Section B: Background

Glossary

General Terms	
Clinical Practice Guideline (or clinical guideline):	A systematically developed statement, based on the best available evidence, to assist health practitioners making decisions. [1]
Duplex Ultrasound (duplex US):	Sonographic imaging utilises grayscale (B-mode) to visualise the vessel and surrounding structures, combined with colour Doppler or spectral Doppler to assess blood flow in veins or arteries. Both displays appear simultaneously on the same screen (duplex), providing overlapping images for easier interpretation.
Reporting clinician:	For the purpose of this guideline, the reporting clinician is a medical specialist (or a sonographer who is recognised to have a reporting role) who provides a clinical ultrasound report based on the findings of a duplex ultrasound examination of the lower limb veins. The report is typically issued to the medical practitioner(s) who requested the examination.
Sonographer:	An allied health professional who performs ultrasound examinations using ultrasound imaging devices to diagnose, monitor and guide treatments for health conditions. In this clinical guideline, a sonographer refers to any health professional, including medical sonographer, vascular surgeon, radiologist or phlebologist, who performs venous insufficiency ultrasound studies.
Vascular care provider:	In this clinical guideline, it refers to a medical or health care worker who may refer patients for a duplex ultrasound examination to investigate chronic venous disease and/or manage patients in relation to their vascular health under relevant legislative requirements. Vascular care providers may include general practitioners, vascular specialists, vascular and endovascular surgeons, phlebologists, interventional radiologists, dermatologists, podiatrists, clinical nurse specialists.
Definition of Venous Terms	
Chronic venous disease (CVD):	Any morphological and functional abnormalities of the venous system of long duration manifested either by symptoms and/or signs indicating the need for investigation and/or care. [2]
Chronic venous disorder:	Refers to the full spectrum of chronic morphological and functional abnormalities of the venous system. [2]
Chronic venous insufficiency (CVI):	A term reserved for advanced chronic venous disease, which is applied to functional abnormalities of the venous system resulting in oedema, skin changes, or venous ulcers. [2]
Pelvic Venous Disorder (PVeD):	The spectrum of symptoms and signs arising from the veins of the pelvis (e.g., gonadal veins, internal iliac veins and their tributaries, and the venous plexuses of the pelvis) and their primary drainage pathways (e.g., left renal vein, iliac veins, and pelvic escape points). [3]
Classification and Assessment Tools	
Aberdeen Varicose Vein Questionnaire (AVVQ):	A questionnaire of 13 questions addressing all elements of chronic venous disease including signs, symptoms, social issues, the effect of varicose veins on daily activities, and the effect of varicose veins from a cosmetic standpoint. [4]
Clinical-Aetiology-Anatomy-Pathophysiology (CEAP) classification:	An internationally accepted standard used clinically for describing patients with chronic venous disorder and to report clinical research findings.[5]
Venous Clinical Severity Score (VCSS):	A score, based on the clinical elements of CEAP (see directly above), provides a progressive ranking of the severity of chronic venous disease, allowing for longitudinal and objective followup of a patients' clinical condition. Clinical items include scoring of pain, varicose veins, venous oedema, skin pigmentation, inflammation, induration, and different items of leg ulcers. [4]
Venous Pathology Terms	
Agenesis:	Vascular anomaly in which a blood vessel fails to develop during embryogenesis, resulting in complete absence of a vein or of a segment of a vein. [6]
Aplasia:	The lack of full development of a vein or vein segment. Aplastic vein is not seen on ultrasound imaging. [6]
Atrophy:	A decrease in size or wasting away of a normally developed vein or segment of a vein, following a degenerative process. [6]
Axial reflux:	Uninterrupted retrograde venous flow between the groin and calf. May be confined to the superficial system (superficial axial reflux), to the deep system (deep axial reflux) or a combination of the superficial, deep and perforating systems. [2]
Deep vein thrombosis (DVT):	Refers to blood clot (thrombus) formation in one or more of the deep veins in the body.
Developmental venous abnormalities:	Include agenesis, aplasia, hypoplasia, dysplasia, venous aneurysm, venomegalia. [6]
Dysplasia:	A complex developmental abnormality of a vein or of a group of veins that greatly differs from the normal conditions in size, structure, and connections. [6]
Hypoplasia:	The incomplete development of a vein or of a segment of a vein; a calibre 50% of normal values seen on ultrasound indicates hypoplasia. [6]
Klippel-Trenaunay syndrome (KTS):	A rare congenital condition in which blood and or lymph vessels fail to form properly. The three main features are 1) vascular malformations of the capillaries (characterised as port wine stain), venous and lymphatic

	vessels, 2) varicosities of unusual distribution, particularly lateral venous anomalies and 3) unilateral soft and skeletal tissue hypertrophy (mostly in the lower extremity).
May-Thurner syndrome (MTS):	As condition caused by the specific compression of left common iliac vein by the right common iliac artery and lumbar vertebrae. MTS produces congestive signs and symptoms with a risk of deep vein thrombosis. It is a subvariant of other mechanisms of iliac vein compression, including distended bladder, endometriosis, iliac vein aneurysm and tortuous iliac artery on the ipsilateral side. [2, 4]
Paradoxical Reflux:	Ascending reflux commonly, but not exclusively exhibited in the cranial extension of the small saphenous vein (or Giacomini vein) during muscular systole or distal compression secondary to venous obstruction in the femoropopliteal vein.
Pathologic perforating vein:	Incompetent perforating vein that is located underneath an active or healed ulcer, indicating the need for intervention. [8]
Perforating vein incompetence:	Reversed flow (deep to superficial direction) of abnormal duration in a perforating vein during muscular relaxation or release after distal compression. [9]
Phlebectasia:	Vein dilatation without tortuosity. [6]
Phlebitis:	Inflammation of a vein. Commonly caused by blood clot formation, known as thrombophlebitis, but can also results from infection, injury, or irritation of the vein. [6]
Phlebosclerosis:	An age dependent fibrotic degeneration of one or all three vein wall layers, predominantly the intima, and with or without calcification. It may impair the venous function and contribute to the development of thrombosis. [10,11]
Post-thrombotic syndrome (PTS):	Chronic venous symptoms and/or signs secondary to deep vein thrombosis and its sequelae. [2] Morphologic characteristics include lumen fluctuations of the veins, dilation of collateral veins, partial occlusions of the original lumen and irregular thickening of the venous wall and venous valves. [12]
PREVAIT:	Acronym meaning **PRE**sence of **V**arices (residual or recurrent) **A**fter **I**n**T**ervention. [2]
Residual varices:	Varicose veins which persist after treatment. [2]
Recurrent varices/recurrent veins after surgery (REVAS):	The reappearance of varicose veins in an area previously treated.[2]
Superficial Vein Thrombosis (SVT) or Superficial Thrombophlebitis (STP):	Represents blood clots formation and inflammation in the thrombosed superficial veins characterised by a painful, warm, erythematous, tender, palpable cord-like structure along the course of a superficial vein. [15]
Superficial Venous Insufficiency (SVI):	Is defined as retrograde flow in the superficial veins of abnormal duration.
Segmental reflux:	Localised retrograde venous flow, which may involve the deep or superficial in any combination in the calf or the thigh, but not in continuity from the groin to the calf. [2]
Truncal (aka truncular varicose veins) varicosities:	Varicosities distributed along the great or small saphenous veins and their tributaries. They may be associated with varicose veins of other venous territories such as pelvis and gastrocnemius and soleus muscles or due to isolated incompetent perforating veins. [13]
Varicocoele:	Refers to presence of scrotal varicose veins (varicose veins of the pampiniform plexus).
Varicose veins (synonyms; varix, varices, varicosities, venectasia):	Refers to superficial veins of the leg which are dilated (>2 mm in diameter), tortuous, with demonstrated retrograde flow indicating venous incompetence. [14] They are divided into primary and secondary varicose veins. Primary varicose veins form due to vein wall weakness, primary valvular dysfunction, pregnancy, hormonal change and prolonged venous statis). Secondary varicose veins result from disorders of the venous system, such as deep vein thrombosis, superficial venous thrombosis, trauma and iatrogenic arteriovenous fistula. Secondary varicose veins may be totally indistinguishable from primary varicose veins [13,15]
Venomegalia:	Diffuse dilation of one or more veins with an increased calibre of 50% or more compared to normal calibre. [6]
Venous aneurysm:	A localised saccular or fusiform dilatation of the vein, at least 50% greater size than the normal vein trunk. [2, 6]
Venous compression:	Narrowing or occlusion of the venous lumen as a result of extra-luminal pressure. [2]
Venous obstruction:	Partial or complete blockage to venous flow, which may be due to external compression or intra-luminal thrombus. [2]
Venous reflux:	An abnormal venous state, when venous flow in a vein is retrograde (flows away from the heart) and lasts longer than normal. [2]
Venous leg ulcer (VLU):	Full thickness defect of skin that does not heal spontaneously and is sustained by chronic venous disease, most frequently occurring in the ankle region.
Venous thromboembolism:	Blockage to venous blood flow due to a blood clot (thrombus).
Vulval varicosities:	Dilated veins in the labia majora and labia minora.
Treatment related Venous Terms	
Endophlebectomy:	Removal of postthrombotic residue from the venous lumen. [2]
Endovenous glue induced thrombus (EGIT):	Thrombus extension into the deep veins following cyanoacrylate closure (CAC). [16]
Endovenous heat induced thrombosis (EHIT):	The propagation of thrombus into the deep vein contiguous with the ablated superficial vein. [17] The EHIT classification include Class 1 (venous thrombosis to the junction but not extending into deep system), Class 2 (nonocclusive venous thrombosis with an extension into deep system of a cross sectional area less than 50%), Class 3 (nonocclusive venous thrombosis with an extension into deep system of a cross sectional area greater than 50%), and Class 4 (Occlusive deep vein thrombosis of common femoral vein or popliteal vein) [18]

Deep vein sclerosis (DVS):	Sclerosis resulting from inadvertent entry of sclerosants into the adjoining deep veins. [19]
Flush Ligation:	Ligation of the great saphenous vein at its union with the common femoral vein.
High ligation (HL):	Ligation at the junction of the superficial vein and the deep vein, i.e. saphenofemoral junction, saphenopopliteal junction. Sometimes a residual stump is left when the procedure is performed at a distance from the deep vein (low ligation). [20]
High ligation and division:	Ligation and division of the great saphenous vein at its confluence with the common femoral vein, including ligation and division of all junctional tributaries. [2]
Ligation:	The surgical tying off of a vessel, usually of a large vein, is performed to prevent blood flow into a diseased or nonfunctioning vein.
Lymph node venous networks (LNVN)/ Transnodal Lymph venous connection:	Are present in the groin, but not always visible on duplex ultrasound. In healthy people, they are small with diameters less than 1mm. LNVNs drain towards the saphenofemoral junction and into the pelvic veins. Reflux in the LNVN can be detected in both primary and secondary varicose veins but is more common in recurrent veins postsurgery (REVAS).
Microsclerotherapy:	Sclerotherapy treatment of spider veins.
Phlebectomy:	Removal of a vein segment through a small skin incision (includes mini/micro phlebectomy, stab avulsion, i.e. removal of vein segment via a small incision). [2]
Neovascularisation:	Defined as new blood vessel formation (angiogenesis) occurring in abnormal tissue or in an abnormal position; requires histological diagnosis. In the 2011 UIP consensus document, neovascularisation was defined as: "presence of multiple new, small tortuous veins in anatomic proximity to a previous venous intervention." In the context of varicose veins surgery, it refers to the presence of new veins situated at the site of the previous saphenofemoral junction or sapehenopopliteal junction ligation. These veins may be newly formed or can arise from dilation of existing groin veins that were invisible on duplex ultrasound before the operation. [20]
Perforating vein ablation:	The destruction of a perforating vein by mechanical, chemical, or thermal means. [2]
Perforating vein interruption:	The disconnection of a perforating vein by mechanical, chemical, or thermal means. [2]
Perforating vein ligation:	The interruption of a perforating vein by mechanical means.[2]
Recanalisation:	The development of a new lumen with blood flow present in a previously obstructed/treated vein. [2] Characteristic appearances are of short, tortuous, small diameter vein with thickened walls and evidence of fibrosis or thrombosis. The blood flow may exhibit either venous or arteriovenous characteristics. This should be differentiated from untreated vein segments filled with small, localised fresh thrombus. Recanalised segments may demonstrate forward, reversed or bidirectional flow with compression manoeuvres. In most cases, significant reflux cannot be demonstrated in the recanalised segments. Inflow sources or drainage pathways include great saphenous vein tributaries, perforating veins, and vasa vasorum. [21,22]
Residual stump:	Almost always follows endovenous thermal or glue ablation procedures due to the position of the tip of laser fibre or catheter. May also be seen after surgery if great saphenous vein ligation has been performed at a distance from the common femoral vein (low ligation) instead of flush ligation. Where the terminal valves are competent, the stump receives inflow from its tributary veins that drain normally into the saphenofemoral junction. However, the stump may also become part of the reflux pathway if terminal valves and/or groin tributaries are incompetent, leading to recurrence of varicose veins with the involvement of anterior saphenous and great saphenous vein remnants or other varices. [20]
Sclerotherapy:	Obliteration of a vein (ablation) by chemical introduction (liquid or foam). [2]
Strip-track haematoma:	Of variable volume and may occur following the great saphenous vein stripping surgery. May be visible on grey-scale ultrasound with noticeable fascial distortion. The presence of strip track-haematoma is likely to stimulate endothelialisation within the fascial compartment, leading to revascularisation along the route of haematoma. [20]
Thrombus organisation:	Thrombus is invaded from the vein wall under the effect of cellular activities, during which the vasa vasorum in the intima and media become considerably dilated and new capillaries derived from these vessels traverse the intimal elastic lamina and invade the thrombus. [23]
Trapped Blood:	A lumpy and hyperpigmented area formed after sclerotherapy due to haemosiderin deposits which will appear as skin staining.
Vein stripping:	Removal of a long vein segment, usually most of the great saphenous vein or the small saphenous vein by means of a device. [2]
Stab avulsion:	When a small stab wound or puncture is made to remove varicose veins. [24]
Venous ablation:	Removal or destruction of a vein by chemical, thermal, or mechanical means. [2] • Chemical ablation: endovenous injection of a chemical drug or solution to achieve endoluminal fibrosis and subsequent vein occlusion. • Venous thermal ablation: any endovenous technique employing heat energy to destroy the vein, including laser, radiofrequency or microwave. The goal is to deliver sufficient thermal energy to the wall of an incompetent vein segment to produce irreversible occlusion and fibrosis. • Nonthermal vein ablation: treatment for truncal venous reflux in varicose veins that does not use heat, currently these treatments include ultrasound guided foam sclerotherapy, mechanochemical ablation, and cyanoacrylate glue.
Venous fibrosis:	Ultimately occurs in areas of the organised thrombus. Vascularisation facilitates collagen growth. As collagen matures, the network of capillaries diminishes. Although the vein wall does not undergo complete fibrosis, there is an increase in collagen that separates the muscle fibres connected to the collagen within the thrombus. Haemosiderin can be deposited in various sections of the vein wall, the fibrosed thrombus, and the surrounding perivenous tissue. [23]

Venous occlusion:	Total obliteration of the venous lumen. [2]
Venous sclerosis:	Occurs in response to irreversible endothelial destruction from sclerotherapy procedure, leading to the formation of scar tissue or fibrosis within a vein. [24]
Other Clinical Conditions and Dermatological Manifestations	
Atrophie Blanche:	Presents as a small white patch on the skin caused by occlusion of dermal arterioles and infarction of the skin supplied by capillary vessels.
Corona Phlebectatica:	Fan shaped intradermal telangiectases (broken capillaries) on the medial or lateral aspects of the foot. [25]
Lipodermatosclerosis:	A chronic inflammatory condition of the lower legs, characterised by subcutaneous skin fibrosis and hardening (also known as sclerosing panniculitis, hypodermitis sclerodermaformis).
Lipoedema:	A complex, genetic and progressive condition characterised by the disproportionate accumulation of adipose tissue, lipoedema almost exclusively affects women. In most cases, the legs and buttock are affected with variable amounts of swelling, resulting in poor mobility and quality of life. Lipoedema typically begins at puberty or during other times of hormonal change and weight gain, such as pregnancy and menopause. In many patients, it is not diagnosed for years or is mistaken for obesity or lymphoedema. [26,27]
Lymphoedema	A condition where the accumulation of excessive amounts of protein rich fluid in the tissue results in swelling of one or more regions of the body. Primary lymphoedema results from genetic malformation of the lymphatics. Onset of swelling may not present until adolescence or adulthood. Secondary lymphoedema is much more frequent than primary lymphoedema. Secondary lymphoedema is acquired due to damage or destruction of lymph nodes or lymphatic vessels. This may occur following surgery, radiation therapy related to cancer treatment, recurrent cellulitis, or injury (trauma or surgery to other organs or structures in the body). [28] A positive Stemmer's test, indicated by the inability to pinch and lift a skinfold at the base of the second toe, is diagnostic for lymphoedema.
Matting:	Refers to vessels with a small diameter of less than 0.2 mm that appear sporadically or in well\defined patches. Occurs spontaneously or after superficial venous procedures including sclerotherapy, surgery, or endovenous laser therapy. Considered a major cosmetic complication of sclerotherapy and other superficial venous procedures. [29] Also referred to as 'flares', and telangiectatic matting.
Pigmentation:	A rusty red patch due to extravasation of red blood cells in the superficial dermis.
Stasis dermatitis/Stasis eczema:	Eczema/dermatitis due to venous stasis or venous hypertension. It often occurs in the lower leg frequently due to both primary and secondary varicose veins. [30]
Venous Anatomy Terms	
Communicating Veins:	Veins that communicate between two different points of the same venous system and should not be confused with perforating veins (i.e., deep-deep, superficial-superficial).
Deep veins (Deep Venous System):	Veins located below the deep (muscular) fascia with a parallel course to the accompanying arteries. [3]
Duplicated vein	Duplicated veins lie in the same territory as the main vein. Duplication of a deep vein of the lower limb (commonly associated with femoral vein and popliteal vein) occurs when the duplicated vessel is joined inferiorly and superiorly or has a common termination with the main vessel. [31] A true duplicated vein of the saphenous vein will run parallel with the main vessel and within the same saphenous compartment. [32]
Intersaphenous veins:	Communicating veins run obliquely between the great saphenous vein and small saphenous vein. The blood usually flows from the small saphenous to great saphenous network. They may act as pathways for reflux. [33,34,35]
Linton's line:	An imaginary vertical line drawn between the upper third of the calf and the superior border of the medial malleolus along the great saphenous vein to locate medial calf perforating veins. Initially described as an incision line for surgical ligation of clinically significant leg perforating veins. [36]
Nontruncal veins:	All epi-fascial veins of the superficial venous system (e.g., tributary veins, reticular veins and spider veins). [37]
Paired vein (vena comitans/satellite vein):	Two or more veins accompanying an artery. They are usually present with the deep arteries of the extremities [39] such as the peroneal, posterior tibial and anterior tibial veins of the calf.
Perforator veins (PV):	Connects between the superficial and deep venous system.
Reticular Veins:	Dilated bluish intradermal veins, usually 1-3mm in diameter.
Saphenofemoral Junction (SFJ):	Located at the saphenous opening and correspond to the orifice of the great saphenous vein. [33] From a clinical perspective, the saphenofemoral junction refers to the terminal section of the great saphenous vein where it is joined by other superficial veins such as ASV, and SCIV, SEV, SEPV, PAGSV (refer to anatomical abbreviations below)
Saphenopopliteal Junction (SPJ):	Where the small saphenous vein terminates directly into the popliteal vein. Is situated at variable levels within the popliteal fossa and may be hypoplastic or absent in 25% of the legs. [38]
Spider Veins (or thread veins):	A confluence of dilated intradermal venules of less than 1mm in diameter, also known as telangiectasia. They appear as fine pink, red, purple or bluish lines just below the skin.
Superficial veins (Superficial Venous system):	Veins located superficially to the deep fascia and are not paired with an artery, including the great and small saphenous veins and their branches (collectively called superficial veins of the lower limb). Normally, approximately 10–20% of venous blood of the leg is returned via these superficial veins.
Truncal veins:	The saphenous veins and their major accessory veins (i.e., the great saphenous, small saphenous, anterior saphenous and posterior accessory great saphenous veins and the Giacomini vein). In cases of saphenous aplasia or hypoplasia, the primary connecting tributary which runs epifascially and in a straight course also constitutes the truncal vein contiguous with the saphenous vein. [21, 37]
Anatomical abbreviations (organised from approximately proximal to distal)	
IVC:	Inferior Vena Cava
CIV:	Common Iliac Vein
EIV:	External Iliac Vein

