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**Title:**

Point-of-care ultrasound for deep venous thrombosis of the lower limb

**Date:**

2020-05-01

**Citation:**

Canty, D., Mufti, K., Bridgford, L. & Denault, A. (2020). Point-of-care ultrasound for deep venous thrombosis of the lower limb. *Australasian Journal of Ultrasound in Medicine*, 23 (2), pp.111-120. <https://doi.org/10.1002/ajum.12188>.

**Persistent Link:**

<https://hdl.handle.net/11343/286741>

## Title Page

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### 10. Short running title

Point of care DVT ultrasound

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of Record](#). Please cite this article as [doi: 10.1002/AJUM.12188](https://doi.org/10.1002/AJUM.12188)

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### **Authorship declaration**

The authorship listing conforms with the journal's authorship policy, and all authors are in agreement with the content of the submitted manuscript.

### **Acknowledgements**

There are no funding disclosures. We acknowledge the significant contributions to performing this study from the administrative staff of the Ultrasound Education Group, The University of Melbourne.

### **Disclosure statement**

Alistair Royse and David Canty are employees of the University of Melbourne, and Alistair Royse is a director of iTeachU limited. Educational content from these entities are available for sale in Australia.

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Article type : Review Article

**Title** Point of care ultrasound for deep venous thrombosis of the lower limb

**Abstract**

The incidence and morbidity of deep venous thrombosis (DVT) and pulmonary embolus are high. Although efforts to increase screening for DVT have been recommended, this is limited by resources. Venous duplex ultrasound has replaced venography as the first-line investigation of choice for DVT, increasing availability and reducing patient exposure to radiation and intravenous contrast. Furthermore, a limited ultrasound where DVT is inferred from incomplete venous compressibility, has an equivalent accuracy to venous duplex. This technique is usually referred to as lower limb venous two- or three-point compression-ultrasound, depending on the number and site of compression points, and is becoming popular in emergency, critical care, and perioperative medicine. In this review, the evolution and method of lower limb venous compression-ultrasound is described along with evidence for its use in emergency medicine, critical care, and preoperative screening in patients at high risk for DVT.

**Key words**

Deep venous thrombosis, screening, point of care ultrasound, venous Doppler ultrasound, compression venography

## Main Text

### Introduction

Venous thromboembolism (VTE), which comprises deep venous thrombosis (DVT) and pulmonary embolus (PE) is the third commonest vascular disorder in Caucasian populations (1) and in Australia, DVT alone (without concomitant PE) affects 52 persons per 100 000 annually (2). Approximately 2 million patients are diagnosed with a deep venous thrombosis (DVT) annually in the United States (3), resulting in estimated 600,000 hospitalisations and 200,000 deaths resulting from pulmonary embolism (PE)(4, 5) and the short-term mortality rate from untreated pulmonary embolus probably exceeds 20%(6). It is estimated that many more cases of DVT are not diagnosed(7).

In many regions ultrasound has replaced venography as the first-line investigation of choice for DVT(8-13) due to its comparable (but slightly lower) accuracy (9, 13) with the lack of exposure to staff and patients to radiation and lack of exposure to patients to intravenous contrast. Venography is now usually reserved for when ultrasound is not adequate or available.

The basic principles of ultrasound identification of DVT (known as 'venous duplex') is visualization of a thrombus within vein lumen which results in reduced or absent blood flow in the vein using colour flow and spectral Doppler. It has been realized that inability to completely compress the vein with the ultrasound probe has an equivalent accuracy (false positive and negative predictive value) to venous duplex, and this technique can be easily taught to non-radiologists and non-sonographers, enabling point of care application and therefore potentially saving considerable time and cost of referring patients to the radiology department. This technique is usually referred to as lower limb venous two- or three-point compression-ultrasound, depending on the number and site of compression points, and is becoming popular in emergency, critical care, and perioperative medicine. In this review, the evolution and method of lower limb venous compression-ultrasound is described along with evidence for its use in emergency medicine, critical care, and the current evidence for its use in preoperative screening in patients at high risk for DVT.

## Sonoanatomy of the lower extremity deep venous system

Starting proximally, the highest vessels that are usually identifiable with linear probe ultrasound are the external iliac vessels (Figure 1 above). The external iliac vein becomes the common femoral vein as it passes under the inguinal ligament.

