evidence-based guidelines emphasize that the

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diagnostic process for patients with suspected DVT must begin with risk stratification [2]. If the probability of DVT is low, a negative d-dimer test sufficiently rules out DVT. In high-risk patients, the treatment should be initiated based on their risk, and imaging (including ultrasound testing) plays confirmatory role and thus can be safely delayed.

The outlined strategy is supported predominantly by the evidence obtained in a population of symptomatic outpatients, and the data on other patient populations, such as inpatients, pregnant women, children, surgical patients, and cancer patients is insufficient for making similar recommendations. Additionally, such strategy is only applicable for the initial diagnostic step. In high-risk patients and in patients who remain symptomatic, duplex ultrasound scan can provide valuable information that can change patient management. This includes identification of iliofemoral DVT that may require more aggressive treatment compared to femoropopliteal and to calf vein thromboses. It also may help to identify other causes of patient symptoms, such as intramuscular hematoma and Baker's cyst. Many other conditions that cause similar symptoms and signs in the leg cannot be diagnosed with ultrasound; thus the diagnostic value of the whole leg ultrasound for suspected DVT remains to be defined.

Significantly higher incidence of pulmonary embolism (PE) and postthrombotic syndrome PTS [3] justifies more aggressive management of patients with iliofemoral DVT compared to those with distal DVT. Performing surgical thrombectomy and catheter-directed thrombolysis is not currently universally practiced. For institutions performing these procedures, using urgent ultrasound examination to identify eligible high-risk patients may be a reasonable policy. If such treatment is not considered or not possible, urgent ultrasound scans cannot be sufficiently justified, and a delayed scan is a reasonable approach for determining whether anticoagulation should be stopped or continued.

Diagnostic Criteria of Acute DVT

Whole-leg duplex ultrasound allows to use the five basic criteria for diagnosis of acute DVT. They are non-compressibility of the vein, the absence of spontaneous blood flow, inability to augment the flow in the vein by compressing more distal limb, the presence of echogenic material in the lumen of the vein, and the increased diameter of the vein. Non-compressibility is the most reliable of these criteria and can be used as the sole diagnostic criterion in two- or three-point compression ultrasound [4]. In significantly swollen limbs and in obese patients, compressing the vein by applying pressure to the ultrasound transducer is often difficult or impossible, making the whole-leg duplex scan a more appropriate technique [5, 6].

The whole-leg duplex ultrasound, however, is not the most ideal diagnostic tool, as its false-positive and false-negative rates are quite high in some patient populations [1].

Ultrasound Diagnosis of Recurrent Thrombosis and Postthrombotic Disease

Following the acute phase, venous thrombus undergoes a complex transformation that results in different degrees of lysis and organization. In addition, inflammation takes place in the thrombus and vein wall, leading to the wall remodeling. Within 7–10 days, thrombus becomes adherent to the vein wall, making treatment modalities such as systemic thrombolysis and thrombectomy less effective or impossible in the third of the patients [7–9].

It is desirable, therefore, to be able to diagnose an acute DVT and to determine the age of the thrombus. The onset of the clinical manifestations of DVT is an unreliable indicator of the start of thrombosis, and conventional imaging techniques are rarely helpful in determining the age of the thrombus [10]. Initial results with ultrasound elastography to gauge thrombus age were promising [11, 12] but were later shown to be inconsistent [13]. Most of the studies of ultrasound elastography were done in animal models or ex vivo [14], and clinical validation of this technique has yet to be performed. The use of radiolabeled markers, such as recombinant tissue plasminogen activator, showed the ability to determine if the thrombus is more than 30 days of age [15], and MRI may show that the time from onset of thrombosis exceeds 6 months [16].

In addition to the ability to estimate the age of the thrombus, these tests are suitable for the diagnosis of rethrombosis. If thrombus neither lyses spontaneously nor is removed by treatment, pathologic processes continue predisposing patients to recurrent thrombosis [17]. Data from placebo groups of randomized controlled trials showed that recurrent DVT occurs in 11–18% of patients during the first year after DVT [18–20].

The major challenge in the diagnosis of recurrent ipsilateral DVT is that clinical presentation of rethrombosis is frequently identical to manifestations of postthrombotic disease. This makes risk assessment tools, such as the Wells score ineffective. D-dimer level remains elevated for at least 3 months after thrombus resolution in 46% of the patients [21]. Even when d-dimer is used in combination with risk assessment tools, its negative predictive value is unacceptably low in patients with recurrent DVT [22, 23].

Imaging diagnostic modalities are unable to reliably detect acute thrombus when postthrombotic changes are present in the venous wall and vessel lumen. Ultrasound in such cases shows partial or complete incompressibility of deep veins in up to 70% of patients at 3 months and 40% of patients at 12 months [24]. Such findings increase the frequency of false-positive results when this criterion is used for recurrent DVT. The false-negative results of compression ultrasound have been reported in 5% of patients with suspected recurrent DVT [24, 25].

Availability of ultrasound images obtained before an episode of suspected recurrence may be helpful; however, the interpretation of such images has been shown to have poor to moderate intraobserver agreement [26]. MRI may be able to differentiate thrombi from fibrotic changes in the vein at 6 months after acute DVT [16], but neither MRI nor CTV has been tested in patients with suspected recurrence. In the absence of a reliable test, the diagnosis of recurrent DVT relies mainly on the clinical judgment.