IIV:	Internal Iliac Vein
SGV:	Superior Gluteal Vein
IGV:	Inferior Gluteal Vein
SEV	Superficial Epigastric Vein
SCIV:	Superficial Circumflex Iliac Vein
SEPV:	Superficial External Pudendal Vein
CFV:	Common Femoral Vein
FV:	Femoral Vein (note: Superficial Femoral Vein (SFV) should not be used for this vein)
DFV (formerly PFV):	Deep Femoral Vein (formerly known as profunda femoris vein)
PSV:	Persistent Sciatic Vein
SFJ:	Saphenofemoral Junction
GSV:	Great Saphenous Vein (note: Long Saphenous Vein (LSV), Greater Saphenous Vein and Internal Saphenous Vein are not recommended)
ASV (formerly AAGSV/AASV):	Anterior Saphenous Vein (previously known as Anterior Accessory of the Great Saphenous Vein or Anterior accessory saphenous vein) [39]
PAGSV/PASV:	Posterior Accessory of the Great Saphenous Vein (used interchangeably with Posterior Accessory Saphenous Vein)
LNVN	Lymph Node Venous Network
PAV:	Posterior arch vein (also known as the posterior accessory of the great saphenous vein of the lower leg)
ATCV:	Anterior Thigh Circumflex Vein
PTCV:	Posterior Thigh Circumflex Vein
AAV:	Anterior arch vein (Also known as anterior accessory of the great saphenous vein of the lower leg)
SPJ:	Saphenopopliteal Junction
SSV:	Small Saphenous Vein (note: Short Saphenous Vein, Smaller Saphenous Vein and External Saphenous Vein are not recommended)
TE:	Thigh Extension of the Small Saphenous Vein (also known as cranial extension of the small saphenous vein)
PV:	Perforating Vein
SNV	Sciatic Nerve Varices
SSA:	Small Saphenous Artery

Definition of chronic venous disorder, chronic venous disease, and chronic venous insufficiency

For clarification and consistent reporting, the terms surrounding the diagnosis and management of chronic venous disease have been defined in a consensus document. [2] *Chronic venous disorder* was defined as the full spectrum of venous system abnormalities, whereas c*hronic venous disease* refers to individuals with these abnormalities, but who also require investigation and/care due to their signs and symptoms. The term *chronic venous insufficiency* (CVI) was used to define the subset of individuals who have advanced signs and/or symptoms, with functional venous abnormalities producing oedema, skin changes or venous ulcers.[2]

The term Chronic Venous Disease (CVD) will be the dominant term used in this clinical guideline as it addresses the diagnostic workup with the use of duplex ultrasound (US), also known as venous insufficiency ultrasound, for individuals who require investigation and potentially intervention to alleviate signs and symptoms.

Contributing risk factors

Reported risk factors for CVD include age, sex (female), positive family history, pregnancy, hormones, parity, height, obesity, prolonged standing and prolonged sitting (sedentary lifestyle), genetic factors, decreased physical activity, and previous deep vein thrombosis (DVT) [40-42]. Without treatment, CVD becomes more severe over time. [40]

Signs and symptoms

CVD occurs due to ambulatory venous hypertension, resulting from venous obstruction, weakening of the vein wall, malfunctioning valves and/or deficiency in the muscle pump. [21, 42, 43] Depending on the intensity of haemodynamic disturbance, CVD may not produce any signs or symptoms at the early stage. However, when clinical manifestations do occur, there is a broad spectrum of possible venous signs and symptoms **(Images 1-8)**.

Venous signs are visible manifestations which include dilated veins (telangiectasia, reticular veins, varicose veins), leg oedema, skin changes, (eczema, sclerosis, hyperpigmentation, dermatitis, atrophie blanche, lipodermatosclerosis) and ulcers. [2, 41, 44-46]

Venous clinical symptoms are complaints related to venous disease, which may include fatigue, leg swelling, abnormal sensations (tingling, itching, aching, burning, pain, feeling of throbbing or heaviness), muscle cramps or restless legs. [2,30 44-46] These symptoms may suggest, but are not pathognomonic of CVD, therefore correlation with venous clinical signs, and the results of diagnostic investigations are often required. [2] It is common to have patients presenting with one or two symptoms of CVD but with no clinical signs during physical examination and no apparent abnormalities on duplex US.

The CEAP (Clinical-Aetiology-Anatomy-Pathophysiology) classification (Table 1) is an internationally recognised reliable and reproducible classification system for classifying patients based on signs and symptoms. It standardises reporting and guides the therapeutic strategy and standardise reporting. [5]

Table 1: Summary of clinical classifications of chronic venous disease from CEAP (Clinical-Etiology-Anatomy-Pathophysiology) classification. [5] (The full classification is available in appendix 1)

Summary of clinical (C) classifications	
C class	**Description**
C0	No visible or palpable signs of venous disease
C1	Telangiectasias or reticular veins
C2	Varicose veins
C2r	Recurrent varicose veins
C3	Oedema
C4	Changes in skin and subcutaneous tissue secondary to CVD
C4a	Pigmentation or eczema
C4b	Lipodermatosclerosis or atrophie blanche
C4c	Corona phlebectatica
C5	Healed
C6	Active venous ulcer
C6r	Recurrent active venous ulcer
CVD. Chronic venous disease Each clinical class sub-characterised by a subscript indicating the presence (symptomatic, s) or absence (Asymptomatic, a) of symptoms attributable to venous disease.	

Pathophysiology

Venous hypertension is the underlying cause of CVD. It occurs when there is a disturbance in the physiological drainage of venous blood from the leg to the heart, against the force of gravity. Blood from the lower limb is normally returned to the heart via a system of deep veins which are fed by superficial veins either through direct junctions or via perforating veins. Of the many various causes, valvular incompetence and diminished calf muscle function are the two major causative factors responsible for the development and progression of CVD. As the pump fails to empty the blood in the venous system, ambulatory venous hypertension becomes the sequela which further produces a series of histopathological changes to the vein wall and destruction of the valve leaflets.[43, 44, 46, 47]

Venous valves and valvular incompetence

Venous valves are present in the lower limb, serving to maintain venous function, by acting as mechanical gates that allow blood to travel towards the heart, without peripheral or reverse flow leakage (venous reflux). [21, 47, 48] Typically, there are no valves present in the iliac veins, one (or no) valve(s) in the common femoral vein (CFV), two to four valves in the femoral vein (FV), approximately a dozen valves in the deep calf veins and some perforating veins in the foot.

In relation to the superficial venous system, both the great saphenous vein (GSV) and the small saphenous vein (SSV) have a terminal and preterminal valve near their junctions with the deep venous system. The terminal valve is situated very close to this junction and prevents reflux from the deep system into the

superficial system. The preterminal valves (previously known as subterminal valves) are situated slightly more downstream to the terminal valves. [49]

The number of valves increases towards the distal veins in order to counteract increased hydrostatic venous pressure. [34] At rest, the valves usually remain open, and closure of valves is triggered by muscular activity. Venous reflux (or pathologic reverse flow) resulting from valvular incompetence can occur in superficial, deep and perforating veins (PVs) of the lower limb in either a segmental or axial pattern.

The cause of valvular failure can be primary, secondary or congenital. [2] Primary valvular incompetence is more common and occurs as a result of idiopathic valve dysfunction, [2] whereas secondary valvular incompetence develops from recanalisation during or after previous deep vein thrombosis (DVT), superficial thrombophlebitis (STP), arteriovenous fistula (AVF) or congenital venous malformations. [40, 42, 43]. Congenital valvular agenesis refers to congenitally absent or abnormally developed valves. [2] Secondary venous reflux is more common in the deep veins due to thrombotic event. [46] The pathway of CVD related signs and symptoms due to DVT is often called postthrombotic syndrome. [43]

Varicose veins are a manifestation of the combined negative effects of hydrostatic pressure and valvular dysfunction which disrupts the normal vein wall structure due to weakening and/or loss of elasticity in the connective tissue of the vein wall and damage to the valve leaflets. This leads to local vein dilatation and tortuosity. [40, 43, 46] Venous function is further impaired due to reactive collagen deposition leading to fibrosis and scarring. [40] This pathophysiological process may present in either an ascending pattern (arises in tributaries, followed by saphenous veins, followed by junction), or a descending pattern (reverse order to ascending pattern). [41]

Origins of venous insufficiency

Pathophysiology of CVD in the large leg veins can be described by the origin of the venous insufficiency.

1. Saphenofemoral and Saphenopopliteal Insufficiency (superficial veins)
   Varicosities in the saphenous distribution usually start where superficial veins communicate with deep veins, such as at the saphenofemoral junction (SFJ) and saphenopopliteal (SPJ) junction and in the perforating system. [43] The SFJ is the site where the GSV drains into the CFV; the SPJ is the site where the SSV drains into the popliteal vein. [42, 43] At both sites, the terminal valve can be damaged by constantly elevated venous pressure against it, leading to valvular functional loss over time. Another mechanism of valve impairment is fibrosis secondary to venous thrombosis, where the valve does not return to normal function after vein recanalisation. Impairment of terminal valve function and refluxive forces in the vein result in vein dilation, also increasing pressure on the next upstream valve, leading to a cascading effect of multiple valve failures. [40, 46]
2. Deep Venous Insufficiency with Perforator Vein Insufficiency
   Valve damage and subsequent deep venous insufficiency may occur due to DVT or increased venous pressure secondary to congestive heart failure. Both mechanisms ultimately result in a combination of valve damage and increased venous pressure working to exert retrograde pressure on the perforating veins and subsequent reversed venous flow, which in turn can transmit increased pressure to the connected superficial vein segment. This increased pressure in the superficial vein, facilitates sequential valve failures along its length. [40] Deep venous insufficiency may also be idiopathic. [43]. By contrast, a third of the CFV reflux is caused by volume overload and dilatation of the saphenous venous system, which usually undergoes normalisation after the obliteration of the GSV.[50]
3. *Pudendal Vein and Pelvic Vein Insufficiency*
   Varicose leg veins can be due to vulvar varicosities rather than with reflux of the leg veins. Vulvar varicosities may be associated with clinical symptoms and signs suggestive of pelvic congestion, including uterine retroversion and dyspareunia, menorrhagia, and more commonly occur in multiparous women and those who have had haemorrhoids and vulvar varicosities associated with pregnancy. [43] The pudendal and pelvic veins connect to the GSV and other superficial veins of the leg via small tributaries. These small communicating veins include the superficial external pudendal vein (SEPV), the superficial epigastric vein (SEV), and the superficial circumflex iliac vein (SCIV). The increased venous pressures associated with pudendal vein and pelvic vein insufficiency is transmitted through these communicating veins, leading to GSV reflux and varicosities. [40]

4. Calf Muscle Pump Causes
   The calf muscle pump assists the drainage of venous blood from muscular compartments of the leg to the heart. As the calf muscles contract, the veins are compressed, pumping the blood forward. If there is calf muscle pump weakness, as which can occur with obesity or leg immobility, there will be reduced mechanical action in pumping the blood forward, leading to venous stasis, vein dilatation and valve incompetence. Another calf pump mechanism that can damage valves is activity related sudden vasodilatation such as which can occur with repetitive squats with weights. The sudden, associated increase in blood volume can precipitate valve function over time in predisposed individuals. [40, 47]
5. Plantar Venous Pump and Static Foot Disorder
   The plantar veins of the foot also play an important role in the physiological venous return of the lower extremity. When the foot muscle pump contracts, 50% of the perforating veins of the foot permit flow from the deep to the superficial veins. The impaired foot muscle pump function may lead to CVD. Furthermore, static foot disorder refers to a condition where there is abnormal alignment or positioning of the foot while standing or walking, often due to weakened or imbalanced muscles and ligaments. This can lead to problems such as arch collapse, flat feet, or excessive pronation. While static foot disorder and varicose veins are distinct conditions, they can potentially be interconnected. The altered foot mechanics and misalignment associated with static foot disorder may contribute to increased venous pressure and impaired circulation in the legs, which can exacerbate the development or progression of varicose veins. [51-52]
6. Recurrent Varicose veins
   Recurrent varicose veins may result from failed treatment, neovascularisation posttreatment, or the progression of disease with new incompetence in previously untreated vessels and perforating veins (PV). [34]

Venous hypertension and the microcirculation

The effect of venous hypertension on the microcirculation is different to the insult on the larger veins. The microvessels also have valves which, similar to the large veins, become incompetent, elongated, dilated and become tortuous. With these changes, the endothelium of the microvessels becomes dysfunctional resulting in oedema and skin changes. [42] The changes in microvessels have been linked to reduction of normal nutrition to skin cells and the subsequent development of venous leg ulcers. [43]

Prevalence and socioeconomic burden

The CVD is the most common vascular disease, with reported prevalence rates for women ranging from 25-60% and for men ranging from 15-49%. [53-55] The CVD and its associated symptoms and/or complications can be responsible for chronic pain, disability and decreased quality of life, leading to loss of working days, and early retirement. A recent systematic review study on global prevalence found that the most common manifestations of CVD were telangiectasia and reticular veins (26%) and varicose veins (19%). Additionally, the review reported that 22% of individuals with varicose veins would progress to develop a venous leg ulcers (VLU) within six years. [55] In Australia, VLU make up 12% of the estimated 420, 000 cases of chronic wounds in hospitals and residential care facilities. [56] This poses a health burden on the population, as well as an associated social-economic burden. [57]

In relation to the economic burden, and using VLU as an example, 2012 Australian data estimates that the total number of chronic leg ulcer (CLU) cases (n=49,098) in private and public hospitals and residential facilities represented an economic burden of US$802.55 million (approximate AUD $830.79). [58] Looking at the overall picture, Australian Medicare data demonstrates that in the 2022 calendar year the diagnosis and treatment of CVD disease accounted for 0.14% of the total Medicare expenditure, and varicose vein treatments accounted for 41.9% of all vascular treatments. The expenditure associated with treatment of CVD decreased by 17.8% from 2012-2022 due to the availability of less costly endovenous treatment methods compared to conventional surgeries. Interestingly, the Medicare expenditure on duplex US scans investigating CVD is 7.7 million more than CVD treatments. [59] Therefore, duplex US examination is a large contributor to the CVD economic burden and should be performed to the best standards to reduce unnecessary repeat scans and ensure it generates accurate and comprehensive information, ultimately optimising management and treatment outcomes.

The role of duplex ultrasound in chronic venous disease

Duplex US is the most common imaging technique used in the management of CVD and has been recommended, based on strong levels of evidence, as the primary diagnostic imaging of choice to investigate CVD. [46, 60]

It:

- supports the diagnosis and is helpful for decision making of different treatment options; [44, 49]
- defines associated pathology such as acute DVT, postthrombotic change (PTC) and superficial venous thrombosis (SVT) with accuracies of 95-97%; [21, 43, 46]
- allows the assessment of venous haemodynamics in the veins of lower limb;
- identifies the incompetent veins (including the extent) in the deep, superficial and perforating veins; [21, 43, 46]
- maps the anatomy and morphology of normal and abnormal veins; [46, 61]
- can be used postoperatively to evaluate the success of treatment and to identify complications; [47]
- and can use customised protocols to address the points above. [46]

The advantages of duplex US are that it is regarded as safe, noninvasive, cost effective, reproducible and diagnostically accurate. [43-45] It utilises grayscale (B-mode), colour Doppler and spectral Doppler (also known as spectral Doppler) ultrasound imaging. Grayscale imaging allows the visualisation of the venous anatomy and its patency. Colour and spectral Doppler imaging demonstrate venous flow with directions for identifying venous reflux and determining patency of the deep, superficial, and perforating veins. [21] Grey-scale imaging also allows accurate placement of the spectral Doppler sample volume within the vessel, and colour Doppler assists with the identification of obstruction, turbulence, and the direction of venous and arterial flow. [43] Duplex US is sensitive in detecting even small amounts of reflux in the veins or vein segments.

The visualisation of veins and their haemodynamics may be limited by obesity, severe oedema, and barriers to a good sonographic window such as casts, dressings, indwelling catheters, or limitations in the patient's range of movement (such as joint contractures). Diagnostic quality may be impacted in confused or mentally impaired patients due to lack of cooperation [62] or an inability to tolerate the optimal positions for assessment (i.e. erect or semierect) or the manoeuvres required to assess for venous reflux. [63]
To achieve accurate results, duplex US should be performed by personnel with training, technical expertise and clinical knowledge and using a standardised protocol. [46] Across Australia and New Zealand, there is heterogeneity in how sonographers undertake duplex US to investigate CVD. [64] This clinical guideline will provide education and guidance to sonographers in an effort to standardise practices.

