Section E: Performing and interpreting venous insufficiency (VI) ultrasound examination

What information does the referring vascular care provider need?

Sonographers may be asked to perform duplex ultrasound (US) of the lower limb to investigate chronic venous disease (CVD) either to inform the treatment approach or to follow up after treatment.

The primary aim is to assess the competency of the valves in the deep and superficial venous systems, along with the junctions and perforating veins. The source of reflux responsible for superficial varices should be established and mapped, including any clinically relevant perforating veins, or possible alternative refluxing venous pathways. [21, 45, 81, 85, 99]

Secondary aims include the following, which are relevant to the treatment decisions of the vascular care provider:

- To identify deep venous obstruction, including partially occluded venous segments
- To identify superficial venous thrombosis
- To evaluate the tortuosity of the target vein (for ablation)
- To identify the diameter of saphenous veins
- To identify tributary veins (veins superficial to saphenous fascia) as the target veins for ablation. [41, 79]

Scanning protocol for VI ultrasound examination

The following sections answers the following questions:

- What anatomy should be assessed/recorded?
- What is the recommended scanning protocol?
- What measurements should be made/recorded and at what sites?
- How is a normal vein defined?
- What are common patterns of abnormalities (especially Doppler reflux patterns)?

Recommendation E1: A complete duplex ultrasound examination for chronic venous disease of the lower limb should evaluate deep, superficial, and perforating veins for patency and competency. B-mode ultrasound and spectral Doppler imaging are essential for the assessment; however, colour Doppler is also an important complimentary tool for assessing vein patency and competency. *For guidance on which veins which should be visualised and tested for venous obstruction refer to Table E1.* *For guidance on testing for venous reflux duration refer to Recommendations E3-E5 and Table E1.* *For guidance on which vein diameters should be measured refer to Recommendation E2 and Table E1.*
Level of Evidence: Strong *Strength of Evidence: Strong* *Consensus: High*
Summary Statement This recommendation outlines the overall requirements of a duplex ultrasound examination of the lower limb veins in the setting of chronic venous disease. This is consistent with existing evidence-based guidelines. [9, 8, 60]

The following sections provide further commentary on the role and techniques of B-mode, colour and spectral ultrasound imaging, and to which veins they should be applied, including the expected sonographic appearances when veins are normal or affected by pathologic or physiologic processes. The information has been collated from Information extracted from existing clinical practice guidelines [9, 21, 22, 35, 41, 43, 45, 68, 79,-83, 85-86, 99]

B-mode ultrasound

Normal B-mode sonographic appearance:

On B-mode ultrasound, normal veins have echolucent lumens, with blood displaying anechoic echogenicity. Red blood cell aggregation (or spontaneous echo contrast) may be visualised as echogenic and intraluminal structures moving slowly in a cephalic direction. Compression test is useful for differentiating red blood cell aggregation from venous thrombosis.

The vein walls should be thin with smooth delineation, suggesting normal vascular integrity without abnormal thickening or irregularities secondary to post-thrombotic change. The valve sinus (space between venous cusp and venous wall) may appear slightly dilated and the valve leaflets may be visualised as white and thin structures. Under normal physiological conditions, the diameter of larger veins may undergo changes with deep inspiration or during a Valsalva manoeuvre, reflecting dynamic responses related to increased intraabdominal pressure. Additionally, veins are compressible under gentle pressure from the ultrasound transducer, which differentiates them from arteries. [44-45]

Use transverse B-mode imaging:

- To explore the anatomical arrangement and variations.
- To provide information about structures adjacent to the veins such as accompanying nerves, arteries, side branches, and collaterals resulting from prior thrombosis.
- To assess venous morphology such as tortuosity, aneurysm, ectasia, calcification (phlebosclerosis), and post-thrombotic changes such as webs and wall thickening.
- To offer an overview of vein presence, paths, anatomy, and diameter.
- To identify where a truncal vein exits the fascial compartment.
- To demonstrate vein compressibility. A compressible vein indicates the absence of endoluminal thrombus and confirms vein patency. Compressibility should be tested every 1 to 2 cm along the length of a vein.
- To identify the target vein for endovenous ablation. When the target vein has an extrafascial course, if its anterior wall is less than 5mm from the skin (measured from a transverse section of the vein), this should be identified and noted. It has been suggested that if these veins are ablated, the adjacent skin is at risk of complications, such as burning. [41,100]
- To observe superficial vein diameter and changes in the diameter of the saphenous vein for the following reasons:
    - the calibre of superficial veins provides clues to physiological venous flow disturbances. Enlarged superficial veins (>5mm) may indicate reflux as vein diameter is correlated to venous incompetence, [101] but diameter measurements should not be relied on solely to make judgements on venous competency. A small diameter alone does not reliably indicate venous competence. For example, a decrease in saphenous vein calibre can indicate a peripheral connection with an incompetent tributary vein. Spectral Doppler is required to determine venous competence/incompetence.
    - an increase in saphenous vein calibre can indicate the presence of a feeding incompetent perforator vein or tributary.
    - the saphenous vein typically normalises after reflux flow exits into tributary veins.
    - and vein diameter is useful to provide information for treatments, e.g., for vein access when endovenous ablation procedures are being considered or identifying a GSV at the SFJ with a large diameter placing it at risk of endovenous heat induced thrombosis (EHIT) in endovenous ablation procedures.

Use longitudinal B-mode imaging:

- To demonstrate vein tortuosity and its suitability for a catheter to be passed through it in endovenous treatments.

Vein diameter measurements:

The measurement of vein diameters is used to guide treatment decisions, [8,9, 43, 60 100] and may also serve as surrogate markers for reflux and disease severity as studies have demonstrated associations between diameter measurements and reflux, as well as reflux severity. [102-108]

While a number of existing clinical practice guidelines, when describing the procedure and technique of duplex US, state that measurements of vein diameter should be made, [31, 45, 82-83, 109] they provide little detail on the veins to be measured, the measurement technique or on the evidence based rationale for making these measurements.

One existing clinical practice guideline [21] provides the most detailed guidance on where measurements should be made, and this has been adopted by other clinical practice guidelines. [31, 45, 110] Table E1, incorporates these suggestions, with guideline development group consensus guidance for which veins diameters should be measured, and for which veins diameter measurements are optional. **Vein diameters should usually be measured at the site of the maximal diameter, excepting where otherwise indicated in Table E1**.

Recommendation E2: In relation to the method of measuring vein diameter between the anterior and posterior vein walls, we recommend that the measurement should be made:

a. with patient's legs in a dependent position:

*Level of Evidence: M*oderate
Strength of Evidence: Strong
Consensus: High

b. from a transverse image of the vein

*Level of Evidence: M*oderate
Strength of Evidence: Moderate
Consensus: High

c. between the inner walls

Level of Evidence: Weak
Strength of Evidence: Moderate
Consensus: High

d. with the vein at rest and not during any reflux provocation manoeuvres

Level of Evidence: Weak
Strength of Evidence: Moderate
Consensus: High

e. with the vein uncompressed

Level of Evidence: Weak
Strength of Evidence: Strong
Consensus: High

Summary statement

The anteroposterior (AP) measurement is regarded as more repeatable than a lateral measurement due to better image resolution along the AP axis. [110] The guideline development group provided the following justifications to support the method of vein measurement outlined in this recommendation.

Vein diameter should be measured in the dependent position:

- so that the examined veins are under ambulatory venous pressures and in a position in which the veins would demonstrate valvular incompetence
- so that a consistent position is used for both diameter measurements testing and reflux testing
- because vein size is maximised when measured in the dependent position which results in more accurate and repeatable measurements and provides better information for patient management.

-Measuring vein diameter from a transverse image of the vein is preferred because it is easier to assess the vein walls, the true maximal diameter, and if there is any compression of the vein. This results in more accurate and reproducible measurements. It is particularly important when measuring small veins, as in transverse section there is less impact from slice thickness artefact and reduced contrast resolution.[111] However, in some instances it can be more practical to measure the vein from a longitudinal image. This may occur when the vein is tortuous or varicose and at the saphenofemoral junctions when the vessel is more clearly defined in the longitudinal plane.
-Measuring the inner walls is preferable (even though there would be little difference in a measurement made between its inner walls, compared to a measurement made between its outer walls due to the thinness of vein walls) because it represents the size of the lumen of the vessel, which is important to determine treatment options, and to match the size of needles/cannulas/introducers with the vein lumen size. The inner walls can also be easier to distinguish than the outer walls. An exception to this is in treated veins, when the inner walls are not visible, and the measurement can instead be made between the outer walls. [21]
-Measuring vein diameter during reflux provocation manoeuvres are not recommended because it is difficult to achieve, compromising scanning time, patient and sonographer comfort and measurement accuracy and reproducibility. In addition, reflux provocation manoeuvres will dilate the vessel, and not represent the vein at rest, which is the state they are in during treatment.
-Diameter measurements of an uncompressed vein, represent the vein in its physiological state. Compression of the veins should be reserved for demonstrating vein patency.
-During an examination, if a venous segment is found to be grossly dilated and aneurysmal, particularly outside the valve sinus, its maximum diameter should be measured. A venous aneurysm is generally defined as a persistent, isolated dilatation of the vein to twice its normal diameter, although no consensus exists on the exact definition. [112]

Colour Doppler Ultrasound

Colour Doppler is an efficient and useful survey tool to:

- obtain a general overview of the extent of venous reflux before assessing each individual vein segment with spectral Doppler.
- to clarify internal obstructions/vein patency in noncompressible or partially compressible veins.

Normal colour Doppler appearances:

Using colour Doppler imaging, normal venous Doppler signals should exhibit spontaneity and phasicity with respiratory modulation. The vein typically displays full colour filling without any defects. Proximal augmentation or the Valsalva manoeuvre should interrupt the flow, while distal manoeuvres result in antegrade flow followed by a short reverse flow when normal valvular function is present. [35]

To achieve the optimum colour Doppler signal, the vein should be imaged in a longitudinal section, with an angle of insonation between the transducer and the vein at 45-60 degrees. The sensitivity of colour Doppler imaging can be improved by choosing the appropriate settings, such as low scale, low wall filter and high gain (see Section F).

