Duplex ultrasound for diagnosis of deep vein thrombosis

Introduction

Deep vein thrombosis (DVT) is a common clinical condition, which may cause pulmonary embolus in as many as 20% of those affected (Baxter, 1997). The evolution of real-time venous ultrasound in the 1980s provided a rapid, non-invasive and relatively cheap alternative test for DVT. Such techniques now have a reported sensitivity and specificity in detecting femoral or popliteal vein thrombus of >95% and >98% respectively. Other indications for venous ultrasound are included in *Table 1*.

Venography has been regarded as the gold-standard investigation for venous disease, yet this examination is not without limitations. Setting aside the (small) potential for contrast reaction or vascular endothelial damage, the examination is relatively costly in terms of time and resources, involves ionizing radiation and may be inadequate in up to 10% of cases (Wheeler and Anderson, 1986). It also requires a cooperative patient with adequate venous access in the foot of the affected leg. It is therefore unsurprising that duplex ultrasound has become the preferred first-line investigation for suspected DVT.

Table 1. Indications for venous ultrasound examination

Diagnosis of deep vein thrombosis in upper or lower limb (spontaneous or catheter-associated)
Investigation of chronic venous insufficiency and post-phlebitic syndrome
Assessment of varicose veins
Venous mapping before bypass grafts
Localization of veins for cannulation

Dr Jonathan L Hart *is Specialist Registrar in Radiology,* **Dr Claire Lloyd** *is Specialist Registrar in Radiology,* **Dr Sylwia Niewiarowski** *is Specialist Registrar in Radiology and* **Dr Chris J Harvey** *is Consultant Radiologist in the Imaging Department, Hammersmith Hospitals NHS Trust, London W12 0HS*

Correspondence to: Dr CJ Harvey

Deep vein thrombosis

Risk factors for DVT

Numerous factors, often in combination, contribute to DVT. These may be categorized as acquired (e.g. medication, illness) or congenital (e.g. anatomical variant, hypercoagulant tendency). The most common risk factors are previous DVT, malignancy, surgery, immobility and obesity. Hospitalized and nursing home patients often have several risk factors and account for one half of all DVTs (with an incidence of 1 case per 100 population).

Clinical presentations

Symptomatic DVT

Symptomatic DVT most often arises in the deep veins of the calf and extends proximally. Pain and swelling of the calf may be accompanied by warmth and erythema in the overlying skin. Isolated thrombus arising in the iliofemoral segment is rarer (<10% of DVT). It is usually painful and, if untreated, may ultimately lead to the syndrome of phlegmasia cerulea dolens with a swollen, painful limb with dusky colouration and prominent collaterals.

Asymptomatic DVT

Postoperative screening with venography has shown that 50–80% of patients undergoing major surgery (particularly lower limb orthopaedic procedures) have DVT. Even with prophylaxis, this figure remains 15–45% (Clagett et al, 1995). The vast majority resolve spontaneously without ever causing symptoms or complications and therefore routine screening is not recommended (Robinson et al, 1997).

Lower limb veins

Anatomy

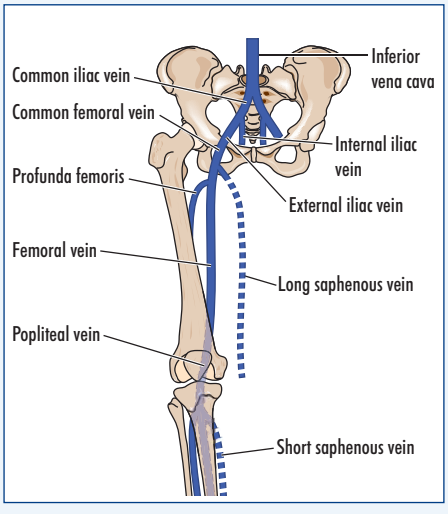
The veins of the lower limb consist of deep and superficial systems which are linked by perforators (*Figure 1*). The paired deep veins accompany the arteries and join to form the popliteal vein. At the upper border of the popliteal fossa, the popliteal vein becomes the femoral vein. This runs with the femoral artery up the medial aspect of the leg beneath sartorius. The profunda vein and long saphenous vein are proximal tributaries.

Technique of ultrasound examination

The examination is performed with the patient supine with the head of the bed raised slightly to promote venous pooling in the legs. A linear 5–10 MHz transducer is used in both B-mode (greyscale) and colour-flow or Doppler modes. A low velocity setting is used on colour-flow or Doppler imaging to detect the slower venous flow.