Section C: Venous anatomy of the lower limb

This section describes the venous anatomy of the lower limb and its variations, as it relates to sonography for investigation of chronic venous disease (CVD).

Some notes about general terminology

'Lower limb' is used to describe the complete lower extremity, from hip to foot.

'Leg' refers to the section of the lower limb from knee to foot, but to avoid confusion the terms 'calf' and 'thigh' will be used to refer to the lower and upper parts of the lower limb respectively.

Venous 'insufficiency' is used to denote a dysfunctional venous system (i.e., chronic venous insufficiency, superficial venous insufficiency).

'Competent' or 'incompetent' describes the functional status of a single vein or segment of a vein with respect to valvular function.

Veins that are situated closer to the heart will be referred to as proximal/more proximal. Veins that are located further from the heart will be referred to as distal/more distal. [6]

The paired deep veins draining the lateral compartment of the calf can be referred to as 'peroneal veins' or 'fibular veins'. The terminology used in this clinical guideline will be 'peroneal veins'.

The term 'perforators' is not used in this clinical guideline. Instead 'perforating veins' will be used to differentiate from perforating arteries.

The terminology in this section is based on the terminology endorsed by the International Interdisciplinary Committee, 2006 [38], and a vein glossary endorsed by the Australia and New Zealand College of Phlebology [6] and agreed on by the guideline development group.

Venous anatomy of the lower limb

The venous anatomy of the lower limb comprises deep veins, superficial veins and perforating veins. The deep veins course in a deep compartment which is bounded superficially by the muscular fascia. [35] The superficial veins lie in the subcutaneous tissues within the superficial compartment, which lies between the dermis and the muscular fascia. [35] The blood in the superficial veins eventually drains into the deep system. The main trunks of the superficial system are 'interfascial', meaning they lie within a 'fascial compartment'. Perforating veins (PV) pass through the muscular fascia to connect the deep and superficial veins. They vary in how they are distributed and arranged. Except in the foot, they have unidirectional valves to maintain flow from the superficial to deep veins. [42, 48]

The superficial compartment is bounded deeply by the muscular fascia, and superficially by the superficial fascia (or membranous fascia). The fascial compartment containing saphenous veins is referred to as the 'saphenous compartment'. [65] Venous structures that lie within this fascial compartment include the great saphenous vein (GSV), small saphenous vein (SSV), vein loops on the dorsum of foot connecting the GSV and SSV, the anterior saphenous vein (ASV) and the posterior accessory of the great saphenous vein (PAGSV). [65] In grayscale ultrasound, the saphenous compartment may have variable appearances. In lean legs, the vein is tightly contained with little intrafascial fat within the compartment, whereas in a leg swollen by lipoedema, the compartment appears enlarged and stretched, with a layer of fat cushioning the saphenous vein **(Image 9)**. [65] The 'Egyptian Eye' sign is used to describe the sonographic feature of the saphenous compartment. The saphenous vein resembles the "iris," the superficial fascial layer resembles the "upper eyelid," and the deep fascial layer represents the "lower eyelid" **(Image 10)**. Any vein situated outside of the saphenous compartment

cannot be called a saphenous vein.[38] Most saphenous tributaries are not contained within the superficial compartment. [35]

Deep venous system

The major deep veins of the lower limb follow the course of the main arteries and are categorised below according to their general location.

Groin

Common femoral vein (CFV): formed by the confluence of the femoral vein (FV) and the deep femoral vein (DFV) to become the external iliac vein (EIV) at the inguinal ligament **(Image 11)**. [35, 38, 40, 45]

Thigh

Femoral vein (FV): originates as an extension of the popliteal vein at the upper margin of the popliteal fossa and courses superiorly in the adductor canal, along the anteromedial thigh, medial to the superficial femoral artery. [40] The FV was previously known as the superficial femoral vein, but this was discontinued to avoid confusing this deep vein for a superficial vein. The FV vein may be duplicated. [35, 38,40, 45]

Deep femoral vein (DFV): arises from the confluence of veins draining the muscles of the posterior and lateral thigh. It is also known as the profunda femoris vein or deep vein of the thigh. [35, 38 40]

Deep femoral communicating veins: are the accompanying veins of the perforating arteries that originate from the deep femoral artery. They were formerly called "perforating" veins, but this has been abandoned to avoid confusing them with 'perforating veins' that connect superficial and deep veins. [35]

Medial circumflex femoral vein: a deep vein that accompanies or parallels the medial circumflex artery.

Lateral circumflex femoral vein: a deep vein that accompanies or parallels the lateral circumflex artery.

Sciatic vein: also referred to as persistent sciatic vein (PSV), is a remnant of the main trunk of the primordial deep venous system (the axial vein of the embryo) resulting from either a failure of the development of femoral vessels or failure in regression of the embryonic sciatic vessels. It courses close to the sciatic nerve and may assume an important role as a collateral pathway for the FV. It is most seen in patients with Klippel-Trenaunay syndrome. [35, 66] The dilated sciatic vein can be recognised when the popliteal vein is extended by a tubular, deep vein. In these cases, the presence of a functional FV must be verified because the PSV occasionally provides the main venous drainage of the limb from the popliteal vein up to the internal iliac vein (IIV). [67]

Knee

Popliteal vein: formed by the confluence of the tibioperoneal trunk and the anterior tibial veins and the large veins of the soleus and gastrocnemius muscles. The popliteal vein continues in the proximal direction through the popliteal fossa, medial to the popliteal artery below the knee, superficial to the artery at the knee, and lateral to the artery above the knee, up to the adductor canal to become the FV. The popliteal vein may be duplicated. [40, 42]

Genicular venous plexus: the complex plexus of interconnecting veins near the branches of the popliteal artery. The term 'genicular veins' should not be used as these deep veins do not correspond exactly to the branches of the popliteal artery (articular arteries). [35]

Calf

Soleal veins/soleal sinuses: Veins of the soleal muscles are often sinusoidal, i.e., without specific form and may be valveless. They drain into the posterior tibial veins or peroneal veins.

Gastrocnemius veins: include medial gastrocnemius veins (having a larger calibre and draining the head of medial gastrocnemius muscle), lateral gastrocnemius veins (having a smaller calibre and draining the lateral

head of gastrocnemius muscle) and intergemellar vein which ascends between both heads of gastrocnemius muscle deep to the SSV **(Image 12)**. They most commonly merge into one trunk and drain into the popliteal vein just before the termination of SSV, or they may also drain into the peroneal or posterior tibial veins or the tibioperoneal trunk as one or multiple trunks. [35] The nonspecific term 'sural veins' should not be used to describe soleal or gastrocnemius veins. [35]

Anterior tibial veins (ATVs): Paired veins that drain tissue of the ankle, knee joint and tibiofibular joints, and the anterior portion of the calf. The paired anterior tibial veins ascend in the interosseous membrane between the tibia and fibula, and merge with the tibialperoneal trunk to form the popliteal vein.

Posterior tibial veins (PTVs): paired veins that receive blood from the medial and lateral plantar veins and drain the posterior compartment of the leg and plantar surface of the foot. Posterior tibial veins lie behind the tibia and join the peroneal veins to form the tibioperoneal venous trunk at the posterior knee.

Peroneal veins (fibular veins): paired veins that run along the posteromedial aspect of the fibula and join the posterior tibial vein at the tibioperoneal trunk before its confluence with the anterior tibial vein to form the popliteal vein.

Superficial venous system

The superficial venous system of the lower limb is composed of multiple veins located between the muscular fascia and the skin. [8,21, 45, 48] Superficial veins can be classified by their relationship to the superficial fascia. Saphenous veins are located between the muscular fascia and the superficial fascia, whereas tributary veins are mainly situated in the subcutaneous tissue layer (epifascial), receiving venous blood from postcapillary venule, subpapillary plexus and subdermal plexus (beneath the skin). They mostly connect with the saphenous veins and are known as the tributary veins of the GSV or SSV. After the tributary veins pierce the superficial fascia, some may continue to travel along with the saphenous vein inside the saphenous compartment before joining it. Additionally, there are tributary veins that directly drain into the deep system via perforating veins, thus they are known as nonsaphenous veins.

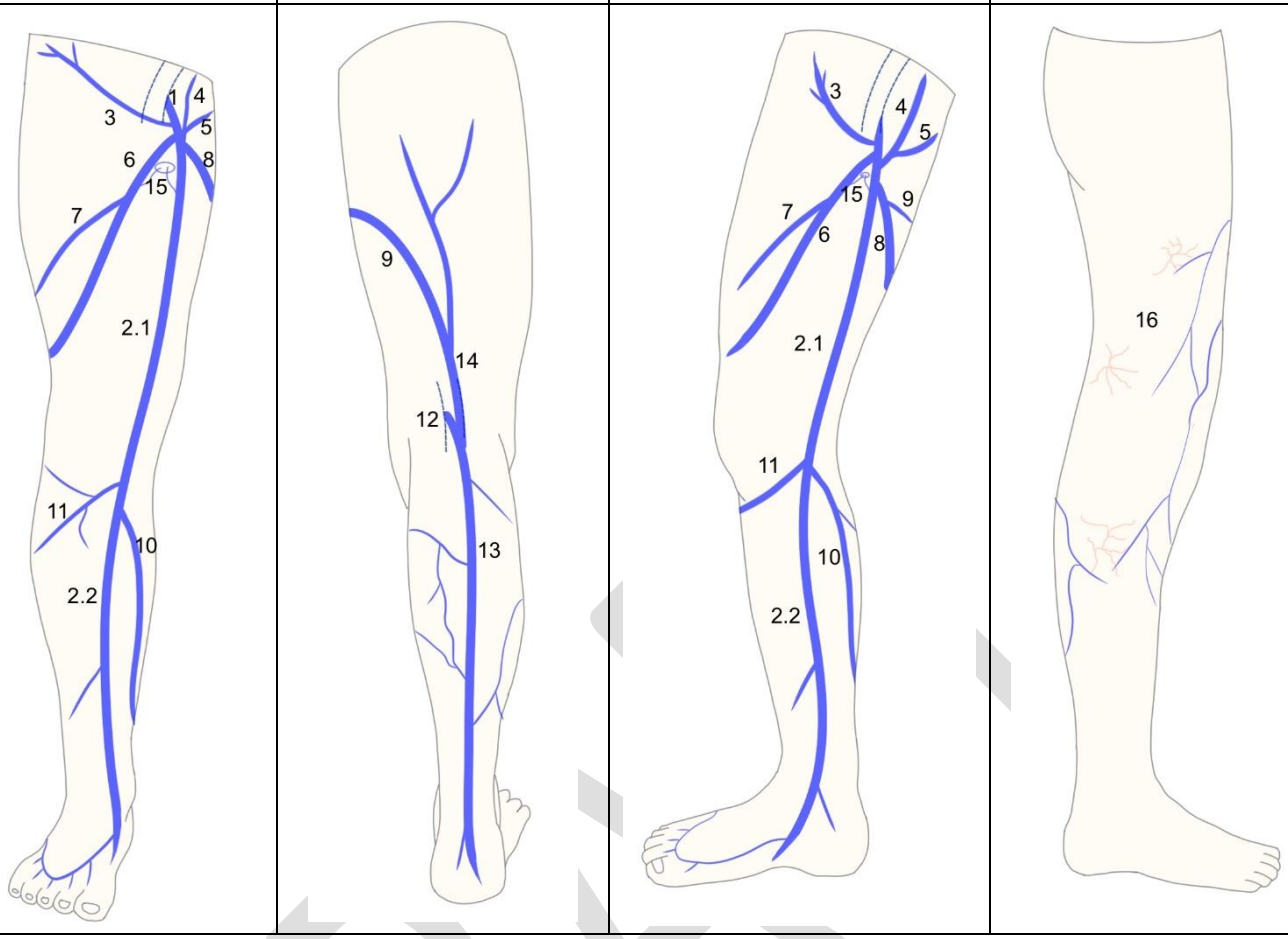
Duplex US is used to identify truncal veins and assess for venous incompetence in them and their tributaries. Some tributaries may only be visible if they are varicose. A large incompetent tributary may be visible on Duplex US, but it may dramatically decrease in size and become invisible further from its origin. [68]

Figure C1 provides a pictorial map of the superficial veins of the lower limb; their courses and sonographic appearances are described in the following text. Note that variations to the depicted course of veins may occur.

Great saphenous vein (GSV)

The term great saphenous vein should be used instead of other terms such as long, greater or internal saphenous vein. [35] Throughout its length, the GSV lies within its fascial compartment and can be identified on Duplex US by the 'Egyptian Eye sign' seen in the transverse plane, and which distinguishes it from parallel subcutaneous tributaries. [38] The GSV starts from the medial marginal vein of the foot. In the distal calf, the GSV lies adjacent to the saphenous nerve. It ascends anterior to the medial malleolus along the medial border of the tibia and the medial gastrocnemius muscle. At the distal third of thigh and proximal third of calf, it can be difficult to identify or distinguish it from a tributary of the GSV because the fascial sheets of its fascial compartment are so closely apposed. On Duplex US, it can be identified by the 'tibiogastrocnemius angle sign'. This sign describes a triangle formed by the tibia, medial gastrocnemius muscle, and saphenous fascia. If the saphenous space is empty, then this indicates that the GSV is absent or hypoplastic. [38]
The GSV crosses the knee medially behind the medial femoral condyle and courses along the medial thigh in its fascial compartment, in a course that returns it to a more ventral position at the inner third of the groin where it drains into the CFV at the SFJ, a few centimetres below the inguinal ligament, medial to the femoral arteries, and inferior and lateral to the pubic tubercle. [65]

Figure C1: Lower limb superficial venous anatomy.

a. Anterior view	b. Posterior view	c. Medial view	d. Lateral view
			

Key:				
1: Saphenofemoral Junction (SFJ).	2.1: Great saphenous vein above knee (GSVa).	2.2: Great saphenous vein below knee (GSVb).	3: Superficial circumflex iliac vein (SCIV).	4: Superior epigastric vein (SEV).
5: Superficial external pudendal vein (SEPV).	6: Anterior saphenous vein (ASV).	7: Anterior thigh circumflex vein (ATCV).	8: Posterior accessory of the great saphenous vein (PAGSV).	9: Posterior thigh circumflex vein (PTCV).
10: Posterior arch vein (PAV, also known as the posterior accessory of the great saphenous vein of the lower leg).	11: Anterior arch vein (AAV, also known as the anterior accessory of the great saphenous vein of the lower leg).	12: Saphenofemoral Junction (SPJ).	13: Small saphenous vein (SSV).	14: Giacomini vein (variation to cranial extension of small saphenous vein).
15: Lymph node venous networks (LNVN).	16: Lateral Subdermic Venous System.			

Variations of the GSV and its tributaries

Named tributaries of the GSV include the anterior saphenous vein (ASV), the posterior accessory of the GSV (PAGSV) in the thigh, and the anterior and posterior arch veins in the lower leg region. Variations of the GSV and its tributaries include:

- A single GSV is present within the saphenous compartment with no large parallel tributary.
- A single GSV is present within the saphenous compartment, a large subcutaneous tributary that pierces the superficial fascia to join the GSV in the thigh is also present (level of junction variable).
- A single GSV lies within the saphenous compartment proximally, as well as a large subcutaneous tributary more distally. The distal subcutaneous tributary pierces the saphenous fascia at a variable level in the thigh to become the GSV within the saphenous compartment. Below this level the GSV is absent or only barely visible on Duplex US (absent or hypoplastic).

- The GSV is duplicated along its full course (rare). They appear as two parallel vessels within the same saphenous compartment.
- The GSV is duplicated (two parallel vessels within the same saphenous compartment) for a distance of 3–25 cm in the thigh **(Image 13)**.
- Two veins, the GSV and ASV are both present in the proximal thigh, merging together just before entering into the CFV. Distally they exist in two separate saphenous compartments.
- The GSV is visible, but there is also a large tributary that begins above the knee, which whether normal or varicose, is sometimes so large that it may be mistaken for the GSV **(Image 14)**.
- The middle portion of the GSV is barely visible or not visible at all (hypoplastic or absent) for a variable length with the 'missing' portion bypassed by a subcutaneous tributary. In these cases, varicose veins are more common than when the GSV is present throughout the thigh and calf. Two patterns have been reported:
    - The GSV cannot be demonstrated for some distance above and below knee. The GSV pierces the saphenous fascia at about the mid-calf to become a subcutaneous tributary, which crosses the knee and again pierces the saphenous fascia in the distal thigh to become the GSV in its saphenous compartment.
    - There is a short absent portion of the GSV just below the knee.
- The GSV is nearly always present from the medial malleolus to the mid-calf. At this location, the GSV demonstrates increasing compliance due to a strong saphenous fascia in the fascial compartment and infrequently demonstrates incompetence.
- Other thigh tributaries: Two or three tributaries may join the GSV in the mid-thigh. A vein may join the GSV from the lateral side linking it with the ASV in the mid-thigh. In the lower thigh, an anterior and posterior tributary may join the GSV. If one of these veins becomes incompetent, the other may become overloaded with reflux from this vein. [65]
- The are usually one or more subcutaneous tributaries in the calf:
    - Anterior arch vein (anterior accessory of the GSV in the leg): runs from the lateral foot via the lateral malleolus, proximal along the lateral edge of the tibia, to traverse the tibia at a variable height between halfway and one third from proximal tibia and join the GSV in the upper third of the calf. Occasionally two anterior arch veins are seen. [65]
    - Posterior arch vein (also known as 'Leonardo' vein, posterior accessory of the GSV in the leg): The posterior arch vein originates posterior to the medial malleolus and runs fairly straight proximally on the inside of the leg. It drains into the GSV below the medial femoral condyle. It is clinically important due to its connection with perforating veins in the calf which lie medially and connect to the posterior tibial veins. [6, 38, 49, 69]

Intersaphenous vein: a vein arising from the SSV which has a variable junction with the GSV near the termination of the posterior arch vein. It may drain below the knee into the upper section of the posterior arch vein, or it may drain above the knee directly into the GSV. [65]

Saphenofemoral junction (SFJ)

The GSV travels through the saphenous opening (fossa ovalis) within the fascia lata of the thigh to connect with the CFV, approximately 3-4 cm below and to the side of the pubic tubercle, approximately at the level of the cutaneous fold in the groin. This termination of the GSV into the CFV is called the SFJ, but more broadly includes a complex of valves and saphenous tributaries. The SFJ has a relatively constant location at the groin crease and is enveloped in the superficial fascia which extends to the inguinal ligament. Relating to the CFV, the SFJ is bordered superiorly by the suprasaphenous valve (may be in the EIV) and inferiorly by the infrasaphenous valve, located distal to the SFJ. Relating to the GSV, the SFJ is bordered inferiorly by the preterminal valve. The preterminal valve can lie up to 8.5 cm caudal to the orifice of the GSV. The terminal valve lies nearer the orifice of the GSV, usually within 1.4 cm of it **(Image 15)**. [70]