Colour Doppler should not be relied on to determine venous competence/incompetence as it does not quantify the duration of reflux.

While performing Doppler analysis, antegrade flow is often designated as blue, whereas red is used to represent reversed flow, this should never be assumed when interpreting images. The colour depicting direction of venous flow depends on how the colour map has been set in relation to the direction of the ultrasound beam and the vein being assessed.

Role of colour Doppler for assessment of venous reflux

Recommendation E3: Sonographers should not use static colour images for the representation and documentation of venous reflux within a sampled vein segment; instead, a spectral Doppler trace should be used.

Level of Evidence: Strong
Strength of Evidence: Strong
Consensus: High

Summary Statement

While colour Doppler is an efficient surveillance tool in detecting venous reflux, static colour Doppler images do not represent the full cycle of venous flow during a reflux provocation manoeuvre and do not allow for accurate measurement of reflux time. [35] Instead, venous reflux should be recorded and documented using a representative spectral Doppler trace, which demonstrates venous flow over time, and from which a measurement of the duration of retrograde flow can be calculated. Colour Doppler can only be regarded as complementary to the Spectral Doppler trace in determining venous incompetence. It can be especially useful at the saphenofemoral and saphenopopliteal junctions and when evaluating venous flow in perforating veins.

Spectral Doppler Ultrasound

Spectral Doppler displays temporal changes of flow over time. It is used to assess and record the flow characteristics of veins, including phasicity and flow direction. This helps identify the source(s) of reflux and determine reflux pathway.

Spectral Doppler appearances:

The variability in amplitude of venous Doppler signals is influenced by changes in respiration, right heart pressures, vessel volume and depth, and the distance of the vein from the heart. There is a noticeable decrease in amplitude as the distance from the heart increases. [45, 113] Moreover, there is a decrease in venous flow velocity with inspiration and an increase in venous flow velocity with expiration. [44] When applying reflux provocation manoeuvres, there will be a prompt increase in flow volume and velocity at the sampled location, followed by a short reverse flow duration representing valve closure. [35, 43-45]

- If phasicity is not evident then proximal obstruction should be suspected and investigated further.
- If femoral waveforms exhibit transmitted pulsatility, the vein on the contralateral side should be assessed as this finding may be suggestive of some level of cardiac dysfunction.
- Flow reversal of prolonged duration after an augmentation manoeuvre is a sign of reflux **(Image 25).** In normal veins, flow reversal will be seen for a short period as normal valves do not close instantaneously **(Image 26).**

- If varicose veins are present, but the GSV or SSV is not responsible for the reflux, then other source(s) of reflux such as incompetent perforators need to be considered. This will require assessment of the medial, posterior, lateral and anterior leg as the refluxing veins are followed back to their source.

How to obtain an accurate spectral Doppler trace:

Recommendation E4:
For best accuracy in detecting venous reflux, a spectral Doppler trace should be made:
- from a longitudinal image of the vein
- with the sample gate placed in the centre of the vein, and covering the entire lumen of the vein
- with spectral Doppler sampling performed with a 45-60 degree angle between the vein wall and the ultrasound beam.

Level of Evidence: Strong
Strength of Evidence: Strong
Consensus: High

Summary Statement

Performing a Doppler trace from a longitudinal view of the vein allows the sonographer to ensure there is a favourable Doppler angle. It is feasible to measure flow from a transverse view of the vein, but it is not recommended because it is not possible to visually confirm that sampling is performed at a favourable Doppler angle.
A Doppler angle of greater than 60 degrees is not recommended as Doppler signals decrease as they approach 90 degrees. [114] In small vessels with slow reflux, poor Doppler angle will result in small Doppler shifts making flow difficult to detect. [35] It is also not recommended to use Doppler angles less than 45 degrees, as this reduces the sensitivity of the Doppler shift in detecting blood flow and velocity. Angle correction is not necessary, unless reflux velocities are being measured, which is not usually the case in duplex ultrasound for chronic venous disease. The spectral Doppler waveform appearance and reflux time is not affected by angle correction. The sample gate should fill the vessel lumen as much as possible without touching its walls, to ensure slow flow reflux occurring near the vein walls is identified. [115]

What cutoff values should be used for diagnosing venous reflux of the veins of the lower limb?

Recommendation E5: Venous reflux is defined as:
- > 1second of reversed flow in the femoropopliteal segments (e.g., common femoral, femoral and popliteal veins).
- >0.5 seconds of reversed flow in superficial veins (e.g., the GSV, SSV, ASV, PAGSV, Giacomini vein), calf veins (e.g. posterior tibial veins) and deep (profunda) femoral veins.
- >0.5 seconds for perforating veins.

Level of Evidence: Moderate
Strength of Evidence: Strong
Consensus: High

Summary Statement

Venous reflux is defined as the retrograde flow of abnormal duration in any venous segment, [45] although a definitive duration cutoff for all vein segments has not been agreed upon in the published literature. [31] Venous reflux is assessed by evaluating the response to accepted provocative manoeuvres documented by spectral Doppler waveforms. [83] Despite this lack of consensus, the method is well accepted and highly practical. It requires an understanding of the waveforms and measurement of reflux. Callipers can be used to measure reflux duration, especially with reflux of short duration, but in cases of extended refluxing flow it is sufficient to use the gradations on the Doppler baseline to identify if reflux duration has exceeded the threshold outlined in Recommendation E5.
It is normal for short reverse flow to be demonstrated in response to the provocative manoeuvre, and it is good practice to wait for the resumption of normal venous flow to ensure that delayed reflux is not missed. [35]
Furthermore, assessment in only the standing position due to the significant number of false positive and false negative findings in the supine position was also recommended by the International Union of Phlebology. The duration of reflux time can be influenced by the provocation manoeuvre, patient position, anatomical variations, and variability of reflux response in different patients and therefore cannot be used to provide a quantitative assessment of reflux severity. [35] Other parameters have been investigated such as reflux waveform surface area, reflux velocity and reflux rate, but these parameters are also influenced by the same variations. [35, 44]

Following the common practice outlined in various guidelines and consensus documents, a threshold of >0.5s is recommended for superficial veins, tibial veins, deep femoral and perforating veins, while >1 second is suggested for the CFV, FV and popliteal vein. However, sonographers and practices may opt for a lower threshold of 0.35s when defining perforator incompetence. This choice is supported by the findings of Labropolous et al., who reported that 97% of competent perforators exhibit reverse flow duration below this 0.35s threshold. [116]

In addition to diagnosing perforator incompetence using the cutoff value, many authors suggested differentiating re-entry perforators from those serving as the source of reflux. The haemodynamic role and clinical significance of the perforators can be determined by evaluating the net flow direction through the perforating veins. Typically, in re-entry perforators, reflux flow from its connecting superficial veins is directed inward during muscle relaxation. If superficial venous reflux is not abolished, these perforators may eventually become dilated and incompetent over time. In contrast, perforators as the reflux source with their valvular dysfunction resulting from deep venous reflux typically display outward flow during muscle relaxation. They can subsequently cause superficial venous hypertension and the associated skin changes. Current practice guidelines suggest that treatment of such incompetent perforators may not be necessary for patients without advanced skin changes. However, it is recommended that treatment for isolated or residual incompetent perforators should be considered if the disease progresses to C4b, C5, or C6 stages. [43, 117-118]

Assessing specific veins (including the anatomy to be assessed and recorded, and different patterns of venous reflux)

The information in Table E1 provides details on which veins should be examined and how. It is acknowledged that different referrers may have different preferences for how a VI examination is performed and recorded, however to minimise the need for repeated examinations, this table outlines minimum requirements for assessing and recording veins when they are present.

Sonographers should also identify, assess and record any venous malformations and anatomic variants. In primary venous insufficiency, the pattern of refluxing veins is mostly descending (from top down). I.e., in the GSV, once the terminal and subterminal saphenous valves fail, the upper GSV dilates with reflux flow exerting pressure on the subsequent lower valves and resulting in valvular failure. This domino effect then progresses toward the lowest section of the lower limb. As the veins dilate, they elongate and change from a straight course to a tortuous varicose course. [35]

Venous reflux may also occur in the deep veins and if this is not recognised, then the treatment for superficial reflux may not be effective. Failure to recognise deep vein reflux may also occur when a duplication of the deep veins is not recognised. [41]

Table E1: Summary of minimum assessments and documentation required for specific veins. *Refer to document "Abbreviations' for explanations of abbreviations in this table*.

Common femoral Vein (CFV)		
Assessment		**Comments**
Visualise	Yes	- just below the inguinal canal the CFV represents the head of the 'mickey mouse'. The lateral 'ear' represents the common femoral artery, the medial 'ear' represents the GSV (at the SFJ) **(Image 27)**. If the medial 'ear' is absent, this represents an absent GSV postsurgery.
Test for venous obstruction	Yes	-testing should be performed with compression manoeuvre and spectral Doppler -a nonphasic or a continuous waveform with normal respiration indicates proximal obstruction. Spectral flow should be spontaneous with respiratory and cardiac modulation. If this is not present, this is a clue to central venous obstruction, which can contribute to CVD. The closure of venous valves may become insufficient due to venous dilatation, which then results in abnormal Doppler findings with augmentation manoeuvres. If the central venous obstruction is not recognised, treatments may be ineffective, as other dilated veins will develop over time. Another clue to possible central venous obstruction is the presence of unusual collaterals such as dilated superficial epigastric veins, pudendal veins, or upper posterior thigh veins. -if there is a suspicion of venous obstruction in the iliofemoral veins, test should be performed bilaterally, even if a unilateral examination is being ordered. Asymmetric phasic CFV waveforms indicate proximal obstruction on the side displaying abnormal flow patterns; symmetric waveforms do not necessarily rule out proximal obstruction as obstructive disease or mass compression might affect the IVC and bilateral iliac veins. Other cross-sectional imaging may be required if central obstruction is suspected. [41]
Test for reflux	Yes	-test for reflux using Valsalva manoeuvre/manual compression of the thigh or calf. -test for reflux above and below the SFJ. The suprasaphenic segment of the CFV may be dilated and exhibit reflux flow due to SFJ incompetence and siphon effect **(Image 28).** Reflux limited to the segment of the CFV between the terminal valve and the next most proximal valve in the CFV should not be mislabelled as deep venous insufficiency, as it may potentially inappropriately exclude the patient from endovenous laser ablation. [41] True deep venous reflux occurs when there is retrograde flow in the infrasaphenic segment, and if this is present, it is necessary to test the full length of the femoropopliteal veins for reflux.