The common femoral vein is usually 2- 4 cm in length, receiving three tributaries, being the great saphenous vein(superficial vein), profunda femoral vein and femoral vein(deep veins). The greater saphenous vein is a superficial vein; receiving venous blood from the anterior medial calf and the foot and runs up along the medial aspect of the thigh. It also usually has a valve in its terminal portion (terminal valve) (14). The femoral vein is a deep vein; drains most of the lower limb and may contain a valve either proximal and/or distal to the junction with the greater saphenous vein. The femoral vein may be dual and can be either medial, lateral, deep or superficial to the femoral artery. The femoral vein continues through the adductor canal where it then forms the popliteal vein, which receives most of the venous drainage from the calf. The popliteal vein is usually superficial (lies on top) of the popliteal artery. The popliteal vein receives several branches including the anterior tibial veins(deep veins), and the small saphenous vein (superficial vein). The posterior tibial veins are in the posterior compartment of the leg and travel with the posterior tibial artery. The posterior tibial veins receive blood from the plantar surface of the foot and pass between the medial malleolus and Achilles tendon then enter the posterior compartment of the calf. They run supero- medially along the lower leg. The soleal sinus is major storage for blood embedded in the soleus muscle. It empties into either posterior tibial or popliteal vein. The soleal sinus is a common site for thrombosis to originate.

## Lower limb venous compression-ultrasound

The conventional venous duplex exam performed by radiology includes ultrasound of the entire venous system of the lower leg. However, the sensitivity of detection of DVT below the knee with ultrasound has been reported as low as 38% (14). In addition, the management of below knee DVT is controversial, as the proximal propagation rate may be low, with some guidelines recommending serial ultrasound examinations to detect proximal propagation of thrombus before

commencement of treatment (15). For this reason, the compression ultrasound techniques have been restricted to above the knee. This practice was verified as appropriate in a report that found above knee compression ultrasound to be comparable to whole leg venous ultrasound for the management of symptomatic outpatients with suspected lower extremity deep venous thrombosis (16).

Lower limb venous compression ultrasound was initially reported as a two-point compression technique, where the two points compressed are the common femoral vein, in the region where it communicates with the greater saphenous vein and profunda vein, and the popliteal vein. The sensitivity and specificity of two point venous compression approaches that of the comprehensive venous duplex scan (data presented below in the emergency and critical care medicine sections). However, as approximately 6% of DVT's are found in the femoral vein (17), which is in between these two compression points, it is possible that a femoral vein thrombus may be missed using the two point technique. A three-point compression ultrasound technique has since been reported, adding the femoral vein, and when compared to two-point compression and venography, the three point-technique was shown to be more sensitive than the two-point technique(18). Although the compression ultrasound refers to compression points, it is probably better to compress the veins above and below the defined three points to reduce the chance of missing a thrombus, which has led some practitioners to use the term compression zone rather than compression point.

With regard to the safety of performing point-of-care lower extremity ultrasound, a literature review from 2007 revealed no articles demonstrating whether or not compression ultrasound results in progression of DVT(19). However, in the presence of an acute and mobile clot in the femoral region, common sense dictates that excessive compression and manipulation should be avoided.

The method of lower limb venous compression-ultrasound is described in the table 1 and video 1 below and the limitations of lower limb venous compression-ultrasound are summarised in Table 2.

## Comparison of *focused compression venous sonography* to “gold standard” medical imaging

The two- and three-point venous compression techniques are simple to perform within 10 minutes, compared to the comprehensive radiological testing that usually requires 30-40 minutes. Although the reported rates of sensitivity and specificity are comparable (data presented below in the emergency and critical care medicine sections), it is possible that there is a small but real false negative rate for compression ultrasound. It is important to emphasise that the reliability of the compression technique is dependent on the operator training and experience and the false negative rate may also be reduced by scanning more of the deep venous system than the two compression points, as described above.

However, an important limitation of the evidence for focused compression venous sonography is the assumption that the radiology scan is the gold standard. If there is a significant time difference between the two exams-hours or a day or more, the findings can change. This is an issue with many focused ultrasound comparison studies. For example, what was a positive above knee DVT at the time of the focused study from a small amount of popliteal thrombus can lyse/break off and be negative in radiology, a ‘false positive’, making the focused DVT study appear less specific. If it was negative at the focused DVT time and later there is some thrombus in the popliteal vein from progression of calf DVT, it becomes a false negative, the focused DVT looks less sensitive. This can happen in planned follow-up after formal imaging both ways as well. Finding out that your scan may have missed a DVT may be disconcerting to the focused ultrasound practitioner, who has likely made treatment decisions on the basis of the first scan.