Venous tributaries commonly drain into the GSV between the terminal and preterminal valves, but sometimes may drain inferior to the SFJ. The number of draining veins can be variable, this number increases as the distance between the two valves increases. [70] These tributaries include proximal veins that drain venous

blood from the abdominal wall and pudendal areas, including veins of the inguinal ligament, the superficial circumflex iliac vein (SCIV), superficial epigastric vein (SEV) and superficial external pudendal vein (SEPV). These veins may be single or multiple and are clinically important as they may transmit retrograde flow into the GSV even with a competent terminal valve. Distal tributaries are often relatively large, and their paths can be variable. They include the ASV and the PAGSV. The PAGSV may represent the proximal end of the Giacomini vein at a variable distance from the SFJ, often distal to the preterminal valve. Other tributaries are the anterior thigh circumflex vein (ATCV) and the posterior thigh circumflex vein (PTCV) which occur in the thigh. The ATCV travels obliquely through the anterior thigh, anterolateral to the ASV, draining either to the ASV or separately to the GSV. The PTCV travels obliquely through the posterior thigh, posteromedial to the PAGSV and or separately to the GSV. Other veins may branch from accessory veins or drain directly to the GSV, but specific naming of these vessels is not clinically important. Close to the SFJ, the GSV medially and the ASV laterally often lie within the same saphenous compartment. [6, 35, 38,]

Anterior saphenous vein (ASV)

The ASV may originate from the ATCV, the trunk of the GSV or tributary veins of the anteromedial thigh. It runs parallel to the GSV, but anterior to it. It most commonly drains into the GSV at the SFJ below the terminal valve but may also drain into the GSV at the upper thigh below the preterminal valve, or directly into the CFV via a separate junction. [65] The ASV in the upper thigh is contained within its own fascial compartment, with a saphenous 'eye' similar to the GSV. To distinguish between these two vessels in the upper third of the thigh, the ASV can be identified by the 'alignment sign' as when imaged in the transverse plane, it lies over the superficial femoral artery and femoral vein (FV) **(Image 16)**. Sonographers should be aware that in cases where the GSV is absent or hypoplastic, then a visible 'eye' sign is likely due to the visualisation of the ASV acting as a functional replacement to the GSV. Near the SFJ, the coexisting GSV and ASV often lie within the same fascial compartment, with the GSV medial and the ASV lateral. [35, 38] The ASV can be distinguished from the circumflex veins, such as the ATCV, by its parallel rather than oblique course to the GSV. The ASV and its tributaries can be variable in frequency, diameter, length and course. At the mid-lower thigh, there may be no ASV, but a duplicated GSV. A duplicated GSV can be differentiated from the ASV by identifying two vessels lying in the same saphenous compartment for a distance of 3–25 cm. A large subcutaneous tributary that pierces the superficial fascia to join the GSV at any point in the thigh should not be mistaken for an ASV. [38] Due to the anatomical characteristics of the ASV as an interfascial truncal vein rather than an accessory epifascial tributary vein, the international multidisciplinary panel of the American Venous and Lymphatic Society (AVLS), American Venous Forum (AVF), and International Union of Phlebology (UIP) recommended replacing the old term "anterior accessory of the great saphenous vein" with the more appropriate term "anterior saphenous vein." [39]
The ASV is the most important site of recurrence after a prior GSV treatment. An incompetent ASV is often responsible for varicose veins in the anterolateral thigh, lateral knee, and calf region when both the SFJ and GSV are competent. In some cases, reflux may be present in both the GSV and ASV. The ASV reflux, as the sole source in the absence of reflux in the GSV, may be associated with the veins of inguinal lymph nodes and tributary veins from the pelvic region and abdominal wall. [71]

Anterior accessory of the GSV refers to any segment ascending parallel to the GSV and located anteriorly, both in the calf and in the thigh. [35]

Posterior accessory of the great saphenous vein (PAGSV)

The PAGSV, more commonly seen than the ASV, refers to any segment ascending parallel but posteromedial to the GSV thigh segment **(Image 17)**. It drains into the GSV just before the SFJ, although this can vary and runs parallel to the GSV for a significant length of the thigh. Similar to the ASV in its proximal section, it runs within the saphenous compartment, and in some cases, it remains in this compartment for its entire length. The PAGSV may be haemodynamically important when it forms a connection between the GSV and the SSV. Three variants of these connections are:

- The PAGSV courses from the GSV in the calf up to the thigh where it turns posteriorly, breaching the superficial fascia to run freely in the subcutaneous fatty tissue where it disperses into small vessels that cannot be differentiated on Duplex US.

- The PAGSV is an entirely subfascial structure which connects the GSV with the SSV. On Duplex US, it can be easily traced as it runs proximally from the SSV as far as the middle third of the thigh from where its course is in the middle of the posterior thigh. It then pierces the muscle fascia and courses medially under the saphenous fascia around to the inner thigh to join the GSV usually below the groin.
- The PAGSV is extrafascial and connects the GSV with the SSV. Its courses from the GSV in the calf to turn posteriorly in the thigh to breach the superficial fascia and course freely in the subcutaneous tissue. One of the subcutaneous branches is visible as a large vein in the back of the thigh. This vessel may join the SSV in the popliteal region or pierce the muscle facia to join a cranial extension of the SSV in the lower part of the posterior thigh. [65]

Superficial accessory of the great saphenous vein

The superficial accessory saphenous vein is a vein which runs parallel to the GSV but lies outside the saphenous fascia. This common extrafascial vein is often segmentally present in the mid to lower thigh and the upper to mid-calf and often serves as the primary flow channel when the true GSV is either hypoplastic or aplastic in these areas. It should not be interpreted as a GSV close to the skin because it does not lie within a saphenous compartment. However, this becomes difficult below the knee due to the poorly developed saphenous compartment at this site. [35, 68]

Lymph Node Venous Networks (LNVN)

In the femoral triangle, there is a complex venous network with its veins trans-passing the inguinal lymph nodes and eventually connecting to the saphenous vein, pelvic veins and/or directly to the CFV via perforating veins. The lymph node venous networks (LNVN) are thin and small (diameter <1mm) in healthy subjects and may not always be visible on Duplex US. One of these lymph nodes is quite constant and sits in the angle between the GSV and ASV before they merge **(Image 17)**. The LNVN can become dilated and incompetent, being a source of reflux or lying in the pathway that links the incompetent SFJ with the GSV or ASV in patients with primary CVD. On Duplex US, the typical morphological appearance of lymph nodes is easily recognised and associated with the presence of a dilated central vein, producing a peculiar image that has been referred to as the ‘‘ganglionic eye’’ sign. It is important for sonographers to recognise the incompetent vessels as surgery of the groin is contraindicated and ultrasound guided foam sclerotherapy is instead the method of choice in these cases. [35,51] The pathological LNVN is more common in recurrent veins after surgery (REVAS) with connections to the residual or recurrent varicose network. Following groin surgery, these vessels seem to have undergone vascular remodelling and dystrophic change due to healing process and inflammatory reaction under local angiogenic factors. [51,71] They should be meticulously assessed in patients with primary or recurrent varicose veins using both distal augmentation and Valsalva manoeuvre.

Small saphenous vein (SSV) and saphenopopliteal junction (SPJ)

The term small saphenous vein should be used instead of short, external, or lesser saphenous vein. The SSV is an important superficial vein in the posterior calf. It begins from the lateral marginal vein of the foot, ascending along the posterior calf after passing behind the lateral malleolus. In the upper calf, it passes the heads of the gastrocnemius muscle, joining the popliteal vein in 75% of the cases. Absence of the saphenopopliteal junction (SPJ) is present in 25% of the population. For its entire length it is embedded within the saphenous compartment between superficial and deep layers of the muscle fascia. Similar to the GSV in the thigh, the SSV demonstrates an ‘eye’ on Duplex US, occasionally showing two “irises” when duplicated **(Image 18)**. In the proximal calf, this saphenous compartment is typically triangular and defined by the medial and lateral heads of the gastrocnemius muscle and the superficial fascia that stretches over the intermuscular groove. The terminal part of the SSV includes two valves: the terminal valve and the preterminal valve. The terminal valve is located 1-2 mm distal, and the preterminal valve is located 3-5 cm distal to the SSV termination. [35] If a Giacomini vein or cranial extension (thigh extension) of the SSV is present, then preterminal valve will usually be located more distally. [38]

The SSV terminates at the SPJ where it joins the popliteal vein **(Image 19)**. The SPJ is a complex which also includes terminations of the tributaries (including their own terminal valves) which join the SSV between the terminal and preterminal valves. [6] The SPJ is most often situated within 5 cm of the popliteal skin crease, but

its level is variable. It is most seen at 2-4 cm above the knee crease and rarely below the knee crease. A higher percentage of people with a SPJ within the popliteal fossa (0-7 cm above the popliteal line) will have incompetence of the SPJ, compared to people with a more proximal SPJ (i.e., more than 7 cm above the popliteal line). [38] The SSV may join the popliteal vein on its posterior aspect (15%), posteromedial aspect (30%), posterolateral aspect (12%), lateral aspect (42%), or on its anterolateral aspect (1%). Gastrocnemius veins may drain into the popliteal vein, the upper SSV, or their confluence at the SPJ **(Image 20)**. The SSV is occasionally duplicated with two or even three veins of various lengths running in its compartment. [35, 38]

There are three variations of SSV termination:

1. The SSV joins the popliteal vein at the SPJ and joins the deep venous system at a more proximal level through a cranial thigh extension (CE) or joins the GSV via a Giacomini vein (see explanation below).
2. The SSV continues upwards as a CE or Giacomini vein, but it also connects with popliteal vein through an 'anastomotic' tiny vein.
3. There is no connection of the SSV with the deep veins (popliteal vein) in the popliteal fossa and it continues proximally in the thigh as the CE or vein of Giacomini. [38]

Explanation of cranial extension (CE) of SSV and Giacomini vein

The CE, a cranial extension of the SSV is a common entity which also has been known as thigh extension of the SSV (TE). It runs beneath the muscle fascia in the groove between the biceps femoris and semimembranosus muscles up the posterior thigh to where the bulge of the semitendinosus muscle meets the long head of the biceps femoris muscle in the midline (apex of popliteal fossa). At this point it may remain deep to the muscle fascia or emerge from the fascia and run epifascially. It may not always connect to the GSV. Its course in the thigh is variable: it can reach the gluteal region and drain into the inferior gluteal veins, travel through posterior or posterolateral perforating veins to drain into the DFV or terminate in the subcutaneous or muscular venous plexus.

The term Giacomini vein refers to a variation of the CE which drains into the GSV network through a cranial extension in the thigh extension. This extension communicates with the GSV or the PAGSV via the PTCV. It ascends posteriorly and within a triangle shaped compartment that resembles the saphenous compartment for the SSV from the popliteal fossa to the thigh, where it turns medially and courses, outside of the saphenous compartment. [35, 38, 69]

The CE and Giacomini vein may transmit reflux from proximal incompetent veins (e.g. GSV, perineal veins, thigh PVs) to the SSV, or conversely may transmit an 'ascending reflux' from the SPJ upwards to GSV and/or varicose veins of the posterior aspect of the thigh.

Subcutaneous tributaries of the SSV, the CE and Giacomini vein can be recognised as they pierce the superficial fascia to enter the saphenous compartment and join the truncal vein. A tributary to note is the 'popliteal fossa vein' which runs subcutaneously along the posterior aspect of the calf and popliteal area; sometimes parallel to the SSV and typically forms a separate junction with the popliteal vein usually lateral to the SPJ. [8, 42, 45, 48, 68, 72]

Superficial accessory of the small saphenous vein

This vein ascends parallel to the SSV and is located superficial to the saphenous fascia. [35, 67]

Anterior thigh circumflex vein

This vein drains blood from the lateral side of the thigh, sometimes originating in the lateral venous system (see section below). It ascends obliquely across the anterior aspect of the thigh and terminates in the GSV or the ASV. [35]

Posterior thigh circumflex vein

This vein drains blood from the posterior and medial sides of the thigh (often originating from the SSV, cranial extension of SSV, Giacomini vein, or from the lateral venous system). It ascends obliquely in the posterior thigh. and terminates in the GSV or the PAGSV. [35]

Lateral venous system

The lateral venous system is subdermic and represents the remnant of the embryonic vena marginalis lateralis. It is often associated with reticular veins and telangiectasia with connections to the deep veins via numerous perforator veins. [35, 45]

Nerve veins

Veins of the sciatic nerve run either within the main trunk of the sciatic nerve surrounded by the nerve fibers, or may course spirally around the main trunk of the nerve, but still inside the epineurium. These veins are often not readily visible on Duplex US, until they become incompetent with associated dilatation and tortuosity. They may contribute to the prominence of posterolateral calf tributaries, but which are not visible on the skin surface. Varicosities involving the veins of sciatic nerve, present on Duplex US as either a plexiform network of tortuous, dilated (3-5mm) and refluxing veins located around the sciatic nerve or as small calibre, tubular, refluxing veins within the nerve sheath. They may be an expression of incompetence of the inferior gluteal vein. Varicosities may also be present in/around the tibial nerve, the common peroneal, the superficial peroneal nerve **(Images 21-23)**, and communicating branches. [73,74]

Veins of the foot

Deep veins: The deep plantar venous arch runs from the proximal end of the first interosseous space to the base of the fifth metatarsal. It drains the deep metatarsal veins, which in turn drain the plantar and dorsal digital veins. [35] The medial plantar vein runs along the inner edge of the sole from the end of the plantar arch to the medial malleolus. [38] The lateral plantar vein stretches from the outer end of the deep plantar venous arch across the sole, where it joins the medial plantar vein to form the posterior tibial veins. [38] Dorsal deep metatarsal veins join medially to form paired dorsalis pedis vein. [35]

Superficial veins: The superficial dorsal plexus is clinically important because it is continuous with the superficial veins of the leg and ankle and may be involved in varicose dilatation. These veins are superficial and separated from the marginal veins and the dorsal venous arch by a strong connective fascia which is continuous with the fascia covering the GSV and SSV. The dorsal venous arch lies over the proximal ends of the metatarsal bones and is the origin of the lateral and medial marginal veins. It drains the dorsal metatarsal veins and several perforating veins. The medial marginal vein is contiguous with the GSV, and the lateral marginal vein is contiguous with the SSV. [38]

Perforating veins (PV)

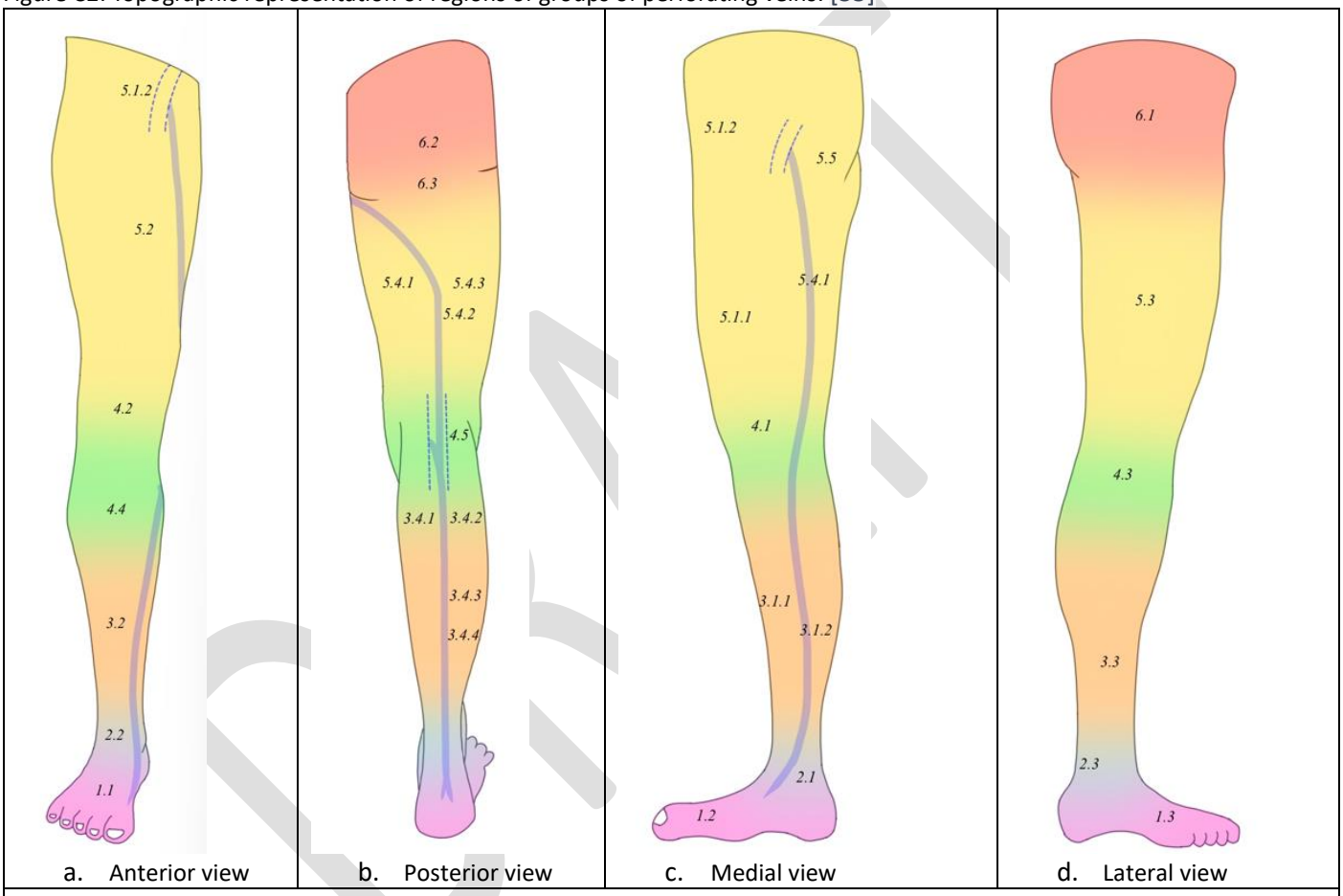
PVs pierce the muscular fascia, connecting superficial veins with the deep veins. [35] In a normal PV, the physiological direction of blood flow is from the superficial veins to the deep veins. If the direction of blood flow is reversed, then this means the PV is incompetent or refluxing. [75] PVs exhibit a wide range of variations in their arrangement, connections, size, and distribution, with a significant number (>120) present. In the UIP consensus document (2002), PVs are categorised as foot, ankle, leg, knee, thigh and gluteal based on their topographical locations. [35] In the normal state, PVs do not exceed 2mm in diameter, and usually possess bicuspid valves. Those less than 1mm in diameter may be valveless with their competence maintained by compression during muscle contraction.-In clinical practice, only dilated PVs, and therefore those visible on Duplex US, are of haemodynamic significance, playing a role as either the source of reflux or re-entry point (re-entry PVs) in a pathologic situation. [35, 76] Sonographers should search for incompetent PVs both when a patient presents for the first time, or postsurgery. Previously thought to be rare, the recurrence of postsurgical incompetent PVs are known to occur due to neovascularisation of previously ligated PVs, or the development of new incompetent PVs due to persistent venous disease rather than poor surgical techniques. [77]