Measure vein diameter	Measure if: there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >12mm), if the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, [119] you are unsure about any of the above.	
Femoral vein (FV)		
Assessment	**Comments**	
Visualise	Yes	-in B-mode, the FV should be evaluated every 1-2 centimetres in transverse for compressibility and postthrombotic change. [45, 86] -in the transverse view, use the vastus medialis at the adductor hiatus as an anterior acoustic window to better view the FV. -be aware of the presence of a duplicated FV, which has a high incidence. -Persistent sciatic vein (embryonic remnant) should be sought for if the FV is hypoplastic or significant smaller than its accompanying superficial femoral artery (SFA) without a history of DVT.
Test for venous obstruction	Yes	-testing should be performed with compression manoeuvre and spectral Doppler -patency can be tested in a supine or reverse Trendelenburg position. -a nonphasic or a continuous waveform with normal respiration indicates proximal obstruction in the CFV. -absent or blunted augmented flow indicates distal venous obstruction without matured collateral veins. -in the case of hypoplasia, collateral veins and embryonic vein remnants should be sought for and tested.
Test for venous reflux	Yes	FV should be assessed at least once. If the FV or popliteal vein reflux, or an incompetent thigh perforator is detected, sampling at multiple sites is recommended to determine the extent of the refluxing segment. -duplicated FVs should be tested individually for venous incompetence.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >16mm), [120] the FV is hypoplastic in the presence of embryonic vein remnants draining flow from the lower limb, the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, you are unsure about any of the above.	
Popliteal vein		
Assessment		**Comments**
Visualise	Yes	-be aware of the duplication of the popliteal vein. -popliteal veins passes through adductor hiatus to become the FV. In rare cases, it may join with the deep femoris vein via the persistent sciatic vein.
Test for venous obstruction	Yes	-testing should be performed with compression manoeuvre and spectral Doppler -patency can be tested in a supine or reverse Trendelenburg position. -a nonphasic or a continuous waveform with normal respiration indicates proximal obstruction. - patients without superficial venous insufficiency should be tested for popliteal vein entrapment, especially when they have below knee oedema, leg heaviness and skin changes.
Test for venous reflux	Yes	-test the popliteal vein proximal and distal to the SPJ or the gastrocnemius vein insertion to confirm popliteal incompetence. [121]
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >13mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, the vein is, or is suspected of being aneurysmal or compressed, if you are unsure about any of the above.	
Saphenofemoral junction (SFJ) **Note:** Many primary lower extremity varices are caused by reflux at the level of the SFJ. [35]		
Assessment		**Comments**
Visualise	Yes (if present)	-at the SFJ, identify the terminal and preterminal valves if possible. -scan within the inguinal lymph node area distal to the SFJ to identify any varicose veins or lymph node venous network (LNVN) in this area. (For more information on LNVN go to subsection on neovascularisation). - various anatomical variations at the SFJ necessitate a thorough evaluation to prevent technical failures.
	No (if not present)	-GSV stripping and flush ligation may have been performed when the SFJ cannot be identified.
Test for venous obstruction	Yes	-systolic reflux during provocation manoeuvre indicates venous obstruction in the iliofemoral veins **(Image 29)**. -continuous flow at the SFJ may indicate obstruction in the femoropopliteal veins if the GSV or pelvic tributaries act as collateral drainage **(Image 30)**.

Test for venous reflux	Yes	-test for reflux above both the terminal and preterminal valves to distinguish reflux at either or both. -if there are varicosities around the SFJ without SFJ incompetence, assess for incompetent pudendal vein or pelvic vein as the source of varicosities. Also check for central venous obstruction, which may also be a cause. -if there is upper thigh GSV reflux without SFJ incompetence: - assess for insufficient pudendal, inferior epigastric, gluteal or other connecting pelvic veins connecting to the upper GSV (especially in multiparous women). -If there is coexisting deep vein insufficiency, the GSV reflux is probably due to perforator vein(s). [35]
Measure vein diameter	Always measure. A large diameter (e.g. 9mm) of the GSV at the SFJ is associated with increased risk EHIT.	
Useful references	**Images 31-34 in Image Gallery** Variation at the saphenofemoral junction (Figure 1 in Quickert and Alagha Sadowska et al. 2018) [122] Schematic diagrams illustrating variable terminations of the GSV (Figure 3 in Liu et al.,2022) [123]	
Great Saphenous Vein (GSV) **Note:** Incompetence of the GSV is the most common cause of primary lower extremity varices. [22, 35, 112]		
Assessment		**Comments**
Visualise	Yes, if present	-note any changes in the GSV diameter. If there is a sudden increase in diameter in the thigh, assess for a connection(s) between the GSV and ASV or perforator, or pelvic sources of venous reflux. If there is sudden decrease in the GSV diameter, assess distally for a major incompetent tributary. -be aware the GSV may be duplicated
	If not present:	-be aware of the possibility of a segmental aplastic or hypoplastic GSV, mostly visualised in the distal thigh and proximal calf. In the region where there is aplasia, the proximal and distal portions of the GSV is often bridged by tributaries. -note that the GSV has the potential to diminish and eventually disappear following endovenous ablation treatment, making it possibly undetectable during duplex ultrasound examinations. -GSV stripping surgery could have been performed if not visualised from groin to lower thigh.
Test for venous obstruction	Yes	-assessing the patency of the GSV is important, as the presence of SVT could impede the passage of endovenous devices like laser fibre or RFA catheter. Furthermore, testing of reflux may yield inaccurate results if there is proximal obstruction.
Test for venous reflux	Yes	-sample every few centimetres along the entire course of the vein; refluxing side branches can reconnect distally to the GSV. -if the GSV is competent in the thigh still assess for reflux below the knee as incompetence in the calf may still occur. - be aware paradoxical reflux flow from the TE of the SSV or the vein of Giacomini may feed the GSV. -the GSV can be segmentally incompetent without a proximal incompetent connecting tributary and drain into an incompetent tributary. -the distal point of the GSV reflux varies; it can be close to the SFJ, with reflux extending into the ASV, or more distally at variable levels, usually at the site of a connecting varicose side branch but also terminates at a perforator. -reflux flow in the GSV may travel down into SSV via intersaphenous vein or other tributaries. -in CVI patients, the GSV may exhibit venous flow characteristics with pulsatility and absence of reflux, known as saphenous pulsation, which is indicative of microcirculation failure **(Image 35)**. -after varicose vein surgery, an incompetent GSV below the knee may fill varices at the ankle and in the foot. -the GSV may undergo adaptive change and act as the collateral vein in cases of occlusive disease in the femoropopliteal veins, demonstrating continuous flow without venous reflux **(Image 36)**.
Measure vein diameter	Always measure. -the GSV diameter should be measured at the proximal thigh (2-3cm below the SFJ), mid-thigh, (10-15cm below the SFJ), distal thigh (2cm above the femoral condyle), the knee, the proximal calf (2cm below the femoral condyle) and at just above medial malleolus.	
Useful references	Patterns of great saphenous vein (GSV) reflux (Figure 3 in Labropoulos 2022) [124]	
Anterior Saphenous Vein (ASV)		
Assessment		**Comments**

Visualise	Yes, if present	-can be located within its own saphenous compartment just lateral to the GSV; both veins often terminate at a common trunk of the SFJ, sometimes, it may join with the CFV via an aberrant junction adjacent to the SFJ. -a 'double ear' sign on one side of the 'Micky Mouse' may be observed at the SFJ when the ASV joins with the GSV at the level close to the ostium. -to aid identification; the ASV aligns vertically with the superficial femoral artery (SFA) and FV (alignment sign). -it usually has a short course, but sometimes runs down the lower third of the thigh, and should be followed from proximal origin to its thigh termination -it is rare to find duplication of the ASV -the length of the ASV should be quantified allowing the treating clinician to make a decision on the most appropriate treatment method.
	No, if not present	-like the GSV, ASV is another target vein frequently ablated during the endovenous treatment, resulting in shrinkage or disappearance.
Test for venous obstruction	Yes	-similar to the GSV, obstruction for the passage of a thermal ablation device may occur due to acute thrombus or irregularities in the vein wall resulting from postthrombotic changes.
Test for venous reflux	Yes	-reflux may develop in the ASV independent of the GSV in patients with primary varicose veins -because of the communicating tributaries between the ASV and GSV at the mid-thigh, reflux flow can travel from proximal ASV to distal GSV or vice versa. -recurrent thigh varicose veins are frequently associated with the ASV incompetence. -isolated ASV incompetence with reflux originating from the CFV is possible if GSV and ASV have separate junctions.
Measure vein diameter	Always measure. Measure 3-5cm below SFJ, and mid trunk if exists at this level. [125] Do not include varix or dilated segment with an incompetent valve in the measurement.	
Useful references	The fate of the ASV reflux (Figure 11 in Caggiati A., et al., 2024) [126]	
Posterior Accessory of the Great Saphenous Vein (PAGSV)		
Assessment		**Comments**
Visualise	Yes, if present	-the termination of the PAGSV in relation to the GSV is inconstant and usually at a much lower level compared to the ASV.
Test for venous obstruction	Yes	
Test for venous reflux	Yes	-the PAGSV may carry reflux from the GSV downward to TE or the vein of Giacomini, conversely, paradoxical reflux from the SPJ may feed the GSV and/or posterior thigh tributaries after passing through the PAGSV. [39]
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, the treating/referring doctor requests it or protocol directs it, if you are unsure about any of the above.	
Superficial Accessory of the Great Saphenous Vein		
Assessment		**Comments**
Visualise	Yes, if present	Can be located anterior to (above) the saphenous facia of the GSV. Typically terminates in the GSV or may connect to the superficial knee tributaries.
Test for venous obstruction	Yes	Similar to the GSV
Test for venous reflux	Yes	Reflux may exist in the Superficial Accessory of the Great Saphenous vein communicating with ASV or GSV. Isolated reflux unusual
Measure vein diameter	Always measure.	
Anterior Thigh Circumflex Vein (ATCV)		
Assessment		**Comments**
Visualise	Yes, if present	This vein should be distinguished from ASV. It arises on the anterolateral thigh and can join the ASV or have its own proximal termination.
Test for venous obstruction	Yes	Similar to the GSV
Test for venous reflux	Yes	Reflux is usually easily detectable as these veins are typically large
Measure vein diameter	Always measure.	