The common femoral vein should be identified in the groin in the transverse plane. Gentle compression is applied to occlude the vein lumen (*Figures 2* and *3*). In the presence of thrombus, the lumen will not collapse (*Figure 4*). Compression must be applied transversely, since longitudinal examination may give false-negative results if the vessel slips out of the plane of the transducer. The examination then proceeds distally at intervals of 3–5 cm as far as the popliteal trifurcation, applying compression at regular intervals. The

Figure 1. The lower limb veins showing the deep and superficial systems.



popliteal region is best examined with the patient supine or in the lateral decubitus position. In the authors' routine practice, the calf veins are not examined as ultrasound is less sensitive in the detection of calf vein DVT and controversy exists regarding its' clinical significance and the requirement for treatment.

A number of additional findings may suggest the presence of thrombus. Acute DVT causes distension of the affected vein. An acute thrombus is usually anechoic and cannot be visualized, but more established, chronic thrombus becomes echogenic and can be visualized directly (*Figure 5*).

Colour flow imaging and Doppler waveform assessment are useful to demonstrate spontaneous flow, normal phasic variation

Figure 2. Normal vein. The superficial femoral vein (arrow) has normal wall-thickness and a completely anechoic lumen on this transverse image.

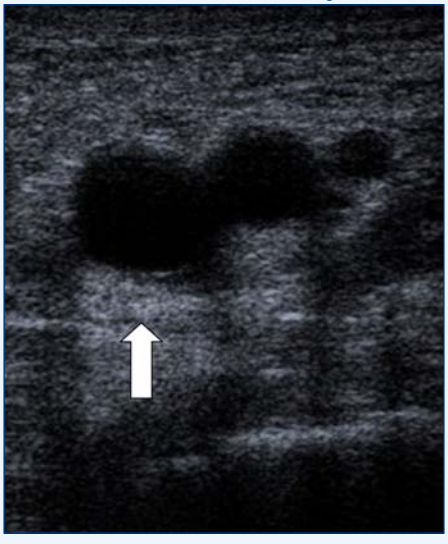
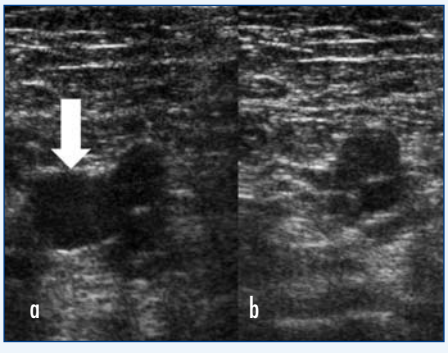


Figure 3. Normal compressibility. Dual image of the proximal superficial femoral vein (arrow) (a) without and (b) with transducer compression. The superficial femoral vein is completely compressible. The femoral artery and profunda artery are seen lying laterally.



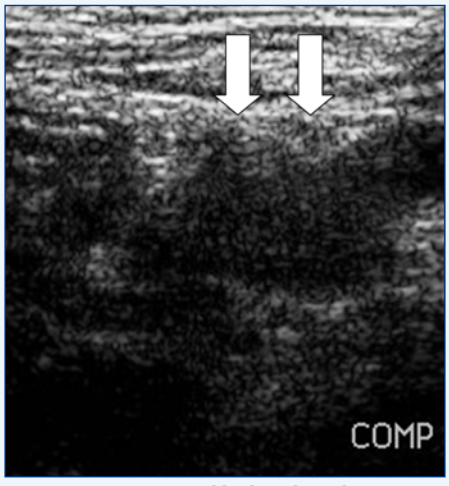
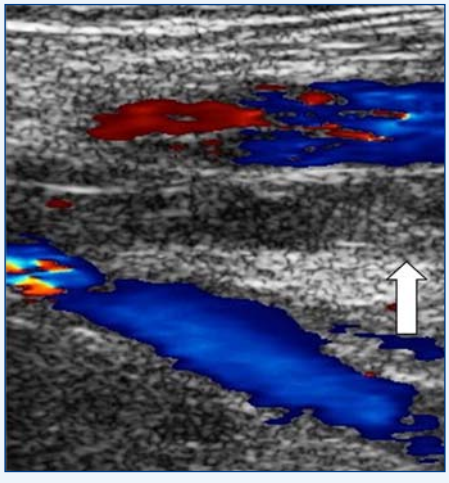


Figure 4. Non-compressible thrombus. The common femoral vein (and long saphenous vein entering on the right) have not emptied despite transducer compression (arrows). Echogenic intra-luminal thrombus is present in the vessels.

of flow with respiration and the augmentation of flow on calf compression (*Figures 6* and *7*). However, these findings do not reliably exclude a thrombus in the context of non-occlusive DVT, adequate collateralization or duplication of the deep venous system (which occurs in the superficial femoral vein segment in approximately 20% of cases).