## Compression venous sonography for deep venous thrombosis in emergency medicine

Compression venous sonography is a core application for emergency medicine and is supported by the American College of Emergency Physicians (ACEP) (20). Much of the validation work for compression venous sonography has been performed by emergency physicians. In a systematic review of 1,162 patients in 6 studies with patients presenting to the emergency department who had clinically suspected DVT, 2-point compression ultrasound performed by emergency physicians had an overall sensitivity of 95% (87-99%) and specificity of 96% (87-

99%) for diagnosis of DVT compared with radiology ultrasound (21). But of course, ultrasound is operator dependent and the true test performance depends upon the skill and experience of the individual performing the scan. Compression venous sonography is used in the emergency medicine setting for two indications; suspected DVT and suspected PE. For suspected DVT, compression venous sonography performed by the emergency physician at the point of care is clinically useful, and decreases time in the emergency department, usually by several hours (22, 23). If a DVT is found it will usually trigger treatment, exclude other differentials, and start consideration for disposition and follow-up depending on symptom severity. A negative study likely excludes proximal DVT at that point in time. But caution should be advised with inadequate studies and lesser skilled operators. Isolated below knee DVT is still possible but given this is much less likely to propagate or result in PE, shared decision-making regarding empiric treatment, and planning for a comprehensive formal leg ultrasound as an outpatient can be pursued. This could be in the next few days and followed up by their primary care provider. The second important scenario, often under-appreciated, is the unstable patient or one who has a high pre-test concern for PE. Even in the absence of leg symptoms, a proximal DVT study can be very helpful, as a positive makes the chances the patient has PE extremely likely (24-26). This can influence immediate decisions regarding treatment, including thrombolysis, and timing of confirmatory PE imaging.

#### Compression venous sonography for deep venous thrombosis in critical care

Deep vein thrombosis is a common cause of preventable mortality and morbidity in the ICU and compression venography is supported by the Society of Critical Care, who recommend scanning using the two-point scan (27). A 3-point compression technique performed by an intensivist in the ICU found a 20% prevalence of DVT, 86% sensitivity and 96% specificity when compared with radiology. Median time delay between the ordering and execution of the exam was 13.8 h (28). A multicenter retrospective study compared matched intensivist-performed focused ultrasound with those performed by certified vascular technicians. The sensitivity and specificity of the intensive care unit (ICU) performed studies compared with the technician studies were 88% and 98% versus 85% and 100%, respectively. Furthermore, ICU studies were available real-

time compared with a median time delay of nearly 14 hours for the vascular laboratory studies (28).

### Compression-ultrasound for deep venous thrombosis in anaesthesia

Deep vein thrombosis is a common cause of preventable mortality and morbidity in patients hospitalized for surgery, as DVT are implicated in up to 90% of PE (29-31). Most data is on screening for patients for DVT after surgery and preoperative thromboprophylaxis for in-patient surgery is recommended in moderate to high risk patients (31) with prophylactic dose anticoagulation and venous compression stockings. However, there have been some reports on screening before surgery where the incidence of above knee preoperative DVT was reported for surgery for excision of brain tumour (3 (32) to 23% (33)), spinal metastasis (1.5% to 25% (34-36)), and surgery for hip fracture (18.9% (37)) and trauma (10% (38)). Unfortunately, the quality of evidence for patient benefit remains poor, with the bulk of the literature being observational and a lack of any randomised trials (Table 3). If a DVT is identified preoperatively, the decision whether to treat is tied to the anticipated risks of haemorrhage during and after surgery, as preoperative anticoagulation has been reported to be associated with a clinically important increased risk of bleeding (37, 39). In several centres, preoperative therapeutic anticoagulation was stopped prior to neurosurgery and an inferior vena cava filter inserted to prevent proximal migration of the DVT during the perioperative period when anticoagulation was ceased (40-46). Although it is logical that earlier detection and treatment of DVT may result in less morbidity and mortality from PE, there is some doubt (47) but due to the lack of adequately powered randomised trials, this research question is yet to be proven either way. The Guidelines from the American College of Chest Physicians recommend against routine use of ultrasound to screen for DVTs, but they do recommend treatment with either anticoagulant medication or IVC filter placement in patients diagnosed with an asymptomatic proximal DVT (31).