Tributary veins of the SFJ		
Superficial circumflex iliac vein (SCIV)		
Assessment		**Comments**
Visualise	Yes, if present	-according to Mühlberger, [127] the SCIV presents in 83% of the cases, joins the GSV from lateral at 10.8 mm.
Test for venous obstruction	Yes	-pelvic tributaries such as SCIV may act as collateral veins in case of occlusive DVT in the ipsilateral iliofemoral veins.
Test for venous reflux	Yes	-the SCIV drains venous blood from the veins of lower abdominal wall, and when combined with the SEV, they account for 70.3% of non SFJ reflux according to Jiang et al. [129] Under normal physiological conditions, blood in the cranial tributary veins of the SFJ flows downward toward the SFJ. During the Valsalva manoeuvre, persistent venous flow during the straining phase suggests venous reflux, despite the downward direction. -when tested using augmentation manoeuvre, the reflux flow is usually of low velocity (<20cm/s) and longer duration(>6s). [128]
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, if you are unsure about any of the above.	
Superficial Epigastric Vein (SEV)		
Assessment		**Comments**
Visualise	Yes, if present	-according to Mühlberger, [127] the SEV presents in 78% of the cases, joining the GSV from proximal at 11.9 mm.
Test for venous obstruction	Yes	refer to SCIV
Test for venous reflux	Yes	refer to SCIV
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, the treating/referring doctor requests it or protocol directs it, if you are unsure about any of the above.	
Superficial External Pudendal Vein (SEPV)		
Assessment		**Comments**
Visualise	Yes, if present	-the SEPV is usually tortuous and thin, draining blood from the pudendal region. -according to Mühlberger, [127] the SEPV present in 90% of the cases, joins the GSV from medial at 16.9 mm.
Test for venous obstruction	Yes	-obstruction of the iliofemoral venous flow due to thrombosis may cause dilation of the SEPV with flow from the leg draining to the contralateral side via pelvic-perineal networks.
Test for venous reflux	Yes	-reflux within the SEPV, which is associated with vulval varicosities or varicocoele [35] **Image 37**, can travel down to the GSV, resulting in GSV incompetence.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, the treating/referring doctor requests it or protocol directs it, if you are unsure about any of the above.	
Useful references	Idealized saphenofemoral junction (Figure 4 in Mühlberger et al., 2009) [127]	
Saphenopopliteal junction (SPJ) Many primary lower extremity varices are caused by reflux at the level of the SPJ. [22, 35, 114]		
Assessment		**Comments**
Visualise	Yes, if present	-the SPJ should be visualised in the standing position as the traction effects by the fascia of the hamstring muscle may cause disappearance [128] -identify the exact location of the SPJ (if present) and gastrocnemius veins connection to SSV. If present, measure the level of the SPJ in relation to the popliteal skin crease.
	No, if not present	-high ligation may have been performed if the SPJ cannot be identified.
Test for venous obstruction	Yes	-systolic reflux during provocation manoeuvre indicates venous obstruction in the femoropopliteal venous segment **(Images 38-39)**.
Test for venous reflux	Yes	-upon the detection of reflux at the SPJ, the reflux pathway should be determined whether it travels into the SSV or gastrocnemius veins or both.
Measure vein diameter	Always measure. -like the GSV, EHIT can develop following endovenous ablation treatment and existing evidence suggests the SSV diameter at the SPJ larger than 6mm is a risk factor. [129]	
Useful references	Combined classification of the saphenopopliteal junction (Figure 2 in Veselá M., et al., 2024) [130]	

Small saphenous vein (SSV) Incompetence of the SSV is the second most common cause of primary lower extremity varices. [22, 35, 113]		
Assessment		**Comments**
Visualise	Yes, if present	-identify in the saphenous space in the upper third of the calf between the gastrocnemius muscles or more distally at the lateral malleolus. Follow its course to its termination(s), noting its relationship to any varicose tributaries, popliteal vein or other major veins of the popliteal fossa. -note: -if it terminates at the popliteal vein or by thigh extension of variable length that runs in the saphenous space on the posterior aspect of the thigh. -if it terminates on the medial, posterior or lateral aspect of the popliteal vein. -its relationship to the sural nerve. It is often visualised close to the distal segment of the SSV. -if it is accompanied by an artery (i.e., small saphenous artery). This is important when sclerotherapy is being considered. -identify any alternative sources of reflux including communication of the SSV with a popliteal fossa perforator, GSV tributaries, pelvic veins traced to the buttock or perineum, the thigh extension of SSV, or the vein of Giacomini.
	No, if not present	-the SSV may be aplastic at the upper calf with its flow from the mid-calf draining into the GSV via an intersaphenous vein. -similar to the GSV, the SSV also has the potential to diminish and eventually disappear following endovenous ablation treatment, making it possibly undetectable during duplex ultrasound examinations.
Test for venous obstruction	Yes	-the proximal segment of the SSV may demonstrate continuous antegrade flow above the intersaphenous vein if obstruction occurs in the GSV due to SVT. -the proximal segment of the SSV may demonstrate continuous retrograde flow that arises from the SPJ and drains into the GSV via intersaphenous anastomosis if obstruction occurs in the femoropopliteal venous segment. -SVT in the SSV may impede the passing of laser fibre/radiofrequency catheter.
Test for venous reflux	Yes	-sample every few centimetres along the entire course of the vein -the SSV incompetence is usually segmental, predominantly affecting the upper one third or one half of the vein and reflux rarely extends down to the lower calf.
Measure vein diameter	Always measure. -the SSV diameter should be measured 3-5cm below the SPJ where the preterminal valve is present (at the knee crease if no SPJ) and just above the lateral malleolus. [21] -a mid-calf measurement should also be made. [21] -do not include varix or dilated segment with an incompetent valve in the measurement.	
Useful references	Patterns of small saphenous vein (SSV) reflux (Figure 2 in Engelhorn et al., 2005) [131] SSV reflux by location (Table 1 in Neuhardt et al., 2009) [132]	
Thigh extension of the SSV or Giacomini vein		
Assessment		**Comments**
Visualise	Yes	-should be examined along its entire course to identify its termination if visible. -identify any connections with posterior thigh veins or veins from the gluteal or pelvic area. -the vein of Giacomini is deep to the fascia in most of its course. Determine its distal SSV connection and proximal connection into the GSV.
Test for venous obstruction	Yes	-paradoxical reflux originating from the SPJ, with both systolic and diastolic flow exhibiting an antegrade direction, indicates possible venous obstruction in the femoropopliteal venous segments.
Test for venous reflux	Yes	-examine for reflux along its entire course as sometimes it may only have segmental reflux. -determine flow direction and whether there is reflux down from the SFJ incompetence to pass to the SSV or paradoxical reflux up from the SPJ incompetence to pass to the GSV **(Image 40)**.
Measure vein diameter	Always Measure.	
Un-named tributaries		
Assessment		**Comments**
Visualise	Yes	-normal tributaries usually do not require further testing unless there are incompetent intercommunicating vessels. [35] -large varicose tributary veins are easy to visualise and they are usually fed by the reflux originated from saphenous vein or perforator.

		-small tributary veins of diameter less than 2mm may be difficult to visualise in B-mode, especially when they are superficial to the skin.
Test for venous obstruction	Yes	-tributaries of the saphenous vein may not show reflux if obstructive superficial thrombus is present in the saphenous vein. Likewise, reflux may not be detectable in the tributary veins at the distal portion of the reflux pathway if proximal veins are thrombosed.
Test for venous reflux	Yes	-large tributary veins that are visible on skin surface must be tested for the source of reflux and draining point. -the intersaphenous veins in the calf may exhibit bidirectional flow, they must be examined thoroughly when either GSV or SSV is incompetent.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, if you are unsure about any of the above	
Perforating veins (PV) Perforating incompetence can either be the cause of CVD or a consequence of it. [35]		
Assessment		**Comments**
Visualise	Yes	-search for PVs in patients with CEAP clinical stages C5 and C6, in patients with recurrent varicose veins or with atypical clinical presentation, in patients with ulcer, atypical located varicose veins, severe skin changes, absence of reflux from the SFJ or SPJ. Not all PVs can be detected. -consider perforating veins adjacent to ulcerated areas as pathologic. -thigh perforating veins: -usually found on the medial aspect of the thigh, in the middle and lower thirds of the thigh, but can also occur more proximally near the SFJ. -look in the vicinity of any thigh varices -calf perforating veins: look for calf PVs around the whole circumference of the calf.
Test for venous obstruction	Yes	-outwards flow in the PV during muscular systole indicates deep venous incompetence or venous obstruction.
Test for venous reflux	Yes	-As a general rule, normal perforating veins have a diameter of <3mm. [133] All clinically relevant perforating veins include but are not limited to the presence of a superficial ulcer, varicosities, matting, telangiectasia, large tributary vein, cluster veins. Any veins relating to those findings, including those >3mm, should be tested for reflux, with the Doppler sample placed within the perforating vein at the level of the deep fascial plane. Provocation manoeuvres include distal muscle squeeze or toe elevation manoeuvre. -if it is proving difficult to demonstrate abnormal flow in a perforating vein, test the vein several times, at different sites, especially near local varices in the vicinity of the perforating vein. -testing can help differentiate between an escape point (EP) perforating vein and a re-entry (RP) perforating vein. An EP perforating vein demonstrates reflux after provocation (outward flow from deep to superficial system) and represents the source of reflux. A RP perforating vein demonstrates increased flow from superficial to deep system (inward flow) after provocation representing flow draining from an insufficient superficial system **(Images 41-47)**.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, the treating/referring doctor requests it or protocol directs it, if you are unsure of any of the above. Measure vein diameter where the perforator traverses the deep fascia. [81] Measure distance of the PV from a landmark such as medial malleolus or knee skin crease [133]	
Non-saphenous veins:		
Vulval Varicosities		
Assessment		**Comments**
Visualise	Yes	-varicose veins appear near the labia minora and labia majora **(Image 48)**. -most vulval varicosities become evident during pregnancy and regress spontaneously within 6 weeks after delivery. -they are best imaged in the standing position with the leg externally rotated or in the lithotomy position.
Test for venous obstruction	No	