When there is clinical suspicion of an iliofemoral DVT, the common femoral vein should be examined with compression as proximally as possible and the external and common iliac veins assessed

Figure 5. Chronic deep vein thrombosis. The superficial femoral vein (arrow) contains organized echogenic thrombus and flow is absent on colour imaging. The femoral artery lies immediately superior to it. The patent profunda femoris vein lies deep to the thrombosed superficial femoral vein.



for patency with colour flow imaging. If necessary, the inferior vena cava may also be assessed. A lower frequency (3–5 MHz) curvilinear probe is often required in these circumstances to achieve the necessary depth of view (*Figure 8*).

The principal goal of venous duplex ultrasound (DUS) examination is to estab-

Figure 6. Normal colour Doppler imaging appearances. Longitudinal image of the external iliac artery and vein showing flow in each.

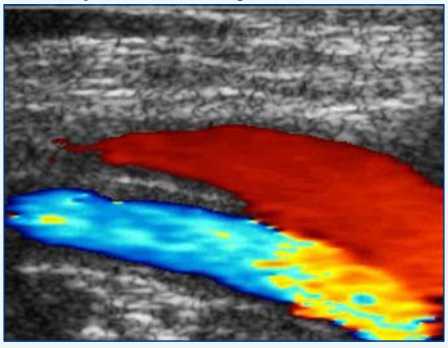


Figure 7. Normal Doppler waveform trace. Phasic variation with respiration of the spectral Doppler waveform in the popliteal vein.

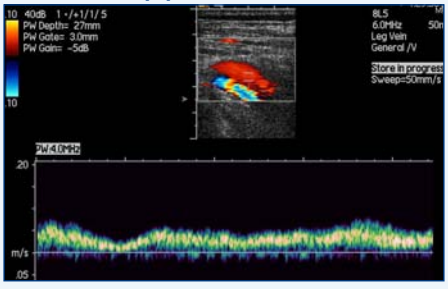
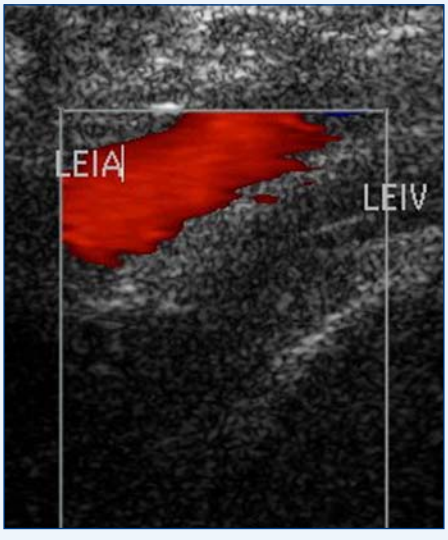


Figure 8. External iliac vein deep vein thrombosis. The external iliac vein (LEIV) is completely occluded with echogenic thrombus and shows no flow on colour imaging. Normal flow is seen in the adjacent external iliac artery (LEIA).



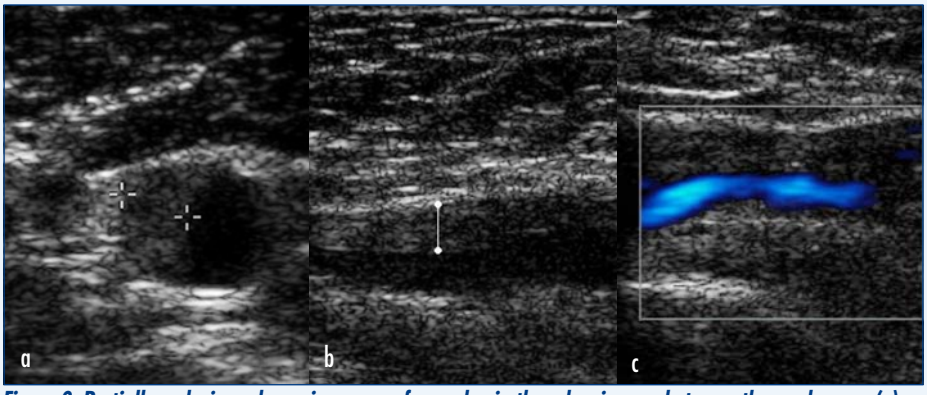


Figure 9. Partially occlusive echogenic common femoral vein thrombus is seen between the markers on (a) transverse and (b) longitudinal images. c. Colour imaging confirms the presence of flow in the residual lumen.