Sonographers should also be aware of bone PVs (or incompetent intraosseous PVs) that can become incompetent. They allow venous drainage from the interosseous to the extraosseous venous circulation and can be a source of lower limb varicose veins at the anteromedial side of the calf. Incompetent bone PVs can be recognised on Duplex US as a vein feeding through an osteolytic defect in the bone cortex. The cortical orifice/defect is visualised as a lack of continuity of the bone. To identify the vein as incompetent, there will be associated venous dilations on the medial side of the tibia, either above or below the cortical orifice and

spontaneous or induced refluxive flow in a direction from the intraosseous veins to the tributaries. The reflux may be identified at the site of a secondary feeder vein, rather than at the main venous pathway through the cortical defect. [67]

Figure C2 and table C1 demonstrates PV sites and their nomenclature.
Historical eponyms used for describing PVs are discouraged, such as Hunterian (upper femoral canal), Dodd (lower femoral canal), Boyd (upper paratibial), Cockett (lower posterior tibial), Sherman (lower paratibial), Hach (posterolateral thigh), May (intergemellar), Bassi (para-Achilles), Gillot (medial gastrocnemius) and Thierry (popliteal fossa). PVs should be described by their anatomical location and/or deep and superficial connections. Refer to figure C2 and table C1), rather than using eponyms. [35]

Figure C2: Topographic representation of regions of groups of perforating veins. [35]



a. Anterior view | b. Posterior view | c. Medial view | d. Lateral view

Key:					
Foot Perforating veins	1.1: Dorsal foot	1.2: Medial foot	1.3: Lateral foot		
Ankle Perforating veins	2.1: Medial ankle	2.2: Anterior ankle	2.3: Lateral ankle		
Leg (calf) Perforating veins	3.1.1: Paratibial	3.1.2: Posterior tibial	3.2: Medial leg (calf)	3.3: Lateral leg (calf)	3.4.1: Medial gastrocnemius
	3.4.2: Lateral gastrocnemius	3.3.3: Intergemellar	3.3.4: Para-Achillean		
Knee perforating veins	4.1: Medial knee	4.2: Suprapatellar	4.3: Lateral knee	4.4: Suprapatellar	
Thigh perforating veins	5.1.1: Femoral canal	5.1.2: Inguinal	5.2: Anterior thigh	5.3: Lateral thigh	5.4.1: Posteromedial thigh
	5.4.2: Sciatic	5.4.3: Posterolateral thigh	5.5: Pudendal		
Gluteal perforating veins	6.1: Superior gluteal	6.2: Mid gluteal	6.3: Lower gluteal		

Table C1: Groups of lower limb perforating veins (PV) based on the anatomical and topographical locations. (adapted from [69])

Group	Subgroup	Description
Foot PVs	Dorsal foot	It is located more proximal and connects the medial marginal vein and the dorsalis pedis vein just at the level of the inferior extensor retinaculum. It carries blood from the surface to the depths, running beneath the tendon of the anterior tibialis muscle and the extensor hallucis longus muscle. The junction of this vein with the dorsalis pedis vein is sometimes considered as the arbitrary starting point of the anterior tibial vein.
	Medial foot	Consists of two PVs: the navicular PV, which runs close to the tuberosity of the navicular bone, and the cuneiform PV, which passes along the medial cuneiform bone. Both perforating veins connect the medial plantar veins and the medial marginal vein.
	Lateral foot	Lateral foot PVs, also known as lateral foot PVs, consist of two PVs or two subgroups. They connect the lateral plantar veins and the lateral marginal vein. The calcaneal PV, also called the intertendinous PV or calcaneal group, runs between the tendons of the fibularis longus and brevis muscles. The cuboid PV, also known as the subtendinous PV, metatarsal group, or retrotendinous PV, passes beneath the tendons of both fibular muscles. These PVs usually form a common effluent trunk called the common lateral PV of the foot, which joins the thinner lateral marginal vein behind the lateral malleolus, forming the beginning of the small saphenous vein. However, sometimes it continues proximally as an Achillean vein or tributary, located medially to the Achilles tendon, and joins the small saphenous vein at the distal third of the calf.
Ankle PVs	Medial ankle	Formerly known as '*May-Kuster Perforator'*. Connects PTV and GSV. Kuster described four veins 2.6–5.33 cm from the malleolar centre.
	Anterior ankle	Includes premalleolar PV connecting lateral malleolar venous plexus and dorsal veins of the foot, which are tributaries to the deep veins of the proximal part of the foot.
	Lateral ankle	Includes submalleolar PV connecting the deep veins of the proximal part of the foot (tributaries to the peroneal veins) with lateral malleolar venous plexus. This PV often has a direct connection into the lateral marginal vein.
Leg (calf) PVs	Medial leg	Medial perforating veins of the leg include paratibial and posterior tibial perforating veins.
		Paratibial: Formerly known as '*Sherman Perforator'* in the lower and mid leg, and '*Boyd Perforator'* in the upper leg. Connects the main GSV trunk or its tributaries with the posterior tibial veins or calf muscle plexus and lie close to the medial surface of the tibia.
		Posterior tibial: Formerly known as '*Cockett Perforator's*. Connects the posterior arch vein with the posterior tibial veins. Name them as upper, middle, and lower based on topographical location in the leg. They are located 7 1 cm, 13.5 1 cm and 18.5 1 cm above the sole on Linton's line, perpendicular to the sole plane and running about 1.5–2 cm behind malleolus medialis, parallel to GSV. The blood flow is often reversed in the inferior perforator under normal conditions, which serves to reduce the venous blood pressure in the foot.
	Anterior leg	Pierces the anterior tibial compartment fascia to connect the anterior GSV tributaries to the anterior tibial veins.
	Lateral leg	Connects veins of the lateral venous plexus with the peroneal veins.
	Posterior leg	Posterior perforating veins of the leg include the four subtypes below,
		Medial gastrocnemius: Formerly known as *'Gillot Perforator'.* Connect the networks of SSV and muscular veins within medial head of gastrocnemius muscle.
		Lateral gastrocnemius: Connects the network of SSV and muscular veins within lateral head of gastrocnemius muscle on the lateral and dorsolateral aspects of the leg.
		Intergemellar: Formerly known as '*mid-calf perforator of May'*. Connects the SSV with the muscular veins of gastrocnemius and soleus in the middle of the calf.
		Para-Achillean: Formerly known as '*Bassi Perforator'*. Connects the SSV with the peroneal veins.
Knee PVs	Medial knee	Categorised based on the anatomical location and connects to the superficial reticular venous networks and varicose veins around the knee.
	Suprapatellar	
	Lateral knee	
	Infrapatellar	
	Popliteal fossa	Runs subcutaneously along the posterior aspect of the calf and popliteal area to connect SSV with peroneal veins; sometimes parallel to the SSV and typically forms a separate junction with the popliteal vein usually lateral to the SPJ. Formerly known as '*Thierry Perforator*'
Thigh PVs	Medial thigh	Connects GSV/ASV with FV/CFV)
	Femoral canal	Formerly known as *'Hunter Perforator'* in the upper femoral canal and '*Dodd Perforator'* in the lower femoral canal. Connects the tributaries of GSV to the FV.
	Inguinal	Connects the GSV (or its tributaries) with the femoral vein at the groin.
	Anterior thigh	Pierces the quadriceps femoris muscle.
	Lateral thigh	Pierces muscles of the anterior and posterior group of the thigh on its lateral aspect. They drain the lateral venous system into the DFV.
	Posterior thigh	Posterior thigh perforating veins include the four subtypes below,
		Posteromedial: Pierces the muscles of the medial thigh
		Sciatic: Lies along the midline of the posterior thigh
		Posterolateral: Formerly known as '*Hach Perforator'*. Pierces the biceps femoris and semitendinosus muscles.
		Pudendal: Are connections between external pudendal vein and internal pudendal vein in the urogenital region, mainly around the vulva
Gluteal PVs	Superior gluteal	Connects the superficial venous system with the gluteal veins and are classified according to their anatomical location. Rarely, the lower gluteal PVs can be a termination point of the SSV
	Mid gluteal	
	Lower gluteal	

Key: ASV; anterior saphenous vein, CFV; common femoral vein, DFV; deep femoral vein, FV; Femoral vein, GSV; great saphenous vein, PV; Perforating vein(s), SSV; small saphenous vein.

Section D: Pre-examination considerations

What is the purpose of venous insufficiency ultrasound examination?

A full lower limb venous insufficiency ultrasound study is recommended as the primary choice of imaging modality for diagnosis and treatment planning in patients with suspected or clinically evident chronic venous disease (CVD). [42] This is supported by published studies showing better patient outcomes for those who undertake a pretreatment duplex ultrasound (US) compared to those who do not and indicating that CT-venography does not offer additional functional information beyond what duplex US can provide. [46]

Duplex US aims to answer the following questions:

1. Is there venous incompetence or obstruction in the deep venous system, such as deep vein thrombosis (DVT) and popliteal vein compression, and to what extent?
2. Is there any venous reflux in the superficial venous system, including both saphenous and nonsaphenous veins? What is the source of reflux, reflux pathway and re-entry point (where the incompetent superficial vein drains back into the deep venous system?)
3. Is there venous obstruction in the superficial venous system, such as superficial vein thrombosis (SVT), and to what extent?
4. What is the number, location and diameter of incompetent perforating veins?
5. Are there any anatomical variations, especially at the saphenous junction with the deep system?
6. What are the diameters of the truncal veins (e.g., GSV, SSV, ASV, etc.) and nontruncal veins (i.e., tributary veins) throughout the thigh and calf? If incompetent, are they suitable for thermal or nonthermal ablation treatment?
7. Are there developmental abnormalities primarily involving the saphenous veins?
8. Is pelvic venous pathology contributing to incompetence of the lower limb veins?

Existing evidence based clinical practice guidelines support the use of duplex US in the diagnosis of CVD for:

- evaluation of venous insufficiency; [78]
- review of treatment results within 3-6 months postsurgery; [79]
- pre- and post-treatment evaluation of an endovenous thermal ablation procedure. [79]
- investigation of varicose veins and venous malformations; [80]
- and evaluation prior to sclerotherapy in patients with recurrent varicose veins; [80]

What are the indications, contraindications and limitations of duplex ultrasound to investigate chronic venous disease.

Indications

Sonographers usually receive requests from vascular care providers to perform duplex US investigation, to aid treatment planning, and make postoperative assessments. [20] Duplex US identifies the source of reflux as well as the locations and patterns of varicose veins. It is important to investigate for the presence of other venous pathologies that can produce symptoms similar to those of CVD (i.e., arteriovenous fistulas, DVT, venous aneurysms and congenital venous malformations and venous claudication). It has a pivotal role in formulating treatment strategies and planning treatment as the superficial venous system is very variable. [20, 42, 81, 82] For treatment planning purposes, it can be used to identify and mark the target vein on the skin with consideration to anatomical variations, tortuosity and distance beneath the skin particularly when preparing for endovenous treatments. [21, 83, 84]

Table D1 summarises the clinical indications for which sonographers receive referrals to perform venous insufficiency scans. It also provides an 'appropriateness rating' developed by authors in another publication [86] for each clinical indication. The clinical indications and appropriateness ratings in this table inform sonographers about the most common reasons patients are referred to them.

Contraindications and limitations

Duplex US for the assessment of CVD may be limited or rarely contraindicated, when the patient:

- is obese;
- has severe oedema and pain in the lower extremity;
- is unable to stand, or unable to stand for a length of time;[#]
- and/or they have open draining ulcers or other obstructions to the ultrasound imaging window. [85]

[#] *It is recommended that sonographers should perform the venous insufficiency studies with the patient in an upright position (see Recommendation G2, Section G), but due to the reasons and risks outlined in Table D2, this may not always be possible. Under the circumstance, adaptations to the procedure or equipment used will need to be made (refer to Section F).*

If an acute SVT or DVT is identified, the sonographer may need to consider terminating the reflux testing and must notify the referring physician immediately. [86]

Table D1: Clinical indications for venous insufficiency ultrasound studies. (adapted from [80])

Clinical indication	**Appropriateness rating**
Active venous ulcer	**Appropriate** (a strong indication for duplex ultrasound as benefits generally outweigh risks)
Healed venous ulcer	
Symptomatic varicose veins (e.g., pain, ache, burning, throbbing or heaviness)	
Visible varicose veins with oedema	
Skin changes associated with chronic venous insufficiency with/without visible varicose veins (e.g. hyperpigmentation, lipodermatosclerosis)	
Mapping prior to venous ablation procedure	
Prior endovenous (great or small) saphenous ablation procedure with new or worsening varicose veins in the ipsilateral limb	
Entirely asymptomatic varicose veins	**Maybe appropriate** (a moderate indication for duplex ultrasound due to variable evidence or agreement regarding the benefits/risks ratio, potential benefit)
Lower extremity pain or heaviness without signs of venous disease	
Spider veins (telangiectasias)*	**Usually not appropriate** (a weak indication for duplex ultrasound due to the lack of a clear benefit/risk advantage). * Duplex ultrasound might be considered if the spider veins are in the distribution of saphenous veins and treatment was being considered. [68] # An initial follow up for deep vein thrombosis 10 days after the ablation procedure may be requested. [84]
Prior endovenous (great or small) saphenous ablation procedure with no residual symptoms#	

Table D2: Potential difficulties associated with the standing position used in venous insufficiency studies (adapted from [87])

Patient may not be able to stand because:	• of uncomfortable/tired/weak/legs • they feel unstable on one leg • they feel like fainting or falling • they have leg numbness • they have back, knee or foot pain
Duplex ultrasound becomes difficult to perform due to patient:	• fidgeting or unable to stay still • sighing • movement during reflux augmentation manoeuvres • becoming weak, dizzy • fainting or falling
Duplex ultrasound becomes difficult for sonographer due to ergonomic factors requiring them:	• to sit on the floor for distal calf assessment • to have difficulty in visualising monitor or reaching keyboard during calf assessment • to get tired or sore neck, arms and back

What patient preparation is required?

No specific patient preparation is required however the following advice may be useful:
At the time of booking, the patient should be informed:

- to allow full distension of the lower limb veins, not to wear compression stockings on the day of the examination, and that they should arrive as warm as possible; [34]
- to dress in clothes that can easily be removed or adjusted to enable access to the groin, and the full lower limb for scanning; [82]
- that an afternoon appointment is preferred for best results;
- that they should advise the practice if they have a preference for a male or female sonographer.

Immediately prior to the examination, and in the privacy of the examination room, the sonographer should:

- provide a clear explanation about the examination, obtain consent and a medical and surgical history (see sections below);
- ask the patient to advise if they are not feeling well or cannot tolerate the examination;
- ask that any compression stockings to be removed, or ask for consent for the sonographer to remove them;
- if appropriate, remove any remove any items that may interfere with acoustic windows such as dressings. Be sure the patient is comfortable with this action, and that if an active ulcer is present take steps to follow infection control protocols. [82]

What explanation should be provided to the patient prior to the examination?

Prior to the examination, it is necessary to have a conversation with the patient so they understand what is going to be done and are informed to provide consent to proceed with the examination [88], which can lead to improved compliance. [81, 82] This conversation includes:

- verifying the patient's identity; [85]
- sonographer(s) introducing themselves;
- with consideration of the age and mental status of the patient, [85] providing a clear explanation of:
  - why the examination is being performed (e.g., why it is important to assess the entire leg rather than just the varicose veins in the calf), how it will be performed and how much time it will take. [85]
  - how ultrasound gel will be applied to the bare skin from the groin to the foot
  - the positions and manoeuvres required (i.e. semierect position, transducer compression, squeezing of the limb, Valsalva manoeuvre and tip toe movement).
- responding to any questions and concerns the patient may have. [85]
- educate the patient about risk factors and symptoms of CVD. [89]
- refer specific questions that fall outside the sonographer's expertise to the referring vascular care provider. This may include questions about diagnosis, treatment or prognosis (e.g., is my leg bad enough to require surgery?). [85]

What medical and surgical patient history should the sonographer collect?

Prior to commencing the duplex US, the sonographer should obtain the patient's medical and surgical history and their current clinical presentation from either the patient or their medical records.
Table D3 summarises history items relevant to the sonographic examination, such as those that inform expected sonographic appearances or technical adjustments that may need to be made during the procedure.

How should sonographers perform physical assessment prior to the examination?

The sonographer should complete a physical assessment of the patient before commencing the duplex US examination. This should also include an assessment of the patient's ability to tolerate the procedure and of any conditions that may limit the procedure. [34]

Visual inspection and palpation of the lower limb is helpful in determining the scope of the scan, [34, 47, 82] identifying sources of reflux, and assists in making the duplex US easier and quicker. It also decreases the probability of missing a relevant finding such as varicose tributaries or an atypical source of reflux. [34, 38, 45, 47, 81]. The sonographer should make visual assessment with the patient standing, thoroughly examining the trunk, both legs, groin, and pubic area, and documenting any visual findings listed in Table D4. Sonographers should be aware that some patients may regard palpation of the groin area as an intimate examination and guidelines for consent, and if applicable guidelines for consent for intimate examinations should be followed.