Test for venous reflux	Yes	-the presence of vulval varicosities should raise suspicion of pelvic venous insufficiency, particularly ovarian vein incompetence. -reflux may feed the contralateral side due to transverse anastomosis
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, the treating/referring doctor requests it or protocol directs it, if you are unsure about any of the above.	
Gluteal Varicosities		
Assessment		**Comments**
Visualise	Yes	-varicosities associated with the superior gluteal escape point are located in the middle of the buttock, running transversely to the posterolateral aspect of the thigh. -varicosities associated with the inferior gluteal escape point are found at the inferior edge of the buttock, feeding the sciatic nerve varices **(Image 49)**. -the gluteal PV can be difficult to visualise due to its small diameter **(Image 50)**.
Test for venous obstruction	No	
Test for venous reflux	Yes	-the presence of reflux in the gluteal veins is likely to be associated with pelvic venous insufficiency, particularly the internal iliac vein.
Measure vein diameter	Measures if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, if you are unsure of any of the above.	
Popliteal Fossa Vein (PFV)		
Assessment		**Comments**
Visualise	Yes, if present	-tortuous tributary veins related to the PFV may be visualised at the back of the knee or the upper portion of the posterolateral calf **(Image 51)**. -at the popliteal fossa, these veins pierce the muscular fascia before emptying into the popliteal vein -the PFV is situated in close proximity to the common peroneal nerve (CPN). The SSV can adopt a lateral trajectory and communicate with the PFV. If this is the case, this should be brought to the clinician's attention, otherwise, endovenous ablation can cause irreversible nerve damage.
Test for venous obstruction	No	
Test for venous reflux	Yes	-the SSV ligation increases the likelihood of developing PFV reflux. -Reflux in the PFV may be of high velocities and volume due to the associated deep vein incompetence and small calibre of the PV **(Image 52)**.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, if you are unsure about any of the above.	
Posterolateral Thigh Perforator (PLTP)		
Assessment		**Comments**
Visualise	Yes	-the PLTPs are usually found at 12-25cm above the popliteal crease with connection to the FV, DFV or posterior thigh muscle veins **(Image 53,54)**.
Test for venous obstruction	No	
Test for venous reflux	Yes	-varicose tributary veins in the lateral or posterior aspect of the thigh may be associated with reflux in the PLTP.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, the treating/referring doctor requests it or protocol directs it, if you are unsure about any of the above.	
Sciatic Nerve Varices (SNV)		
Assessment		**Comments**

Visualise	Yes	-the SNV can be easily identified as the veins within the sciatic nerve which has a honeycomb-like appearance. -the SNV are of diameter 2-3mm, either travelling along the sciatic nerve trunk or taking a spiral route around the nerve within the epineurium. -in the popliteal fossa region, the SNV emerge from the epineurium and joins a network of superficial veins, which are typically observed in the posterolateral or anteromedial region of the upper calf or lower thigh **(Image 55)**.
Test for venous obstruction	Yes	-venous reflux in the SNV may be associated with insufficiency starting in the pelvic or gluteal region.
Test for venous reflux	Yes	-reflux is typically of low velocity and prolonged duration (2.2->5 seconds) **(Image 56)**.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, if you are unsure about any of the above.	
Knee Perforating vein		
Assessment		**Comments**
Visualise	Yes	-knee PVs are usually present in the anterior aspect of the leg below the patella. However, the detection of knee PV is difficult due to its small calibre **(Image 57)**. -they are frequently linked to the reticular vein network and varicosities in the anteromedial and lateral aspects of the upper calf.
Test for venous obstruction	Yes	-venous stasis associated with osteoarthritis has been suggested to be the underlying cause.
Test for venous reflux	Yes	-superficial varicosities may be fed by the reflux from the knee PV which pierces the fascia or aponeurosis **(Image 58)**.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, the treating/referring doctor requests it or protocol directs it, if you are unsure about any of the above.	
Useful references	Diagrammatic presentation of the nonsaphenous veins and their tributaries in the lower extremity (Figure 1 in Labropoulos et al. 2015) [134]	
Bone Perforating vein		
Assessment		**Comments**
Visualise	Yes	-bone PV pierces through an osteolytic defect on the anterior shaft of the tibia, connecting the dilated intraosseous nutrient veins, enlarged bony canal and superficial varices **(Images 59-60)**.
Test for venous obstruction	Yes	-reflux within the venous drainage of the tibia, resulting from deep vein insufficiency, may cause an increase in intraosseous venous pressure. This increase in pressure can lead to bone PV incompetence
Test for venous reflux	Yes	-during diastolic phase/relaxation, reflux flows out of the PTV feeding the subcutaneous varicosities.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, the treating/referring doctor requests it or protocol directs it, if you are unsure about any of the above.	
Lymph Node Venous Network (LNVN)		
Assessment		**Comments**
Visualise	Yes	-small and tortuous veins trans-passing the superficial inguinal lymph nodes -primary LNVN connections are established caudally with the GSV and even more often to the ASV or thigh tributaries **(Image 61)**.
Test for venous obstruction	No	
Test for venous reflux	Yes	-in 6% of the primary CVD cases, the LNVN is the origin of reflux of the GSV trunk. -distal augmentation manoeuvre has higher sensitivity in detecting reflux flow in the LNVN in comparison with Valsalva manoeuvre **(Image 62)**. -if a LNVN is present in primary CVD or recurrent cases, it should be tested for reflux. Trace it proximally looking for a connection with the CFV or pelvic veins, and distally looking for a connection with the GSV, ASV or other varicose veins.
Measure vein diameter	Measure if: there is venous reflux, vein is dilated (i.e. focally dilated without venous reflux, >3mm), the vein appears to relate to the clinical presentation, reflux is suspected, but not demonstrable, or if you are unsure about any of the above.	
Useful references	The complex connections of LNVN at the groin (Figures 8 and 12 in Uhl et al., 2016) [51]	

Extending the examination: when and how (includes information about different patterns of reflux)

Table E2 outlines various circumstances where the sonographer should extend the examination.

Table E2: Circumstances where examination extension is required. [35, 41, 43, 45, 68, 113]

Circumstance	Action
Patient has suspected pelvic venous disorders. *These patients may present with varices in the pubis, labia, perineum, or buttocks, extensive unilateral oedema, abdominal wall cellaterals.*	-The suspected pelvic source of reflux should be recorded even if a pelvic ultrasound study is not performed. -Duplex ultrasound assessment of abdominal and/or pelvic veins, including transvaginal assessment should be considered, including consultation with the reporting physician or vascular care provider (referrer), with regard to patient preferences, the availability of persons with expertise to perform the assessments, alternate cross-sectional imaging and/or, technical difficulty of duplex ultrasound assessment (such as abdominal obesity or the presence of bowel gas). **Guidance for how to perform abdominopelvic duplex US for pelvic venous disorders is outside the scope of the guideline.**
Abnormal CFV flow; loss of spontaneous flow with respiratory and cardiac modulation	At minimum, assess iliac veins and IVC for obstruction. If there is iliac occlusion, collateral circulation in the groin with suprapubic flow that crosses to the opposite groin can be visualised. [44] Further cross-sectional imaging may be required to determine the location and extent of the obstruction. [41]
When an incompetent vein becomes competent.	The outflow needs to be determined.
If multiple segmental reflux is noted in one vein	If multiple segmental reflux is noted, it is important to check for a refluxing vein connecting the two segments.
Patient with varices but without SFJ or SPJ incompetence.	Nonsaphenous sources need to be considered. Assess for incompetent perforating veins and deep veins, tracking varicose side branches both distally and proximally may help locate the source of reflux.
Patient has clinical signs of CVD, but there is no deep or superficial incompetence on duplex ultrasound.	There may be other reasons for these signs which are common in diabetic and obese patients; calf muscle pump deficiency, coexisting microvascular arterial disease, increased central venous pressure from underlying cardiac dysfunction or popliteal vein compression syndrome. [35]
Patient with deep vein reflux to the level of the popliteal vein	Extend assessment to the calf veins. If calf veins are duplicated, both the duplicated vessels should be tested, because one may reflux while the other remains competent.