Ultrasound Diagnosis of Upper Extremity DVT

Swelling of the upper extremity or the neck is the most common reason to rule out thrombosis with duplex ultrasound. Other indications for upper extremity venous ultrasound include tenderness or pain in the arm or neck, evaluation for thrombosis of a venous access line, vein mapping for the creation of dialysis access, and surveillance of either a previously documented upper extremity DVT or a dialysis fistula or graft.

Duplex ultrasound continues to be the methodology of choice for establishing the initial diagnosis of upper extremity deep vein thrombosis. Imaging of the upper extremities should routinely include compression and color flow analysis with and without augmentation in the internal jugular, radial, ulnar, brachial, and axillary veins. The brachial veins are often paired, although there can be variations in anatomy. Both subclavian veins should always be assessed (even in unilateral studies) with color flow and grayscale images, but compression images are not usually possible because of the depth and interference from the clavicle. The cephalic and basilic veins are also commonly imaged along their entire span in the arms. As in the evaluation for lower extremity thrombosis, evidence for intraluminal obstructive mass needs to be characterized based on echogenicity and evidence for associated dilation of the vessel. Noncompressibility, echolucency, and vessel dilation are all strongly suggestive for an acute thrombosis. On the other hand, partial compressibility with bright echos favors a chronic postthrombotic fibrous intimal scar. Spontaneous Doppler flow should show variation with breathing (respirophasicity), but the augmented cardiopetal phase is reversed when compared to the lower extremities; venous inflow is augmented with deep inspiration in the upper extremities because of decreased intrathoracic pressure. This is in contrast to the lower extremities where inspiration leads to a concurrent increase in intra-abdominal pressure and flow into the vena cava is dampened. In addition to respirophasicity, flow is often pulsatile in the innominate, jugular, and proximal subclavian veins due to the proximity to the right atrium with dual reflection of the *a* and *v* components of the atrial pressure wave.

Scanning protocols for upper extremity veins often begin with imaging of the internal jugular veins in transverse and longitudinal planes from the angle of the jaw down to their junction with the subclavian vein. Compression maneuvers should be performed in the neck down to the level of the clavicle along with standard Doppler and color flow analysis. The innominate and subclavian veins are imaged next, but compression maneuvers are not likely to be successful given the proximity of the clavicle unless the transducer head has a small footprint. Distal augmentation maneuvers should also be performed in all upper extremity veins. The axillary vein is imaged next but may require abduction of the arm to be adequately imaged. The often paired brachial veins are also best imaged with 90 degrees of abduction, adjacent to the brachial artery. Medial to the brachial veins, the basilic vein can next be identified in the upper arm and followed distally toward the wrist. With the arm in a neutral position, the cephalic vein can be identified in the transverse plane in the antecubital fossa and followed up the lateral aspect of the upper arm up to its confluence with the subclavian vein. In unilateral studies, the final images are Doppler spectral waveforms of the contralateral subclavian vein for comparison.

Thrombosis in upper extremity veins will have similar ultrasound characteristics to those found in the lower extremities. Noncompressible, dilated, and sometimes echolucent veins seen in the transverse plane suggest acute thrombosis versus characteristics such as partial compressibility and bright echogenicity which would favor a more chronic process (Fig. 3.1). Respirophasic flow will also be compromised or lost with proximal thrombosis or obstruction. Furthermore, in the jugular, innominate, subclavian, and axillary veins, a loss of pulsatility or an absence of flow from the atrial pressure wave will occur with innominate or SVC occlusion (Fig. 3.2).

Ultrasound Diagnosis of Chronic Venous Disease

Venous Reflux

Current diagnosis and management of chronic venous disease (CVD) is predominantly based on identification and correction of two hemodynamic abnormalities: obstruction of the venous flow and venous reflux. In primary CVD, reflux is the only identifiable hemodynamic abnormality, while in the secondary CVD (postthrombotic disease), reflux can be present as the sole finding or in combination with obstruction or it can be absent.

Venous reflux is a hemodynamic phenomenon of reversal of the venous flow. Unidirectionality of the blood flow in veins is secured by function of competent venous valves. This frequently leads to misconception that the presence of reflux indicates valvular incompetence. Some venous segments may have reversed flow without valvular incompetence, for example, a venous segment between two competent valves with two or more tributaries joining it and a competent perforator vein. The flow in this segment sometimes is directed from the tributaries through the segment into the perforator vein. Thus, measuring the flow in this segment results in the detection of reversed flow, which is a reflux, but does not indicate that any of the valves are incompetent. The absence of reflux also does not mean that the valves are competent. Proximal venous obstruction or overload of more distal venous segments results in the absence of reversed flow regardless of the venous valve competency. Current clinical diagnostic testing, however, is unable to directly examine the function of venous valve, and the detection of reflux remains the only indirect indication of abnormal function of venous valves.

Technique

Reflux can be detected during ultrasound examination without performing any special maneuvers. However, this happens rarely and cannot be quantified or judged if this is a pathological sign.