### Conclusion

Point of care application of ultrasound for detection of DVT using the two- and three-point compression technique by non-radiology medical personnel is equivalent in accuracy to conventional venous duplex ultrasound performed by radiology and is becoming incorporated into the curriculum of acute care medical specialties. This practice may result in saving time and cost for referral to radiology and may result in more widespread screening of patients and an earlier detection and treatment of DVT.

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**Table 1** Performing two- and three-point lower limb compression-ultrasound for diagnosis of deep venous thrombosis

**Legend:** CFV, common femoral vein; DVT, deep venous thrombosis; FV, femoral vein; GSV, greater saphenous vein; PV, popliteal vein; \*McConnel sign: global hypokinesis of the right ventricular free wall with sparing the right ventricular apex.

Step	Description
Equipment	<ul style="list-style-type: none"> <li>- High frequency linear transducer (superficial)</li> <li>- Curvilinear transducer (deeper structure or if obese)</li> <li>- Colour flow Doppler may be required to confirm whether a vessel is an artery or a vein</li> </ul>
Patient positioning	<ul style="list-style-type: none"> <li>- Reversed Trendelenburg position with the bed tilted up to 20° to allow venous dilatation form blood pooling.</li> <li>- Knee 20-30° bend and hip 30° externally rotated (frog’s leg position) to allow full access to the medial part of the thigh and the popliteal fossa. (Figure 2)</li> <li>- The popliteal vein can also be evaluated with the patient in decubitus position with the study leg side up.</li> </ul>
Examination technique	<ul style="list-style-type: none"> <li>- Discrimination of arteries and veins is critically important, and the following features are useful:               <ul style="list-style-type: none"> <li>○ Veins are easier to compress with external force from the probe than arteries, which is the most reliable technique. Only veins contain valves.</li> <li>○ Arteries have a more visible (thicker) wall, are pulsatile and may have atherosclerosis</li> </ul> </li> <li>- The relationship of the artery to the vein is not a reliable method of discrimination between the two types of vessel</li> <li>-If any doubt, colour or pulsed-wave Doppler can be used (Video 2)</li> </ul>
Examination technique	<ul style="list-style-type: none"> <li>- Transverse plain 2-D ultrasound imaging with compression.</li> <li>- Probe’s indicator to the patient’s right</li> </ul>

	<ul style="list-style-type: none"> <li>- Three-point technique examines the junction of CFV and GSV, FV and PV (Figure 1)</li> <li>- Two-point technique examines the CFV junction and PV</li> <li>- The CFV represents the most medial vessel inferior to the inguinal ligament which connects the pubic symphysis to the anterior superior iliac spine. The CFV usually extends 2 cm proximal and 2 cm distal to junction point between CFV and GSV</li> <li>- Point 1 is defined at the junction of CFV and GSV, which has a clinical significance where DVT at the junction point must be treated. In this view, the femoral and profunda femoris arteries are usually visualised (Figure 3).</li> <li>- Point 2 is defined at FV which is essentially located in the adductor canal below the junction of PFV and FV (Figure 4).</li> <li>- Point 3 is defined at PV and is located in the popliteal fossa (Figure 5)</li> <li>- With the indicator pointed to the patient’s right, the PV is located in the near field of the image and is anatomically more posterior when compared to popliteal artery.</li> <li>- Examiner will image the veins at the three described points then will apply compression in an attempt to completely compress the vein (video 1).</li> </ul>
<p>Assessment of deep venous thrombosis</p>	<ul style="list-style-type: none"> <li>- The walls of thrombus free vein should coapt completely obliterating the vein’s lumen and the adjacent artery may become deformed with compression</li> <li>- Note the degree of occlusion: irregular, heterogenous,</li> <li>- Form, length and mobility</li> <li>- Acute thrombus: anechoic to hypoechoic, poorly attached, spongy texture, dilated vein</li> <li>- Chronic thrombus: hyperechoic or brightly echogenic, well attached, rigid texture, calcifications, contracted vein, large collaterals, thickened vein walls (48)</li> </ul>

	<ul style="list-style-type: none"><li>- Non-compressible vein indicates presence of DVT</li></ul>
Associated features	<ul style="list-style-type: none"><li>- Raised D-dimers</li><li>- Wells score (49)</li><li>- Lung: subpleural infarcts (26)<ul style="list-style-type: none"><li>- Heart (in larger PE's): right ventricular dilatation &amp; dysfunction and D-shaped septum (50), dilated inferior vena cava, McConnell sign* (51), mobile thrombus (rarely seen).</li></ul></li><li>- Unilateral limb desaturation with near-infrared spectroscopy</li></ul>

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**Table 2** Limitations of venous compression ultrasound.