Post treatment considerations

Treatment of varicose veins involves surgical removal or closure by endovenous methods, such as endovenous laser ablation (EVLA), radiofrequency ablation (RFA), foam sclerotherapy or cyanoacrylate glue. Recurrent varicose veins posttreatment occur either due to treatment failure (incomplete or inadequate obliteration of venous reflux), the natural progression of CVD, or misidentification of venous reflux (incomplete or inadequate preoperative evaluation). [61]

If there is recurrence of varicose veins, sonographers are often requested to perform duplex US to identify the nature and source of the recurrence. The duplex US should focus on the regions of the SFJ and SPJ, which are the most frequent sources of recurrence [21, 45] and also on possible perforating vein incompetence, as this is more common after surgery than previously thought. [21]

Post ablation

A vein is successfully ablated if the target vein, in its entire treated segment, demonstrates a complete lack of flow, incompressibility, or has disappeared **(Image 63)**. It can take 6-12 months before complete disappearance of the vein on ultrasound imaging is achieved. [92] Early after treatment, successfully treated vein segments will have no flow, thickened vein walls and a lack of compressibility, sometimes with a small echolucent lumen. The vein will be of the same size or slightly smaller than the vein before treatment and sometimes can demonstrate transient enlargement. This should be distinguished from a thrombosed vein that, in the first few weeks, will demonstrate a central hypoechoic to moderately hyperechoic filling defect. Over the subsequent months, the vein should shrink in size, to the point at 12 months where the vein will be difficult to identify on duplex US and have no flow. [68]

Partial ablation refers to a vein which is partially compressible and demonstrates persistent blood flow. [21] Most treatment failures are segmental, beginning at the saphenofemoral junction and extending downward a variable length to the takeoff of an incompetent tributary. Below the incompetent tributary, it is usual for the treated vein to be successfully ablated. Most treatment failures are usually evident within the first few posttreatment weeks, and exhibit as thrombosed vein segments that subsequently recanalise, or as veins that are unchanged from before treatment. Recanalisation of treated vein segments is more likely to occur in thrombosed veins, compared to thick-walled veins. Recanalisation may be evident on duplex US before the effects on downstream tributary veins become evident. Sometimes, after a long term, the treated vein may be segmentally patent but no longer demonstrates reflux. [68]
After cyanoacrylate glue ablation, glue deposits of varying echogenicity are visible within the treated vein. The vein may become focally dilated at the site of injection, with acoustic shadowing cast by the glue deposits **(Image 64)**. The junction should be patent and clear of thrombus if the saphenous vein was glued, and there may be partially compressible echolucent segments with the absence of flow. Any foreign substance of heterogeneous echogenicity in the subcutaneous tissue at the venous access site is likely to represent granuloma formation.

Post stripping and ligation

After the stripping surgery, the GSV cannot be visualised in the leg from the SFJ down to variable levels of the thigh, but usually, it extends to the lower thigh. A strip track haematoma **(Image 65)** may appear between the superficial and deep fascia, following the course of the stripped GSV. This haematoma may be accompanied by saphenous distortion and a network of multiple small refluxing veins, leading to recanalisation. [21]
At the site of ligation, discontinuation of the vein could be observed with subcutaneous tissue injury **(Image 66)**. When ligation is performed at a lower level above which there are patent tributary veins draining the blood, thrombus can develop in the 'cul de sac'—the GSV stump **(Image 67)**. Immediately below the ligation, there may be a reduction in the diameter of the GSV compared to preoperative measurements. [134]

Post sclerotherapy

Duplex US examination following sclerotherapy treatment is to confirm the successful obliteration of the targeted vein and search for residual patent veins that may require further treatment. The sclerosed veins may resemble blood clots and typically show a hyperechoic appearance within the vein. However, in the presence of trapped blood (coagula), the sclerosed vein may also appear anechoic. [21] Here, the timing may be of importance. If there is an acute thrombus, it could be hypo- or anechoic. Only an old, organised thrombus or if the vein is completely sclerosed will it be hyperechoic. [19]

Post phlebectomy (stab avulsion)

Superficial venous thrombosis may develop in the residual segments of the dissected vein following a phlebectomy procedure, depending on the size of the veins and their interconnections **(Image 68)**. Despite a decrease in diameter, varicose tributary veins may still exhibit persistent reflux.

Post-treatment instructions for the sonographer

- Assess treated and untreated veins [43] including saphenous and nonsaphenous veins (e.g., lateral venous system), as well as the site of previous perforating vein ligation, for the presence or absence of reflux and thrombosis. [92]
- The source of persistent or recurrent varices should be identified by their 'escape points', as either: (a) refluxing vein where a connection with the deep veins exists via a perforating vein, or (b) veins where the reflux is not linked to a perforating vein but is generated by the filling of the incompetent tributary veins. All 'escape points' to varices should be documented where possible. In many cases of recurrent veins, no clear source of the recurrent veins can be identified on duplex US. Visualisation may be difficult due to the small size of vessels or image degradation due to body habitus or soft tissue scarring related to past surgery. To optimise visualisation, correct adjustment of duplex US equipment with sensitive imaging settings and/or vigorous methods of eliciting reflux is required to highlight low velocity reflux.
- Assess for neovascularisation at the surgical site (especially at the SFJ) or arteriovenous malformations.

- Be aware of possible complications (Table E3), and if there are concerning sonographic or clinical appearances, the reporting doctor or referring doctor should be made aware in a timely fashion according to urgency. In most cases, it will be sufficient to provide this information in the report to the referring health practitioner.
- The diameter of the treated vein may be measured. The untreated veins may be assessed for reversal of venous incompetence for consideration of future treatment.

Specific to post-endovenous procedure, the sonographer should:

- Assess for ablation-related thrombus extension (ARTE) at the saphenofemoral or saphenopopliteal junction, which may be either endothermal heat-induced thrombosis (EHIT) **(Images 69–73)** or endovenous glue-induced thrombosis (EGIT) **(Image 74)**, depending on the type of ablation procedure performed.
- Assess for deep vein thrombosis (DVT) and deep vein sclerosis (DVS) **(Image 75).**
- Assess the treated vein for residual patency and reflux.
- Measure the length of patent sections of treated veins. [92, 99]

Further detailed information relating to post-treatment duplex US relating to specific sites is provided in Table E4.

Neovascularisation

In the context of CVD, neovascularisation refers to the presence of multiple new, small tortuous veins close to a previous venous intervention such as ligation or ablation. These newly formed veins may have arisen from dilated existing veins that were invisible on duplex US before the intervention. [135] Test the vessels for reflux with a Valsalva manoeuvre, and/or during release after calf compression. An incompetent terminal valve or refluxing tributaries can be the source of reflux. The largest diameter of neovascular veins may be measured. Situations where measurements might be made include if there is dilatation of the vessel, if reflux cannot be demonstrated.

Groin:

In the groin, these veins are referred to as a 'groin varicose network', and if connected with a lymph node, they are referred to as a 'lymph node venous network (LNVN)', described in section C (anatomy section). The network may be connected distally to a remaining saphenous trunk or with an accessory saphenous vein. Therefore, accessory saphenous veins (in particular the ASV) and the treated saphenous compartment should be assessed for reflux along their course.[45] Sometimes the connecting vessels leading to the larger varicose veins may be smaller than can be confidently resolved by ultrasound. When recurrent varicose veins exist in the GSV territory or when the source of reflux cannot be determined, careful testing using vigorous provocation manoeuvres, and sensitive Doppler settings are required. [35]

If the groin veins demonstrate reflux with a Valsalva manoeuvre, the escape point usually lies in the SFJ area. In some cases, there is a connection with incompetent pelvic veins. If venous reflux is detected only during the calf release phase (and not during Valsalva manoeuvre), this suggests that they fill from the subcutaneous abdominal venous network towards the groin, thigh and leg veins, without a direct communication (escape point) with the deep veins. [21] Sometimes they will have no reflux, but in time a clear connection visible on duplex US develops/becomes larger and may be seen with superficial tributaries or with the LNVN, or with a retained saphenous trunk (intentionally or unintentionally not stripped) or with other veins present in the saphenous compartment after stripping.

Popliteal fossa:

Neovascular veins in the popliteal fossa area may also be present. They connect directly to the popliteal vein, SSV, tributaries at the upper posterior calf, or to incompetent veins in the posterior thigh (e.g., Giacomini vein, thigh extension of the SSV, sciatic nerve varices and persistent sciatic veins). Typically, reflux is most obvious during calf release (diastolic phase), however it may be elicited during calf compression or muscle contraction (systolic phase), with, or without reflux during calf release. This specific haemodynamic pattern is exceptional and may indicate impaired outflow in the popliteal and/or femoral vein due to anatomical or functional abnormalities.