Refer to:

Guide to Consent for Medical Ultrasound Examinations	Clinical Guidelines: Consent for Medical Ultrasound Scans (sonographers.org)
The Guide to Consent and Chaperones for Intimate Medical Ultrasound Examinations	https://www.sonographers.org/publicassets/023b27c7-047b-ef11-9133-0050568796d8/Guide-to-Consent-for-Intimate-Examinations-Sept-24.pdf

Table D3: Medical and surgical patient history items the sonographer should consider prior to the prior to the venous insufficiency ultrasound scan

History item	Rationale
What are the problem areas related to the veins from the patient's point of view?	These questions will inform the sonographer of the concerns of the patient, which may be different to what is evident to the sonographer. For instance, telangiectasia may or may not be a concern to the patient.
Is the patient able to stand for an extended period of time? Does the patient have any mobility issues?	These questions will inform the sonographer of any difficulties in positioning the patient for the examination, which should be performed in the standing position whenever possible as this ensures accurate and standardised measurements of venous reflux. [81, 86-90] The scanning time may also need to be extended if the patient has mobility issues or cannot stand for extended periods.
Does the patient suffer from fainting?	This question will alert the sonographer to the risk of the patient fainting and prompt the implementation of strategies to minimise this risk, such as lowering temperature of the room, having water on hand, providing breaks from standing, and carefully watching the patient for signs of syncope. It is not uncommon for patients to feel faint or light headed during a CVI ultrasound examination, especially among those in a younger age group. The causes are unknown; however, it may be associated with high room temperature, fatigue, anxiety, motion sickness, and a sudden drop in blood pressure due to reduced venous tone. [34, 91, 92]
Does the patient have any tender areas?	This question alerts the sonographer to areas that they should take care in applying pressure to (i.e., transducer pressure, or augmentation manoeuvres). Possible sources of pain and tenderness are lipoedema, superficial thrombophlebitis, neuroma and fibromyalgia.
Is there a history of deep vein and/or superficial vein thrombosis?	This question can alert the sonographer to existing deep or superficial vein thrombosis, a pathology which should be recorded. Additionally, previous clots in the veins may cause damage to the valves, leading to valvular insufficiency and/or venous obstruction if they reside within the lumen of the veins. [79]
Is there a family history of venous thrombosis?	This question alerts the sonographer to the possibility of existing venous thromboembolism as family history is a risk factor. Genetic risk factors relating to a family history of venous thrombosis include Factor V Leiden mutation, Prothrombin G20210A mutation, deficiency in Protein C, Protein S and antithrombin, hyperhomocysteinemia, and sticky platelet syndrome.
Is there a history of trauma to the lower extremity?	This question alerts the sonographer to potential DVT, secondary CVI and venous leg ulcer. Patients with a leg injury may develop DVT and with later complication such as post-thrombotic syndrome. Secondary CVI can arise due to valvular dysfunction and vein wall damage during a thrombotic event. [50] Local trauma to untreated varicose veins has the potential to lead to excessive bleeding and initiate the formation of venous leg ulcer. [30, 42]
Is there a history of venous ulcers and/or varicosities?	The presence or history of venous leg ulcers or varicosities will alert the sonographer to a focused examination to identify refluxing veins responsible for the ulcer, such as pathologic perforating veins. A venous stasis ulcer is an indicator of chronic venous hypertension and local tissue hypoxia. A high percentage of patients with a venous leg ulcer have primary venous insufficiency, with a lesser percentage having secondary venous insufficiency resulting from post-thrombotic syndrome (20-30%). The recurrence rates for venous leg ulcer can be substantial, reaching as high as 50-70% within six months. [7, 67] If the varicose veins are recurrent, then the sonographer should be aware that they may be filled via unusual sites such as a lateral thigh incompetent perforating or vulvar veins. [20, 81]
Is there a history of heart problems such as congestive heart failure?	This question alerts the sonographer to CVI which is linked to venous hypertension. The backward pressure generated by the heart in congestive heart failure may lead to valve dysfunction. [40, 45, 92]
What medications is the patient currently taking?	This information is useful to know as some medications, such as oral contraceptives, hormone replacement therapy, corticosteroids, are associated with DVT and clotting disorders. Sonographers can then concentrate on identifying any residual thrombi and/or postthrombotic change that could result in venous obstruction. Patients who are on long term anticoagulant therapy (e.g., aspirin, rivaroxaban, apixaban, and dabigatran) may have an increased risk if they temporarily discontinue their medication. [21, 42, 45, 93, 94]
Is there a history of vein surgeries or interventions (i.e., vein ablation procedures, venous stripping, vein harvest, iliac vein stenting for iliac vein compression, sclerotherapy)?	Sonographers performing venous insufficiency ultrasound examinations must have a fundamental understanding of the various treatment options, as different procedures can yield distinct outcomes. For instance, the appearance of a treated GSV varies depending on the treatment. 1. Stripping Surgery: After stripping surgery, the GSV typically becomes no longer visible on ultrasound. 2. Thermal Ablation: Once the GSV has undergone thermal ablation, it may gradually dissolve over time, resulting in changes detectable through ultrasound. 3. Nonthermal ablation/cyanoacrylate glue: The GSV treated with adhesive typically exhibits acoustic shadowing on ultrasound, which can serve as a distinctive feature for differentiation from superficial venous thrombus. 4. Sclerotherapy: sclerosed vein with trapped blood may have similar appearance as superficial thrombophlebitis. Understanding these treatment related changes in the sonographic appearance of the treated veins is important for sonographers to accurately interpret ultrasound images and make informed clinical assessment.
Are there results available for comparison or any other relevant diagnostic procedures?	Having this information; 1. Adds to a patient's health and medical history in order to make the most informed diagnosis that guides the treatment decision making. 2. Allows for cross referencing of different diagnostic information leading to a more precise diagnosis, especially as US is operator dependent. It can also help identify any inconsistency or discrepancy in the results. 3. Asking patients about their past diagnostic procedures can also avoid unnecessary redundancy in testing. Previous diagnostic findings can be used for monitoring patient's progress throughout the course of the treatment.

Visual assessment items (of trunk, both legs, groin, and pubic area, preferably made with the patient standing)	**Rationale**
Surgical scars	Surgical scars indicate to the sonographer that there have been prior procedures, such as ligation, stripping, or stab avulsion, offering clues about the visibility of the veins and affecting the sonographic appearances.
Telangiectasia [45, 47]	These items indicate mild to moderate stage of CVD. It is important to note the location, size and distribution of all visible spider veins and varicosities, as they serve as clues for sources of reflux. In addition, telangiectasia frequently has feeder veins which may require sclerotherapy treatment if the patient has aesthetic concerns.
Reticular veins [45]	
Varicose veins [45, 45]	
Prominent veins of the trunk [45]	Prominent superficial veins at the lower abdomen alerts the sonographer to possible venous obstruction in the iliocaval veins. [45]
Oedema [47, 85]	The presence of oedema in the leg may be caused by venous insufficiency or venous obstruction in addition to other causes such as heart failure, renal failure and liver failure. The presence of chronic oedema (>3 months) should alert the sonographer to the possibility of CVI or post thrombotic syndrome. The presence of acute oedema should alert the sonographer to the possibility of deep vein thrombosis. Venous oedema should be differentiated from lymphoedema. Venous oedema primarily manifests in the ankle or lower calf, with relief after rest or leg elevation, and worsening throughout the day. In contrast, lymphoedema often begins on the dorsal side of the foot and can sometimes be identified by the presence of a positive Stemmer sign. [95]
Skin changes (i.e., pigmentation, eczema) [47, 85]	Skin changes should alert the sonographer to the possibility of chronic venous hypertension as a result of venous insufficiency. Skin changes result from erythrocytes escaping into surrounding spaces (erythrocyte diapedesis). Dermal erythrocytes break down, releasing haemoglobin, ferritin, and hemosiderin. Over time, hemosiderin accumulates in the tissue, along with increased epidermal melanin production, causing discolouration, pigmentation and skin changes. [96-97]
Atrophie blanche (porcelain white scars) [47]	The presence of atrophie blanche, which occurs when the small vessels in the superficial dermis become occluded, should alert the sonographer to CVI due to its association with this condition.
Active or healed ulceration [47, 85]	If active or healed venous leg ulcer is present, the sonographer should be alerted to the presence of CVI caused by venous insufficiency. Venous ulcers are usually large but shallow, with a granulating base and irregular border. Nonhealing ulcers in the medial ankle area are most likely due to underlying venous hypertension. Sonographers should search for pathological perforating veins (e.g., incompetent posterior tibial perforating vein) which play a crucial role in the altered haemodynamic of this area.
Does the patient have flat feet?	If the patient has flat feet, the toe elevation manoeuvre may not be as effective in eliciting venous reflux due to deteriorated calf and foot muscle pump function. A deteriorated foot muscle pump mechanism, secondary to static foot disorder or decreased ankle mobility, can lead to inadequate emptying of blood from the lateral plantar veins and reduced flow into the posterior tibial veins. While patients with static foot disorder have increased risk of developing CVD, no studies have been conducted to assess the difference in augmented venous flow between manual calf squeezing and toe elevation manoeuvres. [8, 51, 98]
At medial calf and medial ankle: Varicose veins, oedema, and skin changes	Alerts the sonographer to great saphenous venous reflux. [45]
Dorsal calf and lateral ankle: Varicose veins, oedema, and skin changes	Alerts the sonographer to small saphenous venous reflux. [45]
Varicose veins in the groin and pubic area	Alerts the sonographer to the possibility of: • Pelvic venous disorder with a reflux source in the abdominopelvic region. (Signs and symptoms arising from pelvic origin may include dysmenorrhoea, dysuria, dyspareunia, symptoms of pelvic heaviness, and exacerbation during the menstrual cycle in multiparous women; • Compression of the common Iliac vein ; • Internal iliac vein incompetence; Compression of the left renal vein. [45]
Lateral varicose veins in the thigh	Alerts the sonographer to: • Insufficiency in the posterolateral perforator veins; • Insufficient ASV (these could also show a ventrolateral course); Embryonic lateral marginal vein remnant and if associated with limb hypertrophy, lymphedema, and/or port wine stain, a Klippel-Trenaunay Syndrome can be suspected. [45]

Key: ASV; Anterior Saphenous Vein, CVD; chronic venous disease, CVI; chronic venous insufficiency.

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. [40, 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 assessment; however, colour Doppler is also an important complimentary tool for assessing vein patency and competency. Measurements of reflux duration *(refer to Recommendation E5 and Table E1) and vein diameters (refer to Recommendation E2 and Table E1)* should also be made.
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, 34, 42, 40, 42, 45, 68, 79,80,81,82,83, 85, 86, 99]

B-mode ultrasound

Normal B-mode sonographic appearance:

On B-mode ultrasound, normal veins have an echolucent lumen, 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 postthrombotic 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. [40,100]
- 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, [9, 42, 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, [30, 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. [30, 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.

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. [111] 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. 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. [34]

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).

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 to 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 Doppler spectral 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. [34] Instead, venous reflux should be recorded and documented using a representative Doppler spectral 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. [34, 44, 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 24).** In normal veins, flow reversal will be seen for a short period as normal valves do not close instantaneously **(Image 25)**.
- 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. [34] 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. [30] 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. [34]
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. [34] 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. [34, 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 durations 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. [42, 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.
Sonographers should also identify, assess and record any venous malformations and anatomic variants. In primary venous insufficiency, the pattern of refluxing veins is mostly "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. [34]
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. [40]

Table E1: Summary of assessments 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 26)**. 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 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. [40]
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 27).** 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. [40] 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 (Yes/Optional)	Optional	situations where it might be measured: When 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, when reflux is suspected, but not demonstrable. [119]
Femoral vein (FV)		
Assessment	**Comments**	
Visualise	Yes	-in B-mode, the FV should be evaluated every 1-2 centimetres in transverse for compressibility and post-thrombotic 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	The FV should be assessed at least once. If FV or popliteal 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 (Yes/Optional)	Optional	situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >16mm), [120] if the FV is hypoplastic in the presence of embryonic vein remnants draining flow from the lower limb, if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable.
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 (Yes/Optional)	Optional	situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >13mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the vein is, or is suspected of being aneurysmal or compressed.
Saphenofemoral junction (SFJ) **Note:** Many primary lower extremity varices are caused by reflux at the level of the SFJ. [34]		
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 (see diagram below).
	No (if not present)	-GSV stripping and flush ligation may have been performed if the SFJ cannot be identified.

Test for venous obstruction	Yes	-systolic reflux during provocation manoeuvre indicates venous obstruction in the femoroiliac veins **(Image 28)**. -continuous flow at the SFJ may indicate obstruction in the femoropopliteal veins if the GSV or pelvic tributaries act as collateral drainage **(Image 29)**.
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). [34]
Measure vein diameter (Yes/Optional)	Yes	-large diameter (e.g. >9mm) of the GSV at the SFJ is associated with increased risk EHIT.
Useful references	**Image 30,31,33 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, 34, 112]		
Assessment		**Comments**
Visualise	Yes, if present	-note any changes in 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 34)**. -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 35)**.
Measure vein diameter (Yes/Optional)	Yes	-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 Labropooulos 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 (Yes/Optional)	Optional	-at 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. situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
Useful references	The fate of the ASV reflux (Figure 11 in Caggiati, A., et al 2024) [126]	
Posterior Accessory 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. [38]
Measure vein diameter (yes/optional)	Optional	-measure maximum diameter situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
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 nonSFJ reflux according to Jiang et al. [128] 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). [127]
Measure vein diameter (Yes/Optional)	Optional	situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable.
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 (Yes/Optional)	Optional	situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
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 (34), can travel down to the GSV, resulting in GSV incompetence.
Measure vein diameter (Yes/Optional)	Optional	situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
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, 34, 113]		
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 [129] -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 **(Image 37,38)**.
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 (Yes/Optional)	Yes	-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. [130]
Useful references	Combined classification of the saphenopopliteal junction (Figure 2 in Veselá, M., et al. 2024) [131]	
Small saphenous vein (SSV) Incompetence of the SSV is the second most common cause of primary lower extremity varices. [22, 34, 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 inter-saphenous 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 -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 (Yes/Optional)	Yes	-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) [132] SSV reflux by location (Table 1 in Neuhardt et al., 2009) [133]	
Thigh extension of 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 flows exhibiting an antegrade direction, indicates possible venous obstruction in the femoropopliteal venous segments. -isolated superficial vein thrombosis in the TE is uncommon, and SSV thrombus rarely extends into the TE. However, if venous reflux is present and endovenous ablation, such as cyanoacrylate glue, is planned for obliteration, the patency of the TE should be evaluated along its entire length.
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 39)**.
Measure vein diameter (Yes/Optional)	optional	situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
Un-named tributaries		
Assessment		**Comments**
Visualise	Yes	-normal tributaries usually do not require further testing unless there are incompetent intercommunicating vessels. [34] -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 (Yes/Optional)	Optional	-measure at the site of the maximum diameter Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation,
Perforating veins (PV) Perforator incompetence can either be the cause of CVD or a consequence of it. [34]		
Assessment		**Comments**
Visualise	Yes	-search for perforators 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 perforators 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 perforators 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. - if thrombus is evident during the testing for venous reflux, it may have effects on the detection of reflux in the PV. - if thrombus or deep vein sclerosis following venous procedures is identified in the PV, the extension should be assessed and consideration should be given to performing a full DVT study.
Test for venous reflux	Yes	-all perforating veins >3m in diameter 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 40-46)**.
Measure vein diameter (Yes/Optional)	Optional	-only measure perforating veins ≥3.5mm in diameter or if they demonstrate reflux, at the level of the deep fascia. [134] -measure distance of perforator from landmark such as medial malleolus or knee skin crease Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
Non-saphenous veins:		
Vulval Varicosities		
Assessment		**Comments**
Visualise	Yes	-varicose veins appear near the labia minora and labia majora **(Image 47)**. -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 (Yes/Optional)	Optional	-measure at the site of the maximum diameter. Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
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 (SNV) **(Image 48)**. -the gluteal perforator can be difficult to visualise due to its small diameter **(Image 49)**.
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	Optional	-measure at the site of the maximum diameter Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable.
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. -at the popliteal fossa, these veins pierce the muscular fascia before emptying into the popliteal vein **(Image 50)**.
Test for venous obstruction	No	
Test for venous reflux	Yes	-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 perforator **(Image 51)**.
Measure vein diameter (Yes/Optional)	Optional	-measure at the site of the maximum diameter. Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable
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 52,53)**.
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 (Yes/Optional)	Optional	Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
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 54)**.

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 55)**.
Measure vein diameter (Yes/Optional)	Optional	Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable
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 56)**. -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 57)**.
Measure vein diameter (Yes/Optional)	Optional	Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
Useful references	Diagrammatic presentation of the nonsaphenous veins and their tributaries in the lower extremity (Figure 1 in Labropoulos et al. 2001) [135]	
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 **(Image 58,59)**.
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 perforator incompetence
Test for venous reflux	Yes	-during diastolic phase/relaxation, reflux flows out of the PTV feeding the subcutaneous varicosities.
Measure vein diameter (Yes/Optional)	Optional	Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable, if the treating/referring doctor requests it or protocol directs it.
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 60)**.
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 61)**. -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 GSV, ASV or other varicose veins.
Measure vein diameter (Yes/Optional)	Optional	-measure at the site of the maximum diameter Situations where it might be measured: When there is venous reflux, if vein is dilated (i.e. focally dilated without venous reflux, >3mm), if the vein appears to relate to the clinical presentation, when reflux is suspected, but not demonstrable,
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. [34, 40, 42, 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 collaterals.*	-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. [40]
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. [34]
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. 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, thick 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. 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 observed 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 64)** 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 65)**. 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 66)**. Immediately below the ligation, there may be a reduction in the diameter of the GSV compared to preoperative measurements. [136]

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]

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 67)**. Despite a decrease in diameter, varicose tributary veins may still exhibit persistent reflux.

Post-treatment instructions for the sonographer

- Assess treated and untreated veins [42] 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 nontreated veins may be assessed for reversal of venous incompetence for consideration of future treatment.

Specific to post-endovenous procedure, the sonographer should:

- Assess for endothermal heat induced thrombosis (EHIT) **(Images 68-72)** or endovenous glue induced thrombosis (EGIT) **(Image 73)** which can occur at the saphenofemoral or saphenopopliteal junctions.
- Assess for deep vein thrombosis (DVT) and deep vein sclerosis (DVS) **(Image 74)**.