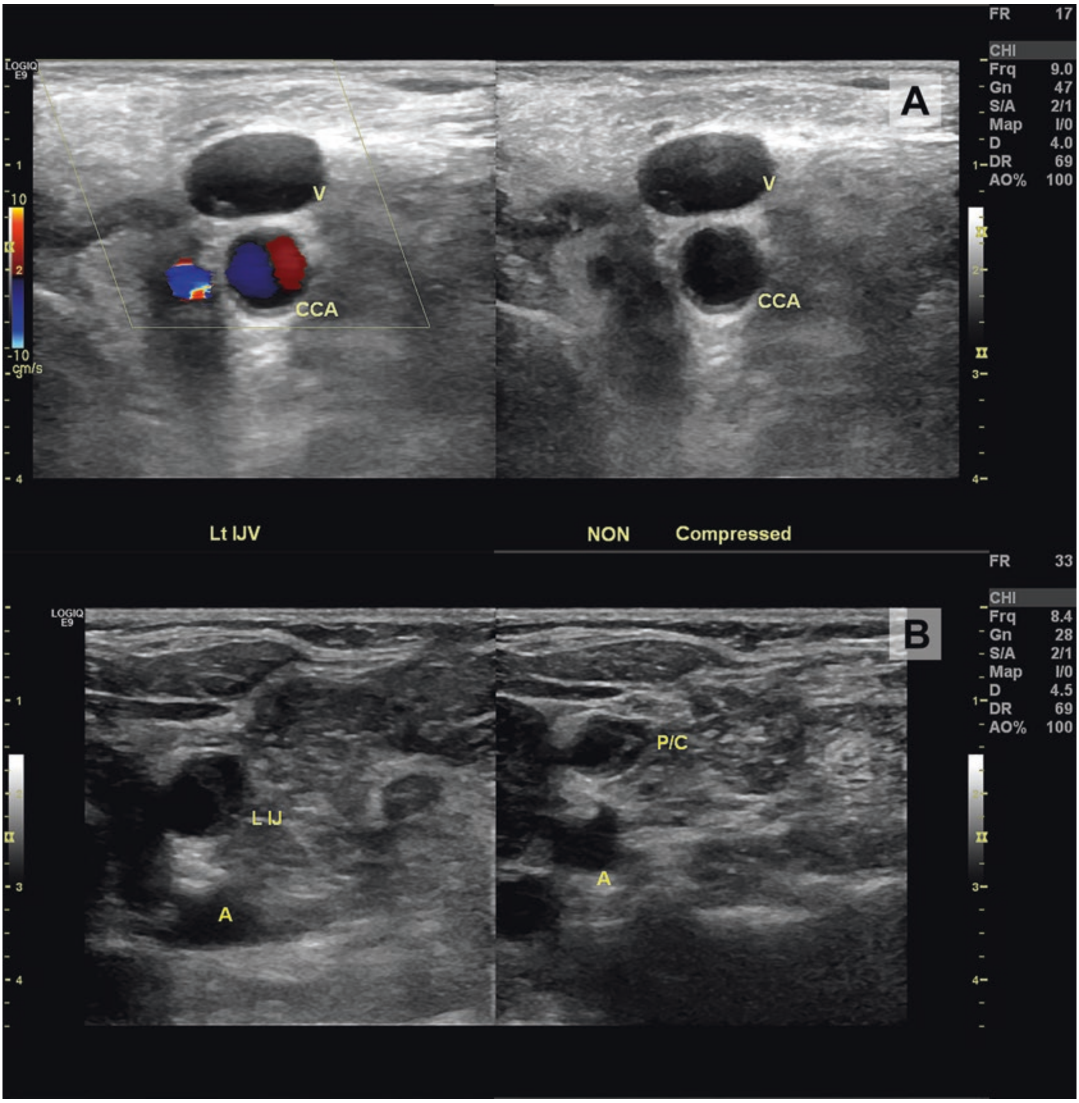

Fig. 3.1 Noncompressible, dilated echolucent internal jugular vein seen in the transverse plane suggests acute thrombosis of the upper extremity (**A**) versus characteristics such as partial compressibility and bright echogenicity which would favor a more chronic process (**B**)

The standard methodology for reflux detection involves reflux-provoking maneuvers such as Valsalva and distal compression-decompression. Valsalva maneuver increases abdominal pressure creating reverse pressure gradient in the veins. This, however, is mostly limited to venous segments in the proximal lower extremity where the valves are absent common femoral vein (CFV) or incompetent. Since there is no emptying of the more distal venous segments prior to performing Valsalva maneuver, their filling with blood may obstruct the ability to detect reflux. Emptying of the venous segments by compression of the segment of the leg distal to the visualized venous segment, followed by a rapid release of the pressure, is the most reliable way to induce venous reflux. This can be done by using operator's hand—or in a more standard fashion, using a pneumatic cuff with a rapid compression-relief device.