Table E3: Complications of varicose vein treatments

Complication	Notes
Superficial Thrombophlebitis (Image 76 in Image Gallery)	Superficial thrombophlebitis (STP) is a painful inflammatory condition characterised by the formation of blood clots in varicose veins. After undergoing phlebectomy or stab avulsion, patients may experience pain, tenderness, and warmth, often accompanied by erythema and the presence of lumps in the operated area. Sonographic appearance: veins with superficial venous thrombosis are partially or noncompressible with internal echogenicity.
Seroma (Image 77 in Image Gallery)	Collection of serous fluid following surgery or caused by trauma. Sonographic appearance: seroma is usually well circumscribed with anechoic or hypoechoic echogenicity, is commonly multiseptated.
Haematoma (Image 78 in Image Gallery)	A collection of blood outside of a blood vessel. Haematoma often develops after stripping surgery, especially in those who take anticoagulant medication. Patient with a soft tissue haematoma may have swelling, pain, erythema, and bruising. Sonographic appearance: A round or ovoids shaped heterogeneous mass with relatively well-defined margin. The internal echogenicity varies according to the stage of coagulation and may range from anechoic or low level echoes in fresh or liquefied haematomas to heterogeneous solid or mixed solid/cystic in organised haematomas.
Venous pseudoaneurysm	Is a rare complication and occurs due to venous injury and is similar to arterial pseudoaneurysm with a sac on one side of the vessel wall filled with hypoechoic blood flow. [135]
Nerve injury (Image 79 in Image Gallery)	Sensory nerves adjacent to the saphenous vein, such as the saphenous and sural nerves, may suffer injury during stripping surgery or endovenous ablation treatments. This could result in dysesthesia and paraesthesia, manifesting as tingling, numbness, electric like sensations, decreased sensitivity, increased sensitivity, or a burning sensation. In the majority of patients, symptoms associated with dysesthesia and paraesthesia tend to alleviate over time. However, a small number of patients may advance to chronic painful condition known as saphenous neuritis or sural neuritis Sonographic appearances: If detectable on ultrasound, sonographic appearances in nerve trauma include focal enlargement with or without the disorganization of the internal fascicular structure, or partial or complete transection of the nerve. [136-138]
Cutaneous necrosis (Image 80 in Image Gallery)	Cutaneous tissue necrosis typically manifests as ulceration, potentially leading to significant tissue loss. Its causes may be related to extravasation of sclerosants, injection of dermal arteriole, injection of undetected arteriovenous fistula, venoarteriolar reflex vasospasm, or excessive cutaneous pressure from the compression garments. It may develop several weeks after the initial injury, accompanied by pain, localised inflammation, and swelling. [139-140]
Membranous fat necrosis: (Image 81 in Image Gallery)	Membranous fat necrosis is an adverse event resulting from subcutaneous inflammation, leading to alteration and necrosis of adipose tissue. It is characterised by multiple tender, erythematous subcutaneous nodules following sclerotherapy. This type of subcutaneous fat necrosis may also be caused by trauma, thromboangiitis obliterans, arteriosclerosis, or scleroderma. Its diagnosis primarily relies on biopsy results. Sonographic appearances: Fat necrosis has variable appearances on ultrasound. The typical appearance is of a hyperechoic and poorly marginated lesion, but also may appear as a hypo-, or isoechoic, or mixed lesion. Other variations include a hypoechoic halo with mixed echogenicity, a poorly defined heterogeneous region with mixed echogenicity, or a well-defined encapsulated hyperechoic mass with cystic degeneration. [141]
Intraluminal neovascularisation within partially treated vein or thrombosed vein (Image 82 in Image Gallery)	Neovascularisation is a biological response to venous treatment and thrombosis, playing a key role in wound healing. This process begins with the activation of endothelial cells and the release of angiogenic factors like vascular endothelial growth factor (VEGF). Angiogenesis, the formation of new blood vessels, can be beneficial for healing but may become pathological if uncontrolled. This process can be triggered by local influences such as hypoxia, mechanical stress, and inflammation. Thrombus resolution involves the organisation of the thrombus, characterised by the infiltration of neutrophils and macrophages, and the development of new vascular channels. Capillary invasion into the thrombus, formation of lumens, and migration of endothelial cells may eventually recanalise the thrombosed vein segment, leading to neovascularisation. Sonographic appearance: Multiple small flow channels with arterialised venous flow within or directly adjacent to a partially treated or thrombosed vein segment.
Iatrogenic arteriovenous fistula (AVF) (Image 83 in Image Gallery)	AVF is a possible complication of thermal ablation. It is a communication between the target vein and a nearby artery that has been thermally induced or is due to needle stick injury. Sonographic appearances: On duplex ultrasound it appears as a partially patent vein segment, demonstrating a pulsatile spectral trace. They have been reported to occur between the proximal SSV and the sural artery branch of the popliteal artery, between the superficial external epigastric artery and proximal GSV and between the GSV and a small unnamed artery in the upper thigh. [68]
Hypersensitivity (Image 84 in Image Gallery)	Type IV hypersensitivity reaction (T4H) following cyanoacrylate glue ablation is an allergic dermal reaction characterised by red patch in the area of the treated vein, itchy skin, pain, discomfort and/or localised swelling.
Granuloma (Image 85 in Image Gallery)	Occurs as a result of extravasation of the glue at the venous access site when recapture of the delivery catheter is not performed. Sonographic appearance: A subcutaneous lesion with an irregular shape, showing heterogeneous echogenicity and acoustic shadowing caused by the glue.
Deep vein sclerosis (DVS) (Image 75 in Image Gallery)	Is an adverse sequela that can occur postsclerotherapy, resulting from the extension of the sclerosant into the deep veins through connecting PVs. A thorough assessment to distinguish DVS from DVT is essential. Sonographic appearances: Perforating vein and its connecting deep vein become partially or noncompressible with increased internal echogenicity.
Neovascularisation	(see section below on neovascularisation)

Table E4: Notes relating to duplex ultrasound assessments post varicose vein treatment for specific veins. [21]

Assess:	Treatment	
	Post ablation	**Post stripping with or without ligation**
SFJ and terminal GSV	• The terminal part of the GSV usually remains open with obliteration of the upper GSV/ASV. • The upper GSV may receive inflow from one or more tributaries of the SFJ, such as from a Giacomini vein or pudendal veins. • A patent terminal portion of the GSV of <3cm length is considered a normal finding. • Assess the CFV for thrombus extension from the GSV; if present, its extent should be assessed. Thrombus extension into the CFV should always be considered a pathological finding. • Assess for reflux, and if present, it is always pathological. • Reflux may not be detectable with obliteration of the upper GSV/ASV as the compliance of the terminal GSV is reduced. • Assess any varicose veins in this area. The source of varicosities may be an incompetent or nonobliterated saphenous trunk, an incompetent part of the GSV in the groin, a pelvic source, recanalisation of previously sclerosed veins, an incompetent ASV or PAGSV, newly developed perforating vein incompetence, or an untreated, refluxing double SFJ. There is usually no detectable connection with any visible varicose veins at short term follow-up.	• A normal postflush ligation performed at the CFV lacks any residual GSV segment or any incompetent superficial vein in the groin. The GSV terminal valve will not be present. A residual stump of the GSV is present if the ligation was performed at a distance from the CFV (low ligation), rather than a flush ligation. In this case, the terminal valve is usually seen with one or more residual SFJ tributaries. The diameter of a residual stump should be measured and reflux in the stump or any of its connections should be assessed. Reflux from the residual stump can connect with a residual ASV or other varices, which differs from the more common pattern of recurrent veins through the SFJ and its residual tributaries. If the terminal valve is competent, the stump receives inflow from its tributaries that drain normally into the SFJ. This pattern of flow is usually seen after successful ablation but may also be found after selective stripping of the GSV trunk with a low ligation which preserves the saphenofemoral confluence.
Above knee GSV and ASV	• Assess both veins as the ASV may be involved in recurrence after the GSV ablation, and vice-versa. • Less frequently, PAGSV and Giacomini vein may have a role in recurrence, but they can be part of the reflux pathway, receiving reflux from the pelvic/perineal region. • Assess veins in entirety, as is usual to treat complete vein above knee, if successful it will be obliterated in its entire course • Vein diameters will vary postablation due to inhomogeneous reduction across vein length, and different rates of absorption in different patients. The vein may be not visible on duplex ultrasound, or visible as a hyperechogenic tract in the saphenous compartment. Sometimes, it may contain heterogeneous content with no flow or reflux, and a partially compressible lumen, possibly representing blood or thrombus in the lumen in an early stage. • Test reflux across the whole length of the vein as reflux can occur across the whole length of the vein or be segmental. Any evident reflux is always pathological. Duplex ultrasound can determine if the reflux is due to primary failure of the ablation treatment or due to recanalisation after initial successful obliteration (usually within 6 months). • Describe reflux distribution and possible escape points (i.e., SFJ, perforating veins, refluxing pelvic veins) • Antegrade flow without reflux may sometimes be demonstrated in a partially or completely patent residual GSV trunk. This may result from reduced vein size and the obliteration of escape points; it may represent a good physiological result, as the reflux is abolished.	Presence/absence should be determined by assessing the saphenous compartment. If still completely or partially present within its 'saphenous eye', the diameter and length of the residual GSV segment should be measured, and reflux assessed. Reflux may be due to persistence in the varicose network after removing the GSV, or to the varicose network dilating and developing reflux postoperatively. Revascularisation of the strip track may occur, with multiple convoluted channels in the track of the previously stripped GSV. This should be described as 'multiple venous channels in the saphenous compartment' to distinguish it from the preoperative varicose network. These venous channels should be assessed for reflux, and for their connections with any clinically obvious recurrent varicose veins. In multiparous women, it is typical for incompetent abdominal pelvic veins to connect directly with residual GSV segments, or superficial tributaries in the thigh after surgery; they may have even been present before surgery.
GSV below the knee	• Assess for reflux and thrombosis • Even if incompetent pretreatment, it is usually ablated just to knee level. • May exhibit reflux or no reflux posttreatment. • Partial or complete thrombosis of the GSV remnant may occur after ablation of the above knee GSV.	
SPJ and the SSV.	• Post ablation, the SPJ is usually patent, with obliteration of the SSV at the proximal-mid calf. • Exclude DVT in the calf muscle veins (e.g., gastrocnemius veins, intergemellar vein) • The proximal tributaries at the SPJ may remain patient, especially any thigh extension of the SSV. • Measure length of the patent SSV from the SPJ, rather than from the skin crease of the popliteal fossa. • Obliteration of the treated SSV segment should be assessed and any residual segments of the SSV should be tested for reflux.	Note if ligation has been performed flush at the level of the popliteal vein, or at the confluence with one or more gastrocnemius veins; in which case, a residual stump has been left intentionally, since it represents a common track between gastrocnemius vein(s) and the proximal SSV. • Assess residual stump for reflux. Reflux is frequently seen after SSV surgery, due to the great variation at the level of the SPJ. • Look for sources of recurrent varicose veins such as:

		- (pre- or) postoperative incompetence of the popliteal fossa vein. - (pre- or) postoperative gastrocnemius vein incompetence - (pre- or) postoperative popliteal vein incompetence. -incompetent proximal veins (e.g., pelvic or gluteal veins, and SNV) which may connect directly with residual SSV segments; often seen in women with pelvic varices.
Perforating veins (PVs)	• Assess treated PVs for obliteration or persistent flow, particularly outward flow during the release (diastolic) phase of the compression release manoeuvre. If the PV remains patent, assess with Doppler to determine its competency. Any extension of the reflux into saphenous or tributary veins should be traced.	After saphenous stripping and phlebectomy, PVs mainly show normal inward flow and a diameter reduction at short and midterm follow-up, though long term data are still lacking.

Differential Diagnosis

Sonographers should always be aware that the signs and symptoms of CVD can overlap or coexist with other conditions. Sonographers therefore need to be aware of other conditions as differential diagnoses or associated conditions. Table E5 describes a range of these conditions and their sonographic appearances.

Table E5. Differential diagnoses that may be encountered during a duplex ultrasound examination for CVD.