lish the presence or absence of thrombus. However, additional information may be derived regarding the proximal extent of the thrombus and the presence of partial or complete occlusion of the affected vessel (*Figures 9a–c*). The identification of free-floating thrombus may be of prognostic significance, being associated with a higher incidence of pulmonary embolus (Voet and Aschrift, 1991).

When no DVT is demonstrated, the ultrasound examination may reveal an alternative diagnosis such as a Baker's cyst, haematoma, arterial aneurysm or superficial phlebitis. The incidence of alternative diagnoses is 11–18% (Langsfeld et al, 1997).

Despite being the preferred initial test for suspected DVT, DUS is not without limitations (*Table 2*). Visualization and compression of the distal femoral vein within the adductor canal can also be difficult, although isolated segmental thrombus is rare. Thrombosis in a duplicated segment may be overlooked (see above).

Table 2. Limitations of duplex ultrasound in diagnosis of deep vein thrombosis

Operator-dependent or non-standardized technique	
Anatomical	Duplicated segments
	Adductor canal
Obese patients	
Lower limb oedema, e.g. congestive cardiac failure	
Recent lower limb surgery	
Bowel gas overlying the iliac veins	

Upper limb veins

Anatomy

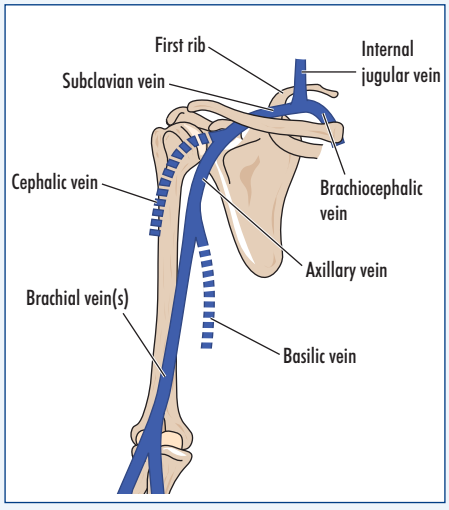
The veins of the upper limb also consist of deep and superficial systems (*Figure 10*).

The paired radial, ulnar and brachial veins accompany the arteries. The superficial veins (cephalic and basilic veins) are more variable than in the leg. The basilic vein pierces the deep fascia and joins the brachial veins at the level of teres major to form the axillary vein. The cephalic vein pierces the clavipectoral fascia in the deltopectoral groove to enter the axillary vein. The axillary vein becomes the subclavian vein as it crosses the first rib.

Ultrasound examination

Fewer than 10% of episodes of venous thrombosis occur in the upper limb but the incidence appears to be increasing. Risk factors include indwelling central venous lines, malignancy and hypercoagulopathy.

Figure 10. The upper limb veins showing the deep and superficial systems.



Subclavian and axillary vein DUS has a sensitivity and specificity similar to that of lower limb examination (Baxter et al, 1991).

The study is usually performed with the patient supine and the arm abducted. The subclavian vein is interrogated above and below the clavicle as it passes over the first rib. The axillary vein is scanned in the axilla from where the brachial veins can be traced to the elbow. The veins distal to this are not usually examined unless there is a specific indication such as a dialysis fistula. If thrombus is demonstrated, the contralateral vessels and both internal jugular veins should also be examined. DUS is also a useful first-line test in determining patency before insertion of central venous lines, particularly where there have been multiple previous insertions.

Controversies and diagnostic challenges

Diagnostic approach in suspected isolated calf DVT

The deep calf veins consist of three paired vessels (anterior tibial, peroneal and fibular) which run with the arterial supply as venae comitantes and two unpaired veins to soleus and gastrocnemius. Widely varying rates (9.3–82.7%) of inconclusive DUS in cases of calf vein DVT were identified in a meta-analysis by Gottlieb et al (1999a). The use of power Doppler may improve the detection rate (Forbes and Stevenson, 1998) but ultrasound is clearly less reliable (and perhaps increasingly operator dependent) distal to the popliteal vein.