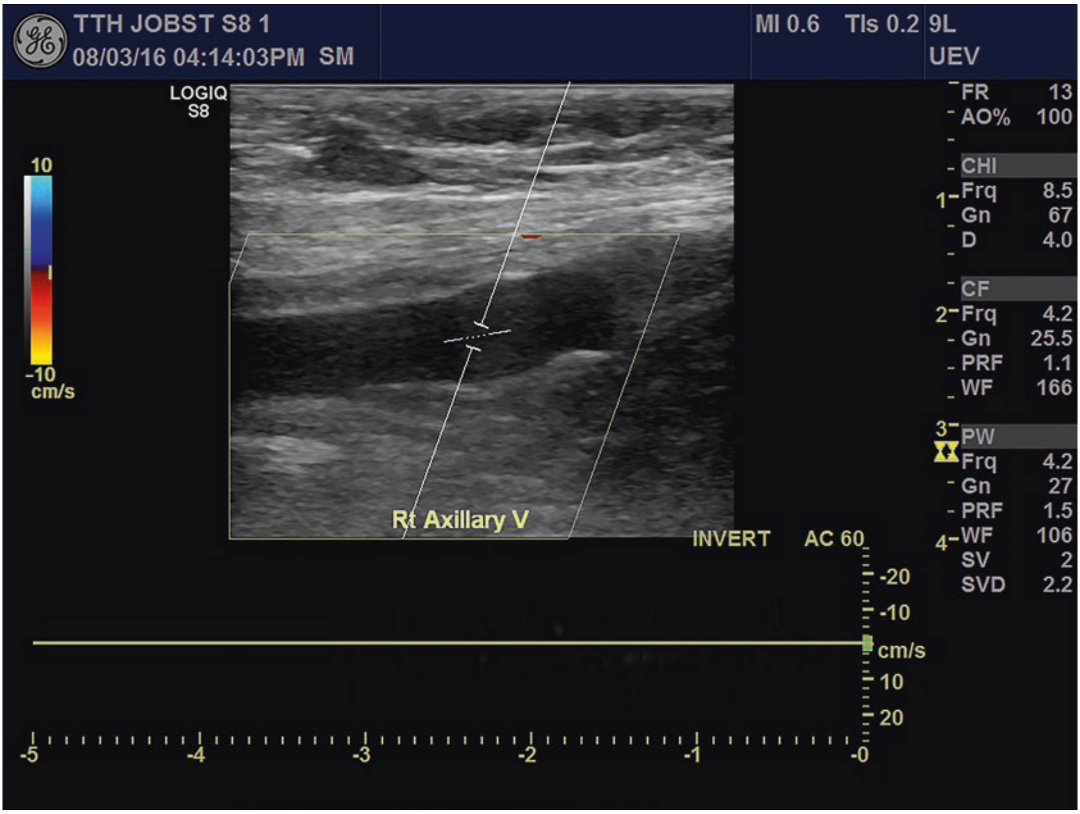

Fig. 3.2 Absence of flow from the atrial pressure wave will occur with innominate or SVC occlusion in the jugular, innominate, subclavian, and axillary veins

Most institutions prefer examining patient in a standing position with the weight of the patient on the contralateral leg. The extremity that is examined is slightly bended in the knee and rotated externally, allowing examination of the entire venous system from the CFV to the veins of the ankle. It has been shown that such position results in more repeatable results [27]. In practice, examining a standing patient is not always possible or desirable. Many patients are unable to stand for the time of the test, and performing the test in this way requires additional equipment or introduces substantial challenges to the ultrasonographer. Performing the study in the reversed Trendelenburg position generates almost identical results and is much more practical [28].

Examining perforating veins (PVs) requires slightly different technique. Thigh PVs can be examined in either standing or reversed Trendelenburg positions, but calf PVs are better seen in patient sitting with legs hanging off the examining table. Ultrasound transducer should be in transverse or oblique plane which is parallel to IP axis. Most of the clinically relevant PVs are located close to the GSV and SSV, so scanning along these vessels and their tributaries is the most efficient way to identify incompetent perforators.

Proper identification of reflux requires real-time duplex or triplex examination. This means that the spectrum Doppler recordings should be performed simultaneously with imaging (B-mode with or without color Doppler). Any other technique introduces uncertainty of which vessel was insonated during reflux-provoking maneuver. These maneuvers result in movements of all anatomical structures, veins including, making possible movement of artifacts and insonation of a tributary, adjoin vessel, or nonvascular structure, increasing false-negative and false-positive findings.

Definition of pathological reflux is consensus-based but is universally accepted around the world. It is based on the time of the reversed flow, and commonly used cut-off points are 1 s and 0.5 s for truncal veins. A multicenter study that most rigorously examined factors influencing reliability of reflux measurements demonstrated that using 0.5 s value has advantage for both superficial and deep veins [27]; however, some laboratories are using different criteria for deep and superficial veins based on their clinical experience and beliefs. The same study demonstrated that the time of the ultrasound examination introduces the highest variability of the measurements. The likelihood of getting different results of the repeated test in the same patient (presence vs. absence of reflux) is much higher when patient is examined at different time of the day than if he was examined in different positions and using different provoking maneuvers.

PVs have a different definition of pathological reflux, which is based on the reflux time (>0.5 s), diameter (≥3.5 mm), and a location beneath open or healed ulcer [29].