**Legend:** DVT; deep venous thrombosis.

<b>Limitation</b>	<b>Description</b>
Iliac veins	<ul style="list-style-type: none"><li>- Iliac veins are also not easily visualised or compressible and although only 1% to 2% of DVT are isolated to iliac veins, clinicians must be cautious if abnormal compression is encountered in the femoral region as this should raise suspicion for a DVT in the iliac vein.</li><li>- Although not within the normal scope of a compression study, an abnormal pulsed-wave Doppler pattern seen in the femoral vein can be used to exclude a complete (not partial) iliac vein thrombosis and an iliac vein thrombus may extend all the way to the inferior vena, which may be identified with echocardiography</li></ul>
Femoral veins	<ul style="list-style-type: none"><li>- Although the addition of the femoral vein compression point may assist in detection of the approximately 6% of DVT's that are not seen at the other two points (52), some advocate imaging as much of the femoral vein as proximal as possible starting at the common femoral vein and translating the probe slowly distally towards the knee.</li><li>- Femoral vein duplication is common and therefore it is important to routinely look for a second femoral vein to avoid missing a DVT (53).</li><li>- Compression may be difficult in obese or oedematous patients particularly in the adductor canal. Therefore, at the adductor canal, a 2-hand technique may be necessary where the examiner places his or her hand behind patient's leg and pushes the soft tissue up towards the transducer (Figure 6).</li></ul>
Calf veins	<ul style="list-style-type: none"><li>- The compression method excludes the calf veins and the iliac veins. Calf DVT's are difficult to identify with ultrasound, with a</li></ul>

	<p>low sensitivity. Calf DVT's diagnosed by venography (previous gold standard) were only clinically important if found to progress proximally, which should be identified by the compression method in the popliteal area (54, 55).</p> <ul style="list-style-type: none"> <li>- Although calf DVT's are often not treated, ultrasound examinations should be repeated as the propagation risk may be significant in high risk patients.(31)</li> </ul>
<p>General/pitfalls</p>	<ul style="list-style-type: none"> <li>- Non-compressible vein may be mistaken for an artery which results in false negative and an artery may be mistaken for a non-compressible vein which results in false positive</li> <li>- Inability to see the vein due to large body habitus, hardware, bandages</li> <li>- Lymph nodes should not be mistaken for a venous thrombus (Figure 7)</li> <li>- No flow in Baker cysts</li> <li>- Arterio-venous fistula</li> <li>- Venous congestion (stasis)</li> <li>- Venous hematoma</li> <li>- Venous valve, a frequent site of clot formation (Video 1)</li> <li>- Intravascular catheter in lumen</li> <li>- Thrombus in only one limb of a duplicated vein</li> <li>- Deep venous segment (false-negative)</li> </ul>

**Table 3** Summary of reported evidence for management of preoperative, above knee, deep venous thrombosis.

**Legend:** Anticoagulation; therapeutic anticoagulation before surgery recommenced at a variable time after surgery, DVT; deep venous thrombosis, IVC filter; inferior vena cava filter inserted before surgery.

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Reference	Study design	Screening	Management	Summary of findings
Neurosurgery				
Zacharia 2017(45)	Retrospective observational	232 patients undergoing spinal metastasis removal	IVC filter	232 of 314 (73.9%) patients screened, of whom 22 (9.48%) had a DVT.
Pandey 2018(46)	Prospective observational	115 patients scheduled for craniotomy for brain tumour	Anticoagulation AND IVC filter	Seven (6%) of the 115 screened patients had DVT. Of these patients, one developed postoperative PE, and another had bilateral DVT postoperatively. None of the patients without preoperative DVT developed VTE postoperatively. There were no deaths and no complications from the anticoagulation or IVC filter insertion.
Dickerson 2019(47)	Retrospective before and after policy change from routine screening to targeted screening	All neurosurgery 485 patients routine screening and 504 patients targeted screening	IVC filter	The DVT rate was higher in the routine screening group (10% vs 3%, $p < 0.01$ ) and IVC filter rate (6% vs 2%, $p < 0.01$ ). There was no difference in the PE rate (2% in both groups, $p = 0.72$ ) or all-cause mortality at discharge (7% vs 6%, $p = 0.49$ ).
Hip fracture surgery				