However, the prevalence of isolated calf DVT is low in symptomatic patients (5–12%) (Gottlieb et al, 1999b) and calf vein DVT is rarely a cause of symptomatic pulmonary embolus. Controversy exists regarding the need for anticoagulant treatment in calf DVT and follow-up studies have reported no adverse clinical outcomes on 3-month follow-up of patients with isolated calf DVT who did not receive anticoagulation (Gottlieb et al, 2003). As a result, in some departments (including the authors') the calf veins are not routinely assessed.

However, there is contradictory evidence (albeit based on relatively dated studies) which suggests that calf DVT propagates to the thigh in 20% of cases and that anticoagulation prevents extension, embolization and early recurrence (Philbrick and Becker, 1988). Furthermore, the risk of

pulmonary embolus is not the sole consideration: it is estimated that approximately 20% of untreated isolated calf vein thrombus will ultimately result in chronic venous disease. For these reasons, some authors advocate a complete assessment of the lower limb veins be performed routinely. An alternative approach is to examine the femoral and popliteal veins and perform a follow-up study at 1 week to exclude proximal propogation of undiagnosed below-knee thrombus. However, in the absence of significant clinical findings, this approach is of dubious value, since it yields positive results in only 1.3% of cases (Goodacre et al, 2005). In addition there are significant cost and patient-compliance issues with follow-up testing. A selective approach to follow-up examination based on level of clinical suspicion would appear more reasonable and is supported by the findings of a prospective randomized study (Gottlieb and Widjaja, 1999).

Bilateral *vs* unilateral duplex ultrasonography

Contralateral asymptomatic DVT is present in 5–7% of symptomatic patients. Generally the clinical implications of undiagnosed contralateral thrombus are minimal if anticoagulation treatment is to be instituted for the symptomatic limb. In patients with DVT diagnosed in one limb who have symptoms in the contralateral limb, a baseline DUS of the contralateral leg may be useful to distinguish whether future symptoms are caused by the initial thrombotic event or recurrent DVT (see below). A bilateral examination is also indicated if screening asymptomatic high-risk patients (e.g. postoperative hip arthroplasty) in whom pulmonary embolus is suspected.

Recurrent DVT (acute-on-chronic thrombus)

Following acute thrombosis, vena venorum develop within the thrombus. Complete recanalization occurs in only 50% of patients in the 6–12 months following the primary event (Murphy and Cronan, 1990). One in three patients will develop recurrent symptoms and one in three symptomatic patients will have recurrent DVT. The annual likelihood of recurrence is of the order of 5–15%. Acute thrombus and chronic thrombus have certain typical characteristics (*Table 3*) but distinguishing between recurrent acute-on-chronic thrombus and chronic thrombus is a diagnostic challenge. Comparison with a baseline study is helpful in making the distinction. Some suggest performing such an investigation routinely at 6 months, although the resource implications would seem prohibitive. **BJHM**

Conflict of interest: none.

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Table 3. Characteristics of acute and chronic deep vein thrombus

Characteristic	Acute	Chronic
Vein	Distended Normal wall thickness	Normal calibre Thickened wall (or contracted or obliterated)
Thrombus appearance	Anechoic or hypoechoic Central Obstructive, filling lumen Contiguous	Iso- or hyperechoic Eccentric Non-occlusive or recanalised Intermittent
Compressibility	Non-compressible*	Non-compressible
Doppler characteristics	Minimal or no flow	Antegrade flow, reflux
Collaterals	None	May be present

*In hyperacute deep vein thrombosis, thrombus may be compressible with strong pressure

KEY POINTS

- Duplex ultrasound is preferred to venography as the initial investigation for suspected deep vein thrombosis. It is a rapid, non-invasive and relatively cheap investigation without the risks of ionizing radiation and contrast media associated with venography.
- Duplex ultrasound has a reported sensitivity and specificity in detecting femoral or popliteal vein thrombus of >95% and >98% respectively. Similar accuracy is reported in the upper limb.
- Ultrasound examination may reveal an alternative diagnosis such as a Baker's cyst, haematoma, arterial aneurysm or superficial phlebitis.
- Controversy remains regarding the appropriate diagnostic approach to below-knee deep vein thrombosis. If detailed examination of the calf veins is not performed, a follow-up study is indicated in patients who remain symptomatic to exclude proximal propagation of a calf thrombus.
- Recurrent (acute-on-chronic) deep vein thrombosis presents a considerable diagnostic challenge.