Venous Compression Syndrome

Upper extremity venous compression syndromes such as venous thoracic outlet syndrome (VTOS) often require additional imaging for conformation. Venous thoracic outlet disease is sometimes also referred to as thoracic inlet syndrome. Thrombosis of the upper extremity veins can be ruled out with a standard scanning protocol (as outlined above), but in the absence of "effort" thrombosis (Paget-von Schroetter syndrome) which can be a presenting feature of VTOS, other maneuvers may be indicated to confirm a suspected diagnosis. In addition to color Doppler and spectral waveform analysis in the neutral position, the patient is subjected to a variety of maneuvers including arm abduction at 45°, 90°, and 120°, the so-called military position (chest thrust forward with shoulders rolled back), and the Adson maneuver which tests the role of compression from the scalene muscles on the structures of the thoracic outlet (subclavian vein, subclavian artery, and the upper and lower brachial plexuses) by rotating the head toward the affected side and taking a deep inspiration (Fig. 3.3). The radial pulse can simultaneously be assessed for dropout while performing the Adson maneuver to assess concurrently for arterial compression. A positive study with TOS maneuvers will demonstrate loss of pulsatile or respirophasic flow with monophasic characteristics or complete obliteration of flow. Simultaneous duplex assessment of the subclavian artery during the maneuvers may be requested as well since arterial and venous compression may coexist. CT, MR, and conventional venography are rarely necessary for the diagnosis of VTOS but may assist with evaluating for the anatomic cause of thoracic outlet compression when surgical corrective measures are considered.

Venous compression involving the lower extremities usually manifests in the pelvic region in the form of May-Thurner syndrome or rarely at the knee as a type 5 popliteal entrapment syndrome. May-Thurner compression, classically defined as compression from the right common iliac artery onto the left common iliac vein as the vein passes anterior to the lumbar spine, has increasingly been appreciated to be present in cases of left iliofemoral DVT. Atypical May-Thurner iliac vein compression has also been described, which can involve the right common iliac vein as well. Diagnostic imaging for all types of suspected iliac vein obstruction usually begins with lower extremity venous duplex images, which should be carried as proximal into the iliac region as the habitus of the patient will allow. Blunted signals with respiration and augmentation in Doppler flow analysis will serve as clues for proximal obstruction. Thrombosis is not uncommonly encountered extending to or beyond the proximal lower extremity veins. CT venography is most commonly employed to assess the compression and degree of any associated thrombosis since venous ultrasound is not always reliable in the pelvic region. Involvement of the IVC can also be ascertained with either CT or MR venography.

Popliteal artery entrapment is a rare entity, which uncommonly can involve significant