- 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. [144] 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 x (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. [34]

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 an 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, pelvic or gluteal veins, 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 75 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 compressible or noncompressible with internal echogenicity.
Seroma/seroma (Image 76 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 77 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 filled low level internal echoes in fresh or liquefied haematomas and 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. [137]
Nerve injury (Image 78 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. [138-140]
Cutaneous necrosis (Image 79 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. [141, 142]
Membranous fat necrosis: (Image 80 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. [143]
Intraluminal neovascularisation within partially treated vein or thrombosed vein (Image 81 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 82 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 83 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 84)	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 74 in Image Gallery)	Is an adverse sequela that can occur postsclerotherapy, resulting from the extension of the sclerosant into the deep veins through connecting perforators. 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	Treatment: 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 followup.	• A normal postflush ligation 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 GSV ablation, and vice-versa. • Less frequently, PAGSV and Giacomini vein may have a role in recurrence. • 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 reduction 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 whole length of 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 perforator 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 followup, 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 85 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. [144] 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. [145]
Lymphoedema **(Image 86,87 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. Lymphedema is an important differential diagnosis in lower limb swelling. [146] 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. 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. [147] It has also been suggested that an unclear lower junction between the dermis and subcutaneous tissues is a possible marker of lymphedema. [148] 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. [147]
Lipodema **(Image 88,89 in Image Gallery)**	Lipedema is a chronic condition, the hallmark of which is a disproportionate distribution of body fat on the extremities. [149] Sonographic appearances: The thickness of the skin and subcutaneous tissues combined are thicker in patients with lipedema compared to patients without lipedema. 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 of lipedema. [148] Lipoedema differs to lymphoedema in that the dermis looks normal, with no dermal thickening as seen in lymphoedema. [149] A significantly thicker and less echogenic subcutaneous fat layer has been demonstrated, using 20 MHz transducer frequency, in patients with lipedema 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 lipedema. [150]
Lipoma **(Image 90 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
Arteriovenous malformation (AVM) **(Image 91 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. 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 and cutaneous ischaemia and ulceration and haemorrhage in severe in extreme cases. High output cardiac failure can occur with large arteriovenous shunts. [152] 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.[153]
Venous malformation	Venous malformations are a low flow vascular malformation. In the extremities, pain is a common symptom which can lead to joint dysfunction and walking disabilities. [154] 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

(Image 92 in Image Gallery)	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. [153, 155] 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. [153, 155]
Muscle Hernia (Image 93 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. 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. [156, 157]
Baker's cyst (Image 94 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. [158-160]
Nerve tumours (Image 95 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. [162-164]
	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 efined, 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 efined, 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. [164-167]
Klippel Trenaunay syndrome (KTS) (Image 96 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. [168] 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. [66, 167] In 20% of people with KTS, embryonic remnants will occur. [170,171] 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. [172]

Section F: General considerations

What qualification or training is required for sonographers performing duplex ultrasound to investigate chronic venous disease?

Recommendation F1: We recommend that sonographers who perform duplex ultrasound in Australia and New Zealand to assess for chronic venous disease in the lower limb should have a recognised qualification. Student sonographers should be supervised by a sonographer or other qualified specialists in vascular ultrasound who have experience in performing venous insufficiency scans.

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

Summary Statement

Two existing evidence-based guidelines [9, 60] recommend that personnel who perform duplex ultrasound for CVD are credentialled or qualified. Direct evidence to support this in not available, however based on a survey of American sonographers in relation to carotid ultrasound, [173] sonographers themselves are likely to believe that qualification is important to reduce unnecessary repeat examinations, and limit examinations performed in a technically inappropriate manner. Accreditation was also identified as in important factor in examination quality in a survey of staff of Intersocietal Accreditation Commission (IAC) accredited vascular testing facilities in North America. [174] A key feature of the standards used for this accreditation is credentialling and continuing education of all staff. Other existing guidelines also recommend sonographers performing venous insufficiency examinations should be appropriately credentialled. [83, 84, 175]

In Australia, qualified sonographers must meet the educational requirements to be eligible for registration with the Australian Sonographer Accreditation Registry (ASAR) as either an accredited general or vascular sonographer. [34] Benefits under the Medicare Benefits Scheme (MBS) are only payable if the sonographer is suitably qualified, involved in a relevant and appropriate Continuing Professional Development (CPD) program and are registered on the Register of Accredited Sonographers held by Services Australia. [176] In New Zealand, credentialled or qualified sonographers will have met the educational requirements to be registered as a sonographer with the New Zealand Medical Radiation Technologists Board (NZMRTB).

Although the sonographers in Australia and New Zealand undergo rigorous training and education to qualify for their roles, it is essential that they not only meet the required credentialling standards but also feel comfortable and confident in performing the examinations. The body of knowledge required by a sonographer includes a thorough understanding of the anatomy (including common variants) and nomenclature, physiology, pathophysiology, and the clinical course pertaining to CVD, as well as ultrasound physics and instrumentation. [21, 175] Training should include theoretical information, practical training and clinical training. [81] This guideline establishes the groundwork for duplex ultrasound examinations for CVD, emphasising the importance of standardised protocols irrespective of the service location and the varying levels of expertise. Using this guideline will enhance diagnostic accuracy, reliability and repeatability. In addition, we strongly encourage sonographers to actively engage in CPD to stay abreast of the latest advancements in ultrasound technology, diagnostic techniques, and venous treatments. Upholding CPD practices ensures that sonographers maintain and improve their knowledge and skills, ultimately enhancing the overall quality of patient care.

In this guideline we do not make a recommendation of how much clinical training is required for a sonographer to gain competence in duplex ultrasound for CVD, as this will vary by sonographer. Indeed, existing published requirements and estimates for the number of cases required to achieve competency vary widely. For example, it has been suggested that a minimum of 250-400 supervised venous insufficiency examinations is appropriate, [34] but the IAC recommends 100 cases. [177] The requirement to obtain the Certificate in Clinician Performed Ultrasound (CCPU) issued by Australasian Society for Ultrasound in Medicine (ASUM) [178] is a minimum of 50 venous insufficiency ultrasound scans of the lower extremity, whereas the Society for Vascular Technology of Great Britian and Ireland recommend at least 600 scans, and at least three years full-time equivalent scanning experience. [179]

What are potential limitations and difficulties that may be encountered in the examination?

Sonographers should record on their worksheet or sonographer report if they encountered any limitations or difficulties when performing the examination. The scan may also require an extended time to ensure a complete examination.

Difficult body habitus

Duplex ultrasound (US) can be technically compromised due to difficult body habitus, such as obesity. Common areas that are difficult to visualise include the groin for imaging the common femoral vein (CFV) and saphenofemoral junction (SFJ), the adductor canal or lower thigh for the femoral vein (FV), and the calf for both deep and superficial veins. Strategies to improve imaging include patient position to improve venous distention (erect or reverse Trendelenburg), and using a lower frequency transducer. [83,113]

Ineffective provocative manoeuvres

Assessment of venous incompetence relies on creating a sufficient pressure gradient across the venous segment under examination using effective provocative manoeuvres.

The adequacy of the augmentation manoeuvre is sufficient if a spike of forward flow during the manoeuvre can be visualised; if the response is insufficient then alternate augmented methods should be used. If augmented forward flow is not detectable during the proper application of augmentation manoeuvre, then venous thrombosis should be suspected.

The adequacy of the Valsalva manoeuvre is sufficient if there is cessation of forward flow with the manoeuvre. If the patient has difficulty understanding or performing the actions needed for an effective Valsalva manoeuvre, the sonographer can simulate this manoeuvre by instructing the patient to take a deep breath and resist pressure that is applied to the abdomen while holding his or her breath. The sonographer pushes on the patient's abdomen during the breath hold, and the patient's resistance to the push simulates the Valsalva manoeuvre. [40]

Patients with small veins that need assessment

The smaller the veins, especially minor cosmetic veins, the more difficult they are to assess. It is helpful to book patients with minor varicose veins towards the end of the day as incompetence usually worsens over the course of the day. The room should be warm, and sometimes performing the duplex US examination in a lighted room will ease locating the veins. The patient should be asked where the problem veins are in case they are not easily evident. [34]

Right Heart failure

Cardiac disease and CVD often coexist in elderly patients. Clinically, these patients commonly present with bilateral leg oedema, a sensation of heaviness, and/or leg ulcers. When right atrial pressure is elevated, venous waveforms may display pulsatile reversed flow on spectral traces, creating a deceptive appearance of reflux flow **(Image 97,98)**. It is essential to differentiate this from venous reflux resulting from valvular failure. When performing a duplex US examination, a straightforward compression of the SFJ with a demonstrated absence of pulsation in the GSV, provides confirmation that venous backflow is caused by right heart failure. [180]

Immobile patients, patients who have difficulty standing

A step stool with a handle can be beneficial for patients, providing them with a secure grip and a sense of safety. Positioning the patient directly in front of or leaning onto the bed can reduce patient fatigue. Patients with arthritis or osteoarthritis may experience pain and tiredness when standing on one leg, requiring short breaks for rest. Care should also be taken when scanning vulnerable patients, such as elderly frail patients or those with dementia, who may struggle with maintaining their balance. For patients unable to bear weight or at a higher risk of falls, duplex US examination in the reverse Trendelenburg position is recommended, particularly if a tiltable bed is available.

Fainting

It is not uncommon for patients to feel lightheaded, dizzy, or even faint during the duplex US examination for CVD due to the standing position, especially among younger patients. The exact cause of vasovagal syncope is not yet clearly understood. However, it may be related to the dilation of the veins in the upright position and insufficient blood flow to the brain, attributed to a neurological reflex.

The main concern with vasovagal syncope is that the patient may fall and become injured. Therefore, sonographers should closely monitor the patient for signs such as the onset of a hot flush, sweating, pale skin, and silence. Sometimes, turning off the Doppler sound effect can also help patients reduce anxiety and emotional stress. Other preventative measures include recommending that the patient eat meals before the duplex US examination, maintaining good ventilation in the scanning room, using a step stool with handles, having a second person assist the patient with standing, advising the patient to avoid watching the ultrasound screen, and maintaining constant communication with the patient during the scan. In case of faintness, the patient should be advised to quickly sit or lie down with the leg elevated. First aid procedures and relevant departmental protocols should be followed. Medical support should be sought if necessary. [34, 82]

Wounds

Venous leg ulceration (VLU) resulting from CVI accounts for 70-80% of lower limb ulcers.[30] Ultrasound has proven effective in identifying the source(s) of reflux responsible for VLU. Patients with VLU typically exhibit multilevel disease affecting deep, superficial, and perforating veins. [44] in one study, an insufficient perforator could be found as in 32% of legs with a chronic venous ulcer. [181] Therefore, assessing perforator incompetence within the ulcerated area is crucial for the management of VLU. According to Society for Vascular Surgery and the American Venous Forum guidelines (2024), [9] refluxing perforating veins (outward flow exceeding 0.5 seconds) are defined as "pathologic" if they have a diameter of more than 3.5 mm.
The care for VLU should be provided by wound care specialists or nurses, and the approach to removing wound dressings for duplex US examination may vary based on individual professional preferences and institutional protocols. If the dressing is retained, and veins in the ulcerated area are not imaged, the ultrasound report should include this information at a minimum. When investigating veins in the ulcerated area, a sterile ultrasound probe cover and gel should be used. Provocation manoeuvres for testing reflux in superficial or perforating veins should be applied away from the ulcerated region. If the ulcerated area is above the saphenous or peroneal nerve, performing calf compression may be painful. Using a soft wool dressing can help disperse the pressure during compression.

Are there any ethical concerns?

Sonographers should refer to the ASA Sonographer Code of Conduct asa sonographer code of conduct (sonographers.org) and any relevant specific national, state, or local policies or procedures.

There would be few reasons to deny a patient this venous insufficiency examination due to its low risk. [43] Examples would be patient refusal, or threat to patient or sonographer safety after reasonable step to mitigate safety risks have been considered or implemented. Sonographers should engage in shared decision making with their patients. Duplex US is a low-risk procedure and therefore written consent is not required unless otherwise indicated by local protocols.

In the case of examining children, safe and sensitive practice should be adhered to. Although not common, children may present for duplex US evaluation of the lower limb veins due to Klippel-Trenaunay syndrome or post-thrombotic syndrome. Venous disease in school-aged children has been estimated at 0.2% to 2.9%, and the incidence of physiologic venous reflux described as approximately 13% in children aged 14 to 16 years. [182]

Assessment of the groin is necessary when performing duplex US for CVD. This should be explained by the sonographer, with the reasons why this is necessary, and the sonographer should recognise any cultural sensitivities. In some cases, it may be considered necessary to offer a chaperone. [82]

Refer to:

Guide to Consent for Medical Ultrasound Examinations	Clinical Guidelines: Consent for Medical Ultrasound Scans (sonographers.org)
The Guide to Consent and Chaperones for Intimate Medical Ultrasound Examinations	https://www.sonographers.org/publicassets/023b27c7-047b-ef11-9133-0050568796d8/Guide-to-Consent-for-Intimate-Examinations-Sept-24.pdf

When should a bilateral examination be performed?

A number of existing clinical guidelines comment as to whether a bilateral examination should routinely be performed. One clinical guideline states that both limbs should be investigated even if only one limb shows evidence of venous disease. [81]. Three clinical guidelines state that the decision to perform a bilateral or unilateral assessment would depend on the patient's clinical presentation, [38, 82, 84] and therefore the decision is usually based on the referrer's preference. All four of the identified clinical guidelines addressing this question were in agreement that department policies should be followed. [38, 81, 82, 84] The trade-off between identifying CVD in a leg without symptoms (in a bilateral examination) compared to the productivity gains in performing unilateral examinations needs to be considered. One study demonstrated that in 95% of patients who had bilateral scans, a unilateral scan was sufficient to inform the treatment [183] Sonographers should be guided by their referrer preferences and departmental guidelines. If a unilateral examination is performed, and transmitted pulsatility or loss of phasicity in the CFV is detected, then a spectral trace of the contralateral CFV would be beneficial to confirm the influence of either a cardiac cause or an intra-abdominal or pelvic obstruction. [45, 84]

What instrumentation and settings are required to perform the exam?

Room requirements and preparation

The duplex US examination should be performed in a room where the lighting can be adjusted to settings for good visualisation of the lower limb to establish the distribution of varices and skin changes, and for optimum visualisation of the images on the visual display monitor of the ultrasound machine.

The examination room should be warm to promote vasodilation and to avoid vein constriction which can occur in a cold environment. [45, 81] It is preferable to perform the examination on a hard, hydraulic, tiltable table with foot supports, brakes and up and down movement capabilities **(Images 99-102)**. [34, 45, 86] This facilitates patient and sonographer positioning for an optimum examination and safety. If a tiltable table is not available, then appropriate support should be provided for the patient to accommodate standing and semi-erect positions with weight bearing on the contralateral leg, or the sitting position. [109] A second person may be helpful in these cases to provide additional support to the patient and relieve sonographer ergonomic stresses.

Equipment:

An ultrasound machine is required to have real-time B-mode, colour and spectral Doppler duplex/triplex imaging capabilities [21, 44, 45] and digital storage capabilities. [85]

A range of transducers should be available, to allow for imaging of all veins at the highest clinically appropriate frequency, understanding the trade-off between resolution and beam penetration. [44, 83, 85] Higher frequencies should be used to investigate the superficial veins, and lower frequencies may need to be used to assess deep veins, or the veins of patients with obesity or oedematous limbs. Transducers with linear footprints are the most suitable, but in some cases, it may be necessary to use a curved array transducer. [43, 45, 48]

Regular equipment maintenance should be planned and performed on all equipment used for vascular ultrasound. [83, 109]

Ultrasound Equipment Settings:

The settings of the ultrasound equipment should be optimised for the depth and location of the target anatomy. [113] If focal zones are adjustable, the focal zone(s) should be set at the deep wall of the vein of interest. [45, 81]

B-mode

The gain and TGC should be set so that the imaged vein can be clearly distinguished from its surrounding connective tissue. Fine-tuning the TGC at the appropriate depth, placing the focal zone just below or at the level of the area of interest, reducing the dynamic range, and utilising rejection, edge enhancement and speckle noise reduction imaging can enhance contrast resolution. This allows for better delineation of the vessel wall and a clearer visualisation of the vein lumen in the absence of thrombosis or red blood cell aggregates. The vein lumen is normally echo free, unless cell aggregates are present with very slow flow, in which case slow moving echogenic foci will be seen. [45, 81]

Colour Doppler

Colour gain should be optimised for wall-to-wall filling. If set too high, the colour may "bleed" into the surrounding tissues and obscure any disease that is present. If set too low, false intraluminal defects may be demonstrated. [81, 113] It is conventional to use blue to represent orthograde venous flow towards the heart and red for the retrograde or reverse (venous reflux) flow away from the heart. [81] However, the sonographer should be aware that the colour representation can vary depending on the orientation of the transducer and the path of the vein. Colour inversion could potentially cause a misinterpretation of the flow direction in the examined vein.

Low flow settings are also required to detect slow venous flow. [81] This includes a low colour scale (or pulse repetition frequency) at 4 to 14 cm/seconds, a low to medium wall filter and a medium-high colour persistence. [113]

In the past, it has been necessary to reduce the colour box size to achieve acceptable frame rates or temporal resolution. Current, modern, high-end ultrasound equipment with multiple beam formers allows for faster acquisition of image frames even with a large colour box placed at considerable depth. The colour Doppler box should be placed with a favourable Doppler angle such as ≤ 60°. [34]

Spectral Doppler

Similar to colour Doppler, spectral Doppler should be performed using a favourable Doppler angle ≤ 60° [34] and low pulse repetition frequencies and wall filters, with an appropriate sample gate based on the size of the interrogated vein to demonstrate low flows. [45, 81, 113]

To demonstrate valve closure and differentiate it from noise artefact, a slow sweep speed is required to avoid interpreting it as reflux. [113] Venous flow must be documented below the baseline prior to augmentation to validate flow reversal above the baseline. [177]

If aliasing artefact occurs, the Doppler scale and baseline should be adjusted to avoid the Nyquist limit. [112]

Ancillary equipment

- A cuff inflation system is optional, depending on the availability and preferences of the sonographer. [85]
- A tape measure or ruler, and/or a method of marking the skin may be useful to indicate the position of specific veins, such as perforating veins, in relation to a surface landmark.

How long should the venous insufficiency ultrasound examination take?

Examination time will vary depending on local protocols, the condition of the patient, the clinical complexity of the investigation, and the experience of the sonographer. Despite these variations it is useful to provide a recommended length of appointment time for booking purposes. The Society for Vascular Ultrasound (United States of America) recommends 45 minutes for a unilateral examination, and 70 minutes for a bilateral examination.[85] Similarly, 30-45 minutes has been recommended for a unilateral examination and 60-75 minutes for a bilateral examination.[34] In a recent survey of Australian sonographers (respondents n=97), the

most commonly allotted appointment time for a unilateral examination was 30-45 minutes (46.4%), and an allocation of greater than 60 minutes was only reported by two sonographers.[64] Another study reported examination times to average from 50-70 minutes, but it is unclear if this was for a unilateral or bilateral examination.[87]

Unilateral study: It is reasonable for a unilateral booking to be 30-45 minutes (a longer time may be required if sonographer is required to produce schematic/worksheet at end of the appointment)

Bilateral study: It is reasonable for a bilateral booking to be 45-90 minutes (a longer time required if sonographer required to produce schematic/worksheet at end of appointment)

What are relevant safety issues, and risk of injuries? How should they be mitigated?