Differential Diagnoses	Explanation
Cellulitis (Image 86 in Image Gallery)	Cellulitis is a soft tissue infection of the lower dermis, associated with subcutaneous tissue, and most commonly occurs in the lower limbs. Signs and symptoms include an acute, tender, erythematous, and swollen area of skin. Blisters, ulcers, oedema, associated lymphangitis, and lymphadenopathy may be present in severe cases. [142] Sonographic appearances: The sonographic appearances of cellulitis result from oedema and inflammation in the skin and subcutaneous tissue. The most common finding seen with cellulitis is described as "cobblestoning." Cobblestoning refers to a reticular pattern in the tissues caused by areas of hypoechoic fluid separating the subcutaneous tissue and fat. Other sonographic findings include thickened, hyperechoic skin and loss of detail in the subcutaneous tissue with increased echogenicity and abscess. Comparison with the unaffected side can assist in recognising subtle abnormalities. [143]
Lymphoedema (Image 87 in Image Gallery)	Lymphoedema is a swelling of a body part due to a chronic disturbance to locoregional lymphatic drainage, resulting in accumulation of lymphatic fluid in the tissue. It most commonly occurs in the lower limb. Lymphoedema is an important differential diagnosis in lower limb swelling. [144] Sonographic appearances: Lymphoedema on ultrasound images is seen as a buildup of fluid in the subcutaneous adipose tissue, however these appearances are not specific to lymphoedema but are also seen in oedema generally (Image 88a,b). There is a thickened dermis, and it is also typical to see a homogeneous echo pattern called a "snowstorm" with prominent subcutaneous septae and a total lack of echo free gaps. Lymphoedema is easy to identify in the medial ankle region, because at this site, even in obese patients, the subcutaneous tissues are usually no more than 10–12 mm thick. If these ultrasound appearances described are present on one side only, then this is characteristic of a lymphatic oedema (Image 89). [145] It has also been suggested that an unclear lower junction between the dermis and subcutaneous tissues is a possible marker of lymphoedema. [145] Visual inspection of the affected limb can help; if there is a hump on the dorsal part of the foot, Stemmer sign (the inability to pinch the skin of the proximal phalanx of the second or third toe) or a distally distributed oedema in an extremity, then this is suggestive of lymphoedema. [146]
Lipoedema (Image 90-91 in Image Gallery)	Lipoedema is a chronic condition, the hallmark of which is a disproportionate distribution of body fat on the extremities. [147] Sonographic appearances: The thickness of the skin and subcutaneous tissues combined are thicker in patients with lipoedema compared to patients without lipoedema. Upper cutoff measurement values for normal of measurements of 11.7mm for the pretibial region, 17.9mm for the thigh and 8.4mm for the lateral leg have been suggested to diagnose lipoedema. [145] Lipoedema differs to lymphoedema in that the dermis looks normal, with no dermal thickening as seen in lymphoedema. [148] A significantly thicker and less echogenic subcutaneous fat layer has been demonstrated, using 20 MHz transducer frequency, in patients with lipoedema compared to patients with lymphoedema. It has also been suggested that the presence of a crenulated junction between the dermis and subcutaneous tissue was a possible marker of lipoedema. [148-149]
Lipoma (Image 92 in Image Gallery)	A lipoma is a benign (noncancerous) tumour made of fat tissue. It typically grows slowly between the skin and the underlying muscle layer and feels soft and lumpy under the skin. Lipomas are usually painless and harmless, though they can sometimes cause discomfort if they press on nerves or grow in sensitive areas
Arterio-venous malformation (AVM) (Image 93 in Image Gallery)	High flow malformations represent approximately 10% of malformations in the extremities. Arteriovenous fistulas are typically acquired and are formed by a single vascular channel between an artery and a vein. The AVMs are typically congenital and consist of feeding arteries, draining veins and a nidus composed of multiple dysplastic vascular channels connecting the arteries and veins, with the absence of a normal capillary bed and a significant solid identifiable mass. Clinical signs include a pulsatile, red, warm mass with a thrill on examinations, arterial steal phenomenon, cutaneous ischaemia and ulceration and haemorrhage in severe in extreme cases. High output cardiac failure can occur with large arteriovenous shunts. [149] Sonographic appearances: On B-mode imaging, tortuous, dilated and poorly defined vessels may be observed. On Doppler imaging high flow will be seen, compared to low flow seen in venous and lymphatic malformations. [149]

Venous malformation **(Image 94 in Image Gallery)**	Venous malformations are low flow vascular malformation. In the extremities, pain is a common symptom which can lead to joint dysfunction and walking disabilities. [150] Sonographic appearances: On B-mode imaging, venous malformations appear as well margined masses with variable echogenicity. Appearances can range from anechoic or hypoechoic to heterogenous structures but are most commonly hypoechoic or heterogenous. Sometimes anechoic tubular structures that represent vascular channels can be identified. The septa between these anechoic structures can range from very thick to very thin. Phleboliths with posterior acoustic shadowing may also be present and supports the diagnosis because these are rare in other soft tissue tumours. Venous malformations are compressible if they are not associated with thrombosis. [149-151] Doppler examination can confirm slow or absent flow in these venous malformations. They usually have a venous phasic spectrum with no arterial or arterialised venous flows within that are more characteristic of arteriovenous malformations. Due to the extremely low flow in these lesions, to confirm vascular flow it may be necessary to use light compression to reduce the calibre of the vessels and increase the velocity of the intravascular flow. The Valsalva manoeuvre, distal augmentation or compression-decompression may also be useful. [149, 152]
Muscle Hernia **(Image 95 in Image Gallery)**	Muscle hernia, also known as myofascial defect, most commonly occurs in the anterolateral compartment of the calf involving the tibialis anterior muscle. Clinically, it presents as a palpable soft tissue mass with pain and cramping sensation. Sonographic appearances: The bulging muscle may appear as a hypoechoic lesion compared to the adjacent normal muscle with a mushroom like appearance and convex superficial contour. It is typically assessed through a dynamic ultrasound test as the muscle hernia becomes more prominent in the erect position with muscle contraction as opposed to the supine resting position. [153-154]
Baker's cyst **(Image 96 in Image Gallery)**	A Baker's cyst, also known as a popliteal or parameniscal cyst, is the accumulation of extruded synovial fluid in the posterior aspect of the knee but can also appear in the medial or lateral aspect of the calf. Baker's cyst typically results from arthritis or a meniscus tear and remains asymptomatic and uncomplicated unless it ruptures. A ruptured Baker's cyst, caused by increased volume and pressure, can lead to symptoms such as acute pain in the knee and calf, swelling, and erythema, resembling thrombophlebitis. Therefore, patients with a ruptured Baker's cyst are frequently referred due to the leg's clinical presentation being similar to that of a suspected DVT. Sonographic appearance: On ultrasound, a Baker's cyst typically appears crescent shaped in the transverse view and wedge shaped in the longitudinal view with clear communication to the synovial fluid. A ruptured cyst is characterised by either partial or complete emptying of the fluid into the adjacent soft tissue. Additionally, intracystic haemorrhage can manifest as hypoechoic bands partially filling the cyst's lumen. [155-157]
Nerve tumours **(Image 97 in Image Gallery)**	Neuroma: Neuroma is a tumour of the peripheral nerve, mostly benign and developed as a result of disorganised growth of axon fibres and non-neural tissue following partial or complete injury, such as sharp or blunt trauma and traction injury. This type of neuroma is known as spindle neuroma. In some cases, it can also develop a few months later following transection of the nerve from amputation procedure, known as terminal/stump neuroma. Symptoms associated with neuroma include burning, tingling, numbness sensation and pain and tenderness on palpation. Sonographic appearance: On ultrasound, spindle neuromas are featured as well-defined, bulbous, hypoechoic and homogeneous lesion in continuity with the adjacent nerve fibre. Terminal neuromas show similar echogenicity but with disruption of the fibre. The nerve adjacent to the neuroma is also of reduced echogenicity indicating nerve degeneration. [158-160]
	Schwannoma: Schwannoma, also known as neurinoma or neurilemoma, is a type of peripheral nerve sheath tumour primarily composed of Schwann cells, responsible for forming the protective lining around nerves and producing myelin. Schwannomas typically manifest as gradually growing tumours that are singular, eccentric, firm, well-defined, and encapsulated. They are most frequently observed in the head and neck (25-45%), with only 13.5–17.5% occurring in the lower extremities. Depending on their size and location, a small schwannoma in the leg may be asymptomatic. However, symptoms can occur due to compression of the adjacent nerve after growth, including pain, numbness, weakness, or tingling ('pins and needles') and tarsal tunnel syndrome. Sonographic appearance: On ultrasound, Schwannomas typically present as well well-defined, hypoechoic round masses with posterior acoustic shadowing. Colour and power Doppler may show increased vascular flow. The cessation of flow under compression has been reported as a valuable diagnostic criterion for differentiating Schwannomas from neurofibromas and lymph nodes. [161-164]
Klippel Trenaunay syndrome (KTS) **(Images 98,99 in Image Gallery)**	KTS is a complex congenital disorder defined as the triad of capillary malformation (port wine stain), venous malformation, and unilateral limb overgrowth, with or without lymphatic malformation. [165] Sonographers should be aware of the potential for the presence of vascular malformations, as well as varicosities that may occur due to persistent embryonic veins, superficial venous malformations, or from deep venous aberrations such as hypoplasia, segmental aplasia, and aneurysmal degeneration. Patients mainly experience lower limb swelling, often with pain, or may have more advanced clinical signs and symptoms of CVD. [67, 166] In 20% of people with KTS, embryonic remnants will occur. [165-168] One persistent embryonic vein, the persistent sciatic vein can be associated with varicose veins, cutaneous haemangiomas, and soft/hard tissue hypertrophy. It is often frequently associated with KTS and is described in Section C: Venous anatomy of the lower limb (deep veins) [66] Another persistent embryonic vein, is the 'persistent lateral marginal vein'. This vein originates from the lateral aspect of the foot and courses upwards along the lateral border of the leg. It forms when the venous trunk fails to mature during the embryonic period and remains as the persistent lateral marginal vein after birth. This vein does not have valves and therefore can cause chronic venous insufficiency. It also carries a higher risk of deep vein thrombosis and pulmonary embolism. [170]