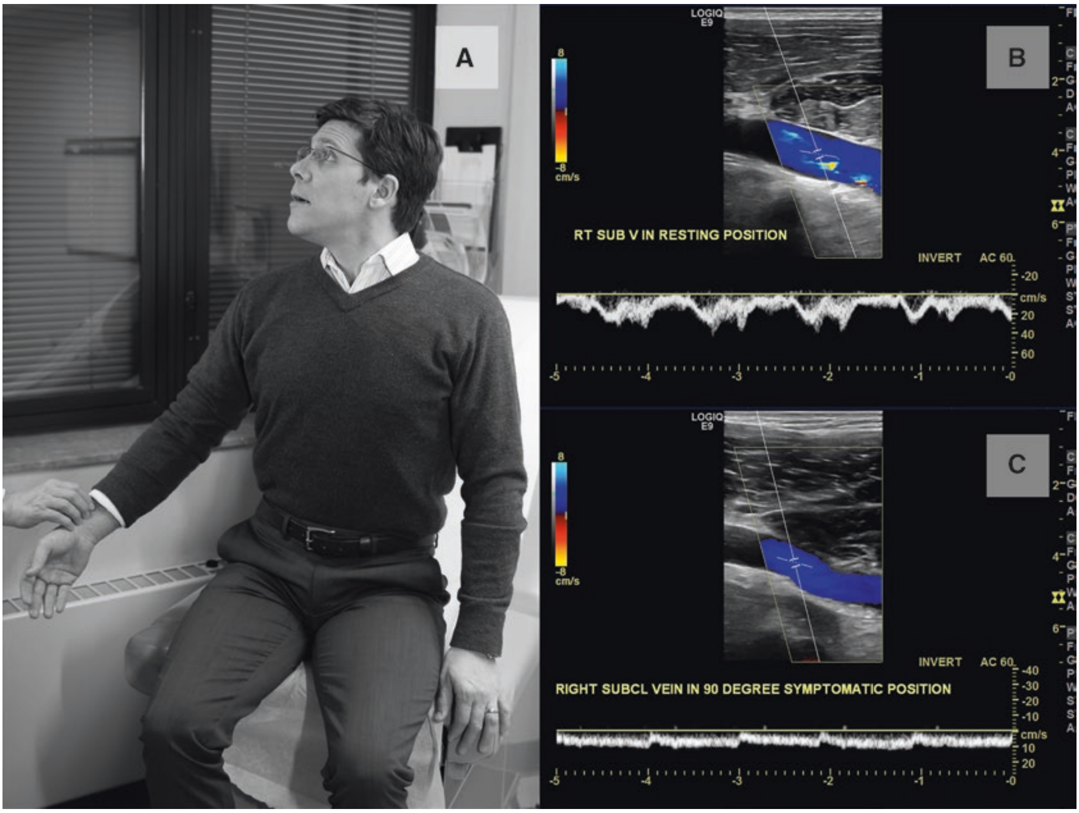

Fig. 3.3 The Adson maneuver depicted in panel (**A**) tests the role of compression from the scalene muscles on the structures of the thoracic outlet by rotating the head toward the affected side, extending the neck, and taking a deep inspiration. Panel (**B**) demonstrates normal respiratory phasic venous flow in the right subclavian vein in a neutral position, and panel (**C**) shows blunted cephalad flow in the same area with a provocative maneuver such as 90° of arm abduction from compression at the thoracic outlet

venous compression as well. This is referred to as a type 5 compression, which will often involve both the vein and artery. Ultrasound can be used as an initial diagnostic tool in the popliteal fossa with both passive and active dorsiflexion of the ankle. Blunted phasic Doppler waveforms or loss of augmentation proximal to the popliteal vein with maneuvers can serve as a clue to the presence of compression. MR angiography is the imaging modality of choice to supplement physiologic testing when assessing for any type of popliteal entrapment in order to ascertain the exact anatomic subset of vascular compression.

Visceral venous compression is rare but has been described in the left renal vein when it is compressed by the superior mesenteric artery and the aorta. This is referred to as the Nutcracker syndrome and can cause renal venous hypertension leading to hematuria and flank pain or gonadal pain. The gold standard for imaging has classically been left renal venography, but CT venography is now used routinely as an initial assessment given the additional anatomic information it provides and the often wide differential that is entertained when patients present with flank or gonadal pain associated with hematuria.

Imaging for vascular malformations needs to be tailored to the region and the type of malformation that is suspected. Arteriovenous fistulas) are most frequently acquired, usually as a minor complication following a percutaneous procedure. Given the relative superficial location with high flow, ultrasound is usually best suited for evaluation, especially in the inguinal areas. The typical