Xia 2018(37)	Retrospective case-control	301 consecutive hip fracture surgery patients	Anticoagulation	<p>Preoperative DVT was found in 18.9% (57/301) and pulmonary embolism (PE) in 1%. Of the DVT's, 22.8% (13/57) were above knee and 77.2% (44/57) below knee</p> <p>In below knee DVT, anticoagulation did not significantly reduce the rate of DVT progression, however did had a significantly lower postoperative haemoglobin concentration than those who did not receive preoperative therapeutic anticoagulation</p>
Zahn 1999(56)	Prospective	61 consecutive hip fracture patients	IVC filter	Of 61 patients screened, 21 patients had a delay of >48hr in surgery in whom 13 had a preoperative DVT (62%)

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## Figure Legends

(<https://drive.google.com/open?id=1ilwaMjT285BoCVuwwsSLjGyx0qq8MYt1>)

Figure 1 Sonoanatomy of the lower extremity venous system

Figure 2 Positioning of the lower limb for compression ultrasound examination  
Knee 20-30° bend and hip 30° externally rotated (frog's leg position) to allow full access to the medial part of the thigh and the popliteal fossa.

Figure 3 Compression point 1 – junction of common femoral vein and greater saphenous vein

CFA; common femoral artery, CFV; common femoral vein, GSV; greater saphenous vein