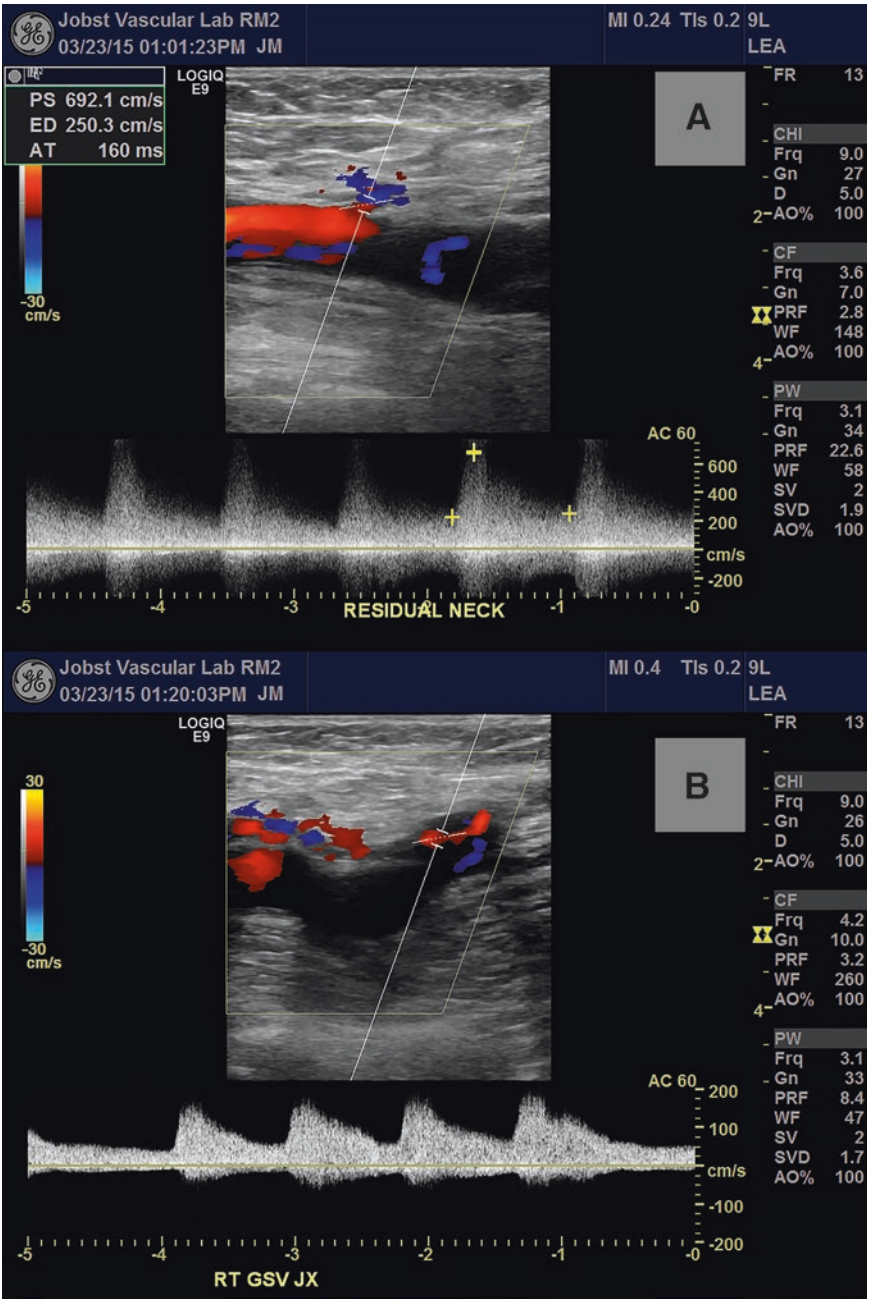

Fig. 3.4 Ultrasound demonstrating an arteriovenous fistula with findings of a high flow "jet" connecting an artery to a branch of the great saphenous vein (**A**) with arterialized flow in the great saphenous vein near the saphenofemoral junction proximal to the fistula (**B**)

ultrasound finding is a high flow "jet" connecting an artery to a vein with arterialized flow in the vein immediately proximal to the fistula (Fig. 3.4). This is in distinction to the "to-fro" flow leading from an artery to a blind-ended cavity with pseudoaneurysms (Fig. 3.5). Other types of vascular malformation sometimes present diagnostic challenges, especially when they are small with low

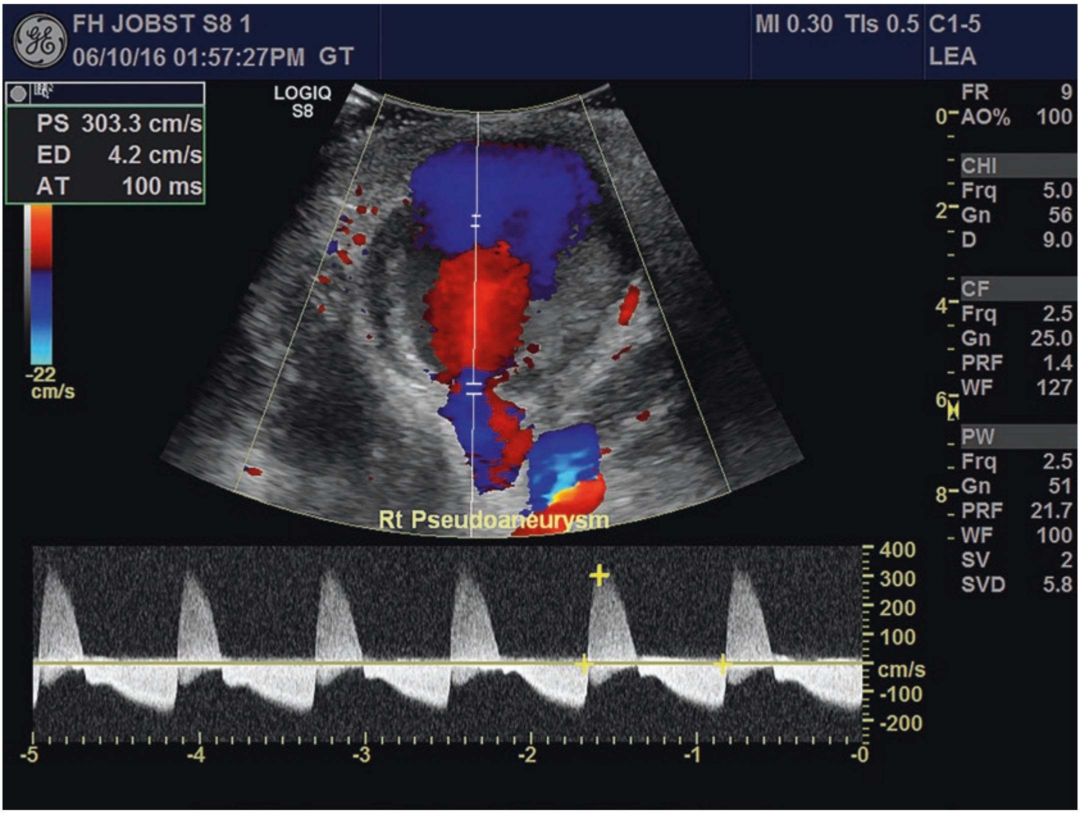

Fig. 3.5 Ultrasound findings demonstrating “to-fro” flow leading from an artery to a blind-ended cavity typical for pseudoaneurysms

flow. Venous malformations can appear as low flow areas of phlebectasia, disorganized aneurysm, or spongiform hypoechoic mass. Lymphatic malformations, on the other hand, often appear cystic on ultrasound. MR venography is often useful when there are multiple suspected venous malformations such as in Klippel-Trenaunay syndrome. Findings on MRI include uniform enhancement around venous structures versus rim or septal enhancement of cyst walls and high T2 signal intensity that is typical for lymphatic malformations. The presence of signal voids provides a clue to the presence of phleboliths characteristic of venous malformations. Finally, conventional venography is often the gold standard for both imaging the associated deep and superficial components of a venous malformation. This often precedes endovascular treatment with sclerosing) or occluding agents or devices for definitive treatment of problematic venous malformations.