Figure 4 Compression point 2 – femoral vein

FA; femoral artery, FV; femoral vein, ProfV; femoral profunda vein

Figure 5 Compression point 3 – popliteal vein

PA; popliteal artery, PV; popliteal vein

Figure 6 Two-hand technique used when obesity limits venous compression

Figure 7 Femoral lymph node

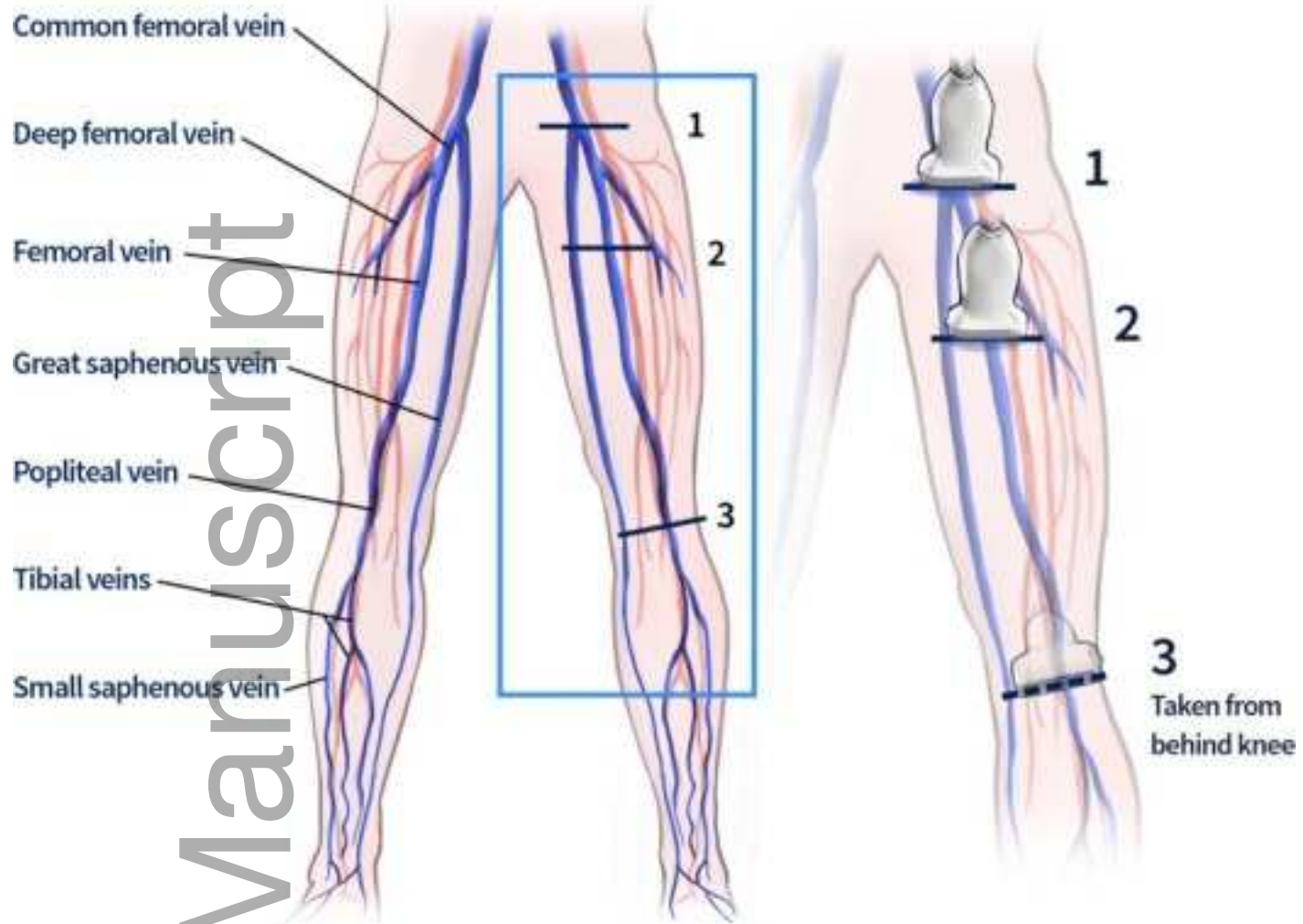
LN; lymph node

Video 1 Performing two- and three-point lower limb compression-ultrasound for diagnosis of deep venous thrombosis

Video 2 Using colour flow Doppler to discriminate between an artery and a vein

Video 3 Absent deep venous thrombosis using compression ultrasound

Video 4 Deep venous thrombosis in the popliteal vein using compression ultrasound



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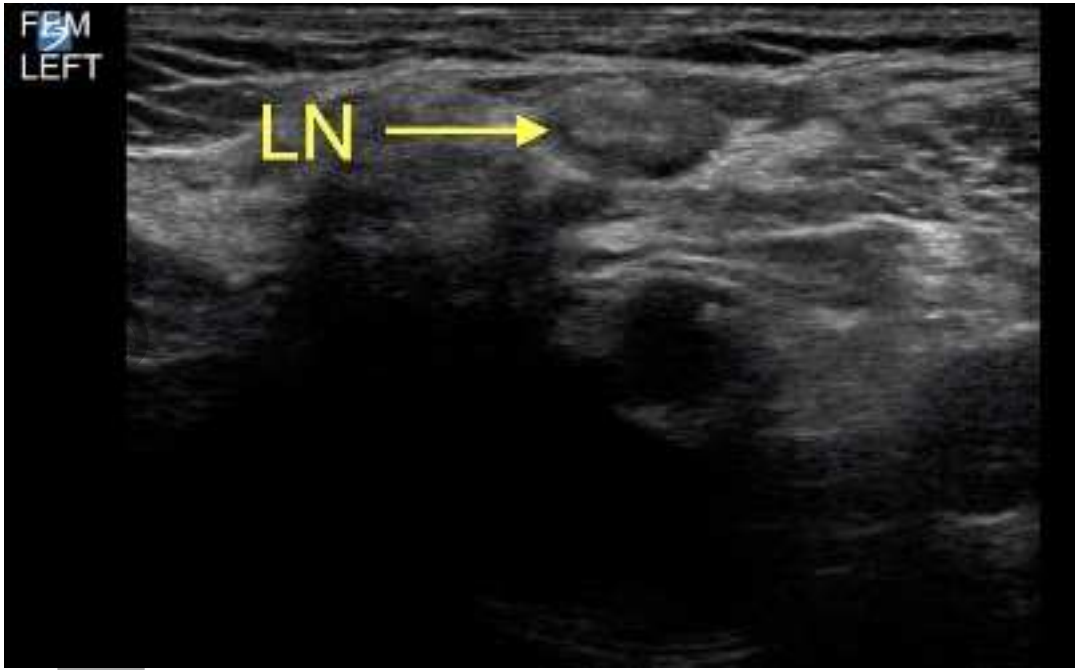


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