Other Imaging Modalities

Venography

Contrast venography is almost completely replaced by duplex ultrasound as an initial test for diagnosing DVT; however, it continues to be the main tool for invasive treatment of deep veins. It is expensive and inconvenient compared with other diagnostic modalities and potentially causes patient discomfort and complications [30, 31]. Direct comparison of diagnostic accuracy of Duplex ultrasound and contrast venography demonstrated a sensitivity and specificity of 96% and 91%, respectively, for contrast venography and 78% and 97% for duplex ultrasonography [32, 33], suggesting that venography still has a place as a backup test for patients with suspected DVT and negative ultrasound [34]. In practice, however, immediate anticoagulation is a better strategy for such patients, and justification for performing an invasive test is questionable in majority of the cases.

Computed Tomographic Venography

Computed tomographic venography (CTV) has major diagnostic advantages in diagnosis of proximal DVT compared with duplex ultrasound; it has a sensitivity of 98% and specificity of 100% in the thigh and sensitivity and specificity of 94% and 100%, respectively, in the pelvis. In a meta-analysis of 13 studies evaluating CTV for the diagnosis of DVT in patients with suspected DVT and PE, the sensitivity ranged from 71 to 100% and the specificity from 93 to 100% [35]. The pooled estimate of sensitivity was 95.5%, whereas the pooled estimate of specificity was 95.2%. They concluded that CTV has a sensitivity and specificity similar to those of ultrasonography for the diagnosis of acute DVT but must be viewed with caution, as duplex ultrasound does not have perfect sensitivity or specificity, which may lead to overestimation of the accuracy of CTV. In addition, when CTV is used in conjunction for evaluation of PE, it adds only 3–5 min to the examination, making it an attractive option as the sole diagnostic modality for acute lower-extremity DVT [36]. The specificity is the most questionable aspect of CTV. Peterson et al. [37] demonstrated that the ability of CTV to accurately diagnose DVT has a specificity of 71%, giving a positive predictive value of only 53%. Others have shown a 50% false-positive rate for CTV for pelvic DVT; at the same time, magnetic resonance venography had a 100% rate of false positivity [38].

Magnetic Resonance Venography

Magnetic resonance venography (MRV) can be used with or without contrast enhancement. Non-contrast-enhanced techniques include time-of-flight imaging and the phase-contrast technique relying on flow-related enhancement [39]. Contrast-enhanced MRV can provide the user with three-dimensional imaging, provided contrast material is injected in a timed sequence. Post-processing can then remove the arterial anatomy leaving only the venous segments in the display image [40].

MRV is used mainly to diagnose acute DVT in larger venous segments, as its sensitivity diminishes when smaller diameter veins are evaluated. Diagnostic properties of MRV are reported as almost identical to contrast venography [40, 41]. In addition, vessel wall enhancement can be visualized with acute thrombus, allowing the examiner a crude detection of thrombus age [42].

Comparisons between the two modalities of MRV have also been examined. Positive and negative predictive values were 90% and 94%, respectively [40]. When more proximal iliocaval DVT is examined, time-of-flight MRV had 100% sensitivity and specificity compared with contrast venography versus 87% and 85%, respectively, for duplex ultrasonography [41]. Perhaps the most impressive and useful aspect of time-of-flight MRV was its 95% sensitivity and 99% specificity in detection of the proximal extent of thrombus in the iliocaval segment compared with 46% and 100%, respectively, for duplex ultrasonography [40]. Contrast-enhanced MRV demonstrated 100% sensitivity and specificity for iliac thrombus and 100% sensitivity with a 97% specificity for the detection of femoral thrombus [43], in addition to being more reliable in distinguishing the proximal extent of these thrombus burdens [42].

Despite such a high diagnostic accuracy, MRV has serious practical disadvantages. It demands a nonmoving patient and long imaging times that, when paired, can be a significant hurdle. The below-knee segments of venous anatomy are often paired, accounting for significant artifact during post-processing of the images [39, 44]. In addition, gadolinium can be toxic in patients with renal dysfunction, and the need for frequent examinations can produce problematic utilization issues in larger institutions. However, MRV certainly has a role in the diagnosis of DVT, especially in the detection of thrombus in centrally located venous structures not always accessible to duplex ultrasonography. Not only is MRV useful for detection of hypogastric venous thrombosis [40], a remarkable 27% of patients who sustained a PE with no detectable source of thrombus by duplex ultrasound had thrombus identified with MRV [45].

In conclusion of this brief review of the imaging modalities that are currently used for diagnosis and management of venous diseases, it is reasonable to emphasize that not a single one of them was developed specifically for this purpose. The situation when new technologies find venous disease as their additional application makes any of the existing imaging modalities less than ideal for practical use. Development of more effective, safer, and more practical treatment options resulted in the situation when the majority of patients with suspected DVT do not need any of the existing imaging tests. In chronic venous diseases, existing imaging tests are incapable to answer the most basic clinical questions, such as assessing the severity of venous obstruction and reflux. Since there are few alternatives, imaging remains one of the main modalities for management patients with venous diseases, but the results of these tests should always be considered as confirmatory to the clinical diagnosis.

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