Published studies have established the prevalence of work-related musculoskeletal disorders in sonographers, with reported incidence rates as high as 98%. Among all vascular ultrasound scans, venous insufficiency (VI) and vein mapping of the lower extremity veins are recognised as physically challenging with difficulties primarily attributed to the standing position which is essential for accurate venous reflux testing.

Sonographers have the right to adapt, shorten, or discontinue the scan if they feel that either the patient or themselves are not safe. An account of adapted or shortened examinations, with justifications should be documented, together with any alternate arrangements or suggestions.

Ergonomics

Workplaces offering VI scanning should provide their sonographer workforce with equipment that offers ergonomic solutions to minimise the risk of work-related musculoskeletal disorders. If augmentation or calf squeeze, which is considered the most effective method for eliciting reversed flow, is performed without considering ergonomics or without access to appropriate equipment, sonographers can find themselves performing the test in uncomfortable positions. For instance, they may have to bend over and reach down to enable manual augmentation with the non-scanning arm, engaging in static and extended arm abduction, maintain a stable transducer position without any arm support for prolonged periods, and endure excessive twisting of the torso and/or neck due to the need to watch the screen while performing the assessment. [89, 184-187]

Both patient comfort and sonographer experience can be improved by scanning the patient in a reverse Trendelenburg position when a tiltable bed is available. To minimise the strain of repetitive manual augmentation, the toe-elevation manoeuvre may be used as an alternative. Alternatively, the use of powered augmentation devices can be used. An ultrasound system with a height-adjustable control panel can be beneficial, eliminating the need for the sonographer's non-scanning arm to reach up for controls. This can be further extended by setting up a second display monitor on the floor or attaching the screen to the bed with a rotating arm to reduce the need for head and neck rotation. Back posture may be improved by having the sonographer sit on a yoga ball or a low chair. Examples of ergonomic room setups can be found in the Image Gallery **(Images 99-102)**.

There are several established guidelines that can be followed for the purposes of improving ergonomics and alleviating the risk of injuries due to the awkward scanning posture. Other strategies to minimise injury include maintaining a varied case mix, reducing the number of scans performed by one sonographer in a day and avoiding consecutive VI scans.

Refer to:

- Guidelines, Policies and Statements ASA and ASUM joint Guidelines for reducing injuries to all Ultrasound Users (2020) ASA-ASUM_WRMSD_GL-Web-Version-11-2020.pdf (sonographers.org)

Infection Control

Sonographers should follow infection control guidelines.

- ASA Clinical Statement: Infection prevention and control (2021) UPDATE---PUB_0874_CS-Infection-Prevention-and-control-update.pdf (sonographers.org)
- ASA Clinical Statement: Safe use and storage of ultrasound gel (2021). PUB_0872_Safe_Use_and_Storage_of_Ultrasound_Gel_FEB21.pdf (sonographers.org)

ALARA (As Low as Reasonably Achievable) principle

The use of diagnostic ultrasound is considered safe if used prudently. [188] Sonographers should be aware of the thermal index (TI) and the mechanical index (MI) when scanning. The TI indicates the potential for tissue heating, and the MI indicates the potential for non-thermal effects. Sonographers should aim to keep these indices as low as possible when scanning, without compromising the diagnostic value of the examination, and keep examination times as short as possible.

How should the venous insufficiency examination be reported?

The sonographer who performs the examination must be able to correctly interpret and report their findings in accordance with local protocols. The sonographer must document the ultrasound examination to allow proper interpretation by referring doctors, reporting physicians and vascular care providers. This includes the recording of B-mode, spectral (with Doppler flow demonstrated below the baseline prior to reflux provocation manoeuvres to validate flow reversal demonstrated above the baseline), and colour Doppler images. Additionally, the sonographer should provide a detailed outline of sonographic findings using standardised text and a vein mapping worksheet (schematic diagram). The schematic diagram, illustrating venous anatomy, anatomical variations, vein diameter, and venous competency, is a core element in facilitating understanding of the venous system and haemodynamics, aiding in determining the suitability of target veins for appropriate treatments. Enhancing the schematic diagram by using colour coding and symbols to denote pathologies can improve its effectiveness for result interpretation and communication (see *Supplementary file 3*). Video recordings may be useful but are not usually required. [34, 42, 48, 81, 82, 113]

The outline of sonographic findings (otherwise referred to as sonographer report or preliminary report) should be provided to the reporting doctor or appropriate health care provider as soon as practicable after the examination. This should be provided urgently in cases where the result of the examination requires immediate medical attention. [82] Examples are bleeding ulcer, superficial or deep venous thrombosis.

Specifically, the following should be recorded:

Patient and examination information

- Patient full name, date of birth and ID number when available
- Date of the examination
- Time of the examination
- Sonographer's initial and surname
- Patient history and clinical information: this information may be sourced from the referrer, existing medical records, the patient's symptoms at the time of the examination, clinical observations or tests (e.g. presence of visible clinical signs, such as varicose veins and their locations) made by the sonographer at the time of examination or reports from past imaging examinations. It is necessary to record information that is relevant to the duplex US examination, the clinical question or any incidental findings. Note should be made of any variations to clinical presentation as described by referrer or change in patients' clinical presentation since previous duplex US examinations.
- Technical considerations
    - the position that the patient was examined in.
    - which leg (s) was examined, and which veins were assessed.
    - the method of reflux provocation manoeuvre (is useful but not essential)

    - any limitations to the examination, including those affecting image quality, or the ability to answer the clinical question.
    - if the examination was extended or reduced in scope from departmental protocol, with justifications provided. This includes variances relating to patient or sonographer safety.
- Diagnostic Findings
    - The answer to the clinical question. In the case of duplex US for CVD this would normally include 1) the location, extent and sonographic appearance of thrombus if present, 2) the location and extent of refluxing veins and varices, 3) the affected veins within the refluxing venous pathway including the source of reflux and connecting tributaries, 4) measurements of vein diameter and reflux duration when applicable, 5) anatomical variations, differential diagnosis or complications relevant to the clinical question, and 6) comparison with previous duplex US examinations.
    - In cases of recurrent varices (i.e. post-surgery), it is useful to determine and record if a recurrence has occurred at a previously ligated junction or whether a previously treated saphenous trunk has recanalised.
    - The reflux duration thresholds used to identify refluxing veins should be defined.

B-mode images

- Transverse images with and without transducer compression, demonstrating patency of the veins assessed (optional).
- If DVT or SVT is present:
    - Its extent
    - Length
    - Appearance of the thrombus by echogenicity to characterise as acute, non-acute or post-thrombotic scarring (chronic).
    - Obstruction (occlusive vs non-occlusive).
    - If a thrombosed vein has recanalised, become incompetent and to what extent?
    - How far from the saphenofemoral or saphenopopliteal junction is the thrombus?
- The diameter of the veins when measured.
- The presence of sonographically visible varices and their location.
- The presence of any veins that are aneurysmal, hypoplastic, absent, or have been removed for bypass grafting or stripped.
- Anatomical variations that could potentially complicate treatment or reflux pathways.
- The presence of any differential diagnosis, incidental findings or complications.

Spectral Doppler images

- Representative images of the veins that have been assessed using reflux provocation manoeuvres, with reflux duration measurements using calipers if reflux is demonstrated. Ideally, reflux should be demonstrated according to conventions. I.e., normal venous flow is displayed below the baseline, and reversed flow (reflux) should be displayed above the baseline. As a cautionary note, anyone interpreting images should be aware of how to interpret flow direction on images.
- Any additional images that demonstrate location and extent of reflux, if possible, its origin and drainage.
- Doppler waveforms distal to suspected obstruction.
- Sampling of the treated vein with appropriate settings, showing successful ablation or sclerosis.

Refluxing veins

- All contributing sources of venous reflux and their location (e.g., incompetent SFJ, perforators, tributary veins originating from non-saphenous origins such as perforating veins or pelvic veins).
- The location and extent of incompetent venous segments.
- Which veins constitute the reflux pathway including saphenous vein and connecting tributaries.

- Any pathology relevant to the venous incompetence or in close proximity to the incompetent veins. Record its nature and location.
- If reflux is segmental or axial.
- Measurement of the length of a straight incompetent vein, together with selection of an access point, measurement of the depth for any sub-fascial segment, and identification of any impediments to the passage of a guide wire or catheter/fibre are beneficial for the treatment process.
- The presence and location (measured from a landmark such as groin, knee crease or ankle malleoli) of perforating veins near active or healed venous ulcers.

Colour Doppler

Colour Doppler is a useful adjunct to the examination, by providing rapid assessment of veins. However, the recording of colour Doppler images in cine loop is only necessary if the pathology being demonstrated is not possible with spectral Doppler imaging. Reflux by colour Doppler images should be demonstrated according to conventions. I.e., red is for reverse flow (reflux). As a cautionary note, anyone interpreting images should be aware of how to interpret flow direction on images.

What criteria should be used to triage patients by urgency for performing and reporting the duplex ultrasound Examination?

Urgency for ultrasound examinations is usually determined by clinicians (e.g., general practitioners, vascular surgeons, dermatologists) who have medical training, and have holistic knowledge of the clinical needs of their patients. This enables them to make informed decisions regarding the priority of the scan based on individual patient's clinical conditions.

In the absence of a medical practitioner at the ultrasound facility, sonographers can adopt an existing evidence-based approach for scheduling an ultrasound appointment, provided a valid ultrasound request is available. They should also prioritise the issuing of preliminary reports to referring doctors to communicate any acute findings. The method used should be systematic, considering the patient's clinical presentation and potential complications, ensuring that timely ultrasound findings address the patient's clinical needs, therefore improving patient safety and facilitating prompt treatment, whether conservative or interventional. To assist, Table F1 has been developed and adapted from The Venous and Lymphatic Triage and Acuity Scale (VELTAS), which is a consensus document developed during the COVID-19 pandemic, [189] to classify clinical conditions by urgency. The indications in this table may be medical information the sonographer received at the time of booking, or information that the sonographer obtained when performing the examination. It is outside of the sonographer's scope of practice to make diagnostic clinical assessments.

Table F1: A guide to triaging venous insufficiency examinations by urgency for sonographers [adapted from 189]

Triage category	Clinical categories	Clinical indications	Implications for sonographers
Emergency	Venous thrombo-embolism	• Massive pulmonary embolism with or without deep vein thrombosis • Acute ilio-femoral deep vein thrombosis with phlegmasia or sepsis • Acute paradoxical embolism and stroke • Venous gangrene	If any of these indications are mentioned in a referral or ultrasound request, the sonographer should first consider performing a lower extremity deep vein thrombosis examination before investigating chronic venous insufficiency. The examination must be performed and reported immediately. Any acute findings, such as deep vein thrombosis, vascular tumours or bleeding due to large varix, should be immediately communicated to a medical practitioner, whether the reporting or referring doctor.
	Chronic venous disease	• Life-threatening blood loss from a bleeding varix • Acute septicaemia or uncontrolled sepsis in a leg wound	
	Vascular anomalies	• Kasabach-Merrit syndrome with severe coagulopathy	
	Venous trauma	• Life or limb-threatening venous trauma	
	Lymphatic disease	• Acute septicaemia or uncontrolled lymphangitis or secondary infection	
Urgent	Venous thrombo-embolism	• Pulmonary embolism, deep vein thrombosis or extensive superficial venous thrombosis	If any of these indications are mentioned in a referral or ultrasound request, the sonographer should first consider performing a lower extremity deep vein thrombosis examination before investigating chronic venous insufficiency. The examination should be performed and reported urgently. If the sonographer identifies acute thrombosis in the deep or superficial veins during the scan, this finding should be communicated to a medical practitioner, either the reporting or referring doctor, as soon as possible because the condition may deteriorate quickly and become an emergency.
	Chronic venous disease	• Temporarily controlled bleeding varices • Infected wounds and ulcers with risk of septicaemia • Squamous cell carcinoma in a venous ulcer	
	Vascular anomalies	• Acute complications including infection, bleeding and thrombosis • Cardiac failure secondary to AVM • Vascular malignancies	
	Venous trauma	• Non-life or limb-threatening venous trauma	
	Lymphatic disease	• Lymphoedema with extensive lymphangitis or secondary cellulitis and risk of septicaemia	
Semi-urgent	Venous thrombo-embolism	• Symptomatic non-extensive superficial vein thrombosis	If any of these indications are mentioned in a referral or ultrasound request, then the examination is not considered as a medical emergency or urgent scan. The scan should be prioritised ahead of non-urgent cases but after emergency and urgent cases, ensuring it is performed within 90 days following the initial management by the referring doctor. If during a duplex ultrasound to investigate chronic venous insufficiency, the sonographer identifies a superficial vein thrombosis, or pelvic venous insufficiency, varicoceles then this finding should be conveyed to a medical practitioner (reporting doctor or referring doctor) in a timely fashion.
	Chronic venous disease	• CEAP: C3-C6 • Highly symptomatic chronic venous disease, irrespective of CEAP classification • Highly symptomatic pelvic venous insufficiency, varicocele	
	Vascular anomalies	• Complex or extensive vascular tumours and malformations • Ulceration and cutaneous complications	
	Venous compression	• Highly symptomatic venous compression syndromes	
	Lymphatic disease	• Chronic lymphoedema with secondary infection or cutaneous changes.	
Non-urgent	Venous thrombo-embolism	• Chronic symptomatic post-thrombotic obstruction	If any of these indications are mentioned in a referral or ultrasound request, then the examination is not considered urgent or semi-urgent. The scan should be performed as soon as practicable, taking into account of patient preferences and the case load of the ultrasound facility, but within 6 months following the initial management by the referring doctor. It is unlikely for a non-urgent study to become urgent or semi-urgent or emergency. However, the sonographer should use their clinical judgement to prioritise the scan according to the patient's needs. The result of the duplex ultrasound examination should be made available to the referring doctor in a timely fashion.
	Chronic Venous disease	• CEAP: C0s-C2 • Mildly symptomatic pelvic venous insufficiency, varicocele	
	Vascular anomalies	• Uncomplicated benign vascular tumours and malformations.	
	Venous compression	• Mildly symptomatic venous compression syndromes including May-Thurner syndrome	
	Lymphatic disease	• Chronic lymphoedema or lipoedema	

Section G: Technical considerations

What time of the day should the venous insufficiency ultrasound examination be performed?

Recommendation G1: For increased sensitivity in the detection and measurements of venous reflux, it is preferable to perform duplex ultrasound in the afternoon to investigate chronic venous disease.

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

Summary Statement

Three studies [190-192] have provided evidence that veins when examined later in the day, as opposed to in the morning, are more likely to exhibit venous insufficiency. This is attributed to the prolonged stress on valves and progressive deterioration of valvular function throughout the day, which occurs in both asymptomatic and symptomatic lower limbs. Notably, as observed by Bishara et al. in 1986, the effect is more pronounced in individuals with symptomatic limbs, and more common in perforator veins (38%) than in the small saphenous veins (9%) and the great saphenous veins (2%), but not in alternate superficial pathways or at the saphenofemoral/saphenopopliteal junction. [191] Therefore, there is potential for incompetent veins, especially perforating and small veins, to be overlooked if duplex ultrasound (US) is performed in the morning. Future research could explore whether increased venous insufficiency is correlated with the time of day the duplex US is performed, whether the activities of the patient before undergoing duplex US are confounding factors and if the time of day the duplex US is performed impacts treatment decision-making and outcomes.

When scheduling a duplex US appointment to investigate chronic venous disease (CVD), an afternoon appointment is generally preferred from a technical viewpoint, except for individuals who have been active during the night, such as night shift workers whose scan are preferably performed in the morning. Patients should be informed about the potential benefits of undertaking the examination in the afternoon. However, in some cases, scheduling the scan in the afternoon may pose challenges relating to waiting list issues, the arrangement of follow-up appointments, sonographer's availability, or patient preferences. Sonographers should communicate to their reporting physicians if they believe there are limitations to the duplex US if performed in the morning.

What position should the patient be in during the venous insufficiency ultrasound examination?

Recommendation G2: We recommend that evaluation of reflux with duplex ultrasound should be performed with the patient standing, with the lower limb under examination non-weight bearing whenever possible. A sitting or reverse Trendelenburg position can be used if the patient cannot stand or if it is not safe for them to stand.

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

Summary Statement

It is widely accepted that a standing position is optimal for demonstrating venous reflux because it replicates the physiological state, allowing for more definitive closure of competent valves and presenting a greater challenge to incompetent valves. This was confirmed in a prospective study of 80 limbs in 40 healthy subjects and 60 limbs of 45 patients with CVD. When leg veins were evaluated with duplex ultrasound for venous reflux, [116] more refluxing venous segments were demonstrated in the standing position compared to the supine position. Similarly, Houle et al. [2] reported lower percentages of false negative results when veins were tested in the standing position. Similar conclusions were made by DeMuth et al. [193] who found in their study, that the median difference in reflux time between the reverse Trendelenburg (RT) and supine positions was 0.15 seconds and the mean difference in the diameter of the great saphenous vein (GSV) between the RT and supine positions was 0.7 mm, with a standard deviation of 0.96 mm ($p < 0.0001$). Their study also revealed 15% of the GSVs that initially tested negative for reflux in the RT position were later found to show venous reflux in the supine position. This observation suggests that even though as standing or RT position is recommended, additional testing in the supine position may be prudent when a patient showing signs and symptoms of venous insufficiency does not demonstrate GSV reflux.

The standing position can be ergonomically difficult for both the sonographer and patient to maintain. A pilot study [89] suggested that several alternative positions (sitting, 10-25 degrees RT) could be used for assessing incompetent veins as long as the patient is not lying horizontal. These alternatives offer flexibility, when the standing position is difficult for patients to maintain, and if the position is ergonomically problematic for the sonographer. However, it should be noted that reflux time will vary with positions. Carty et al. [87] compared superficial reflux evaluated by duplex US in both RT (30 degrees) and standing position in 72 consecutive patients, and noted that reflux duration in the RT position was longer (by a factor of > 2.8) compared with the standing position, and that as a guide, RT reflux values of ≥1.5 sec anywhere along the extremity always correspond to >0.5 sec standing reflux values ($p < 0.001$). Because of this overestimation of reflux time, they suggested that if the RT position was used, and the reflux time was less than 1.5 seconds, then the vein should be retested in the standing position, to compare it against the standing reflux time of 0.5s. Additionally, they found that isolated segmental reflux associated with an incompetent perforating vein is most accurately identified in the standing position. Further research comparing reflux time in alternate positions against standing as the reference standard for deep, superficial and perforating veins is needed and sonographers should test for venous reflux using alternate positions if reflux cannot be elicited in patients with signs and symptoms of CVD.

What provocation manoeuvres should be used to elicit venous reflux?

Recommendation G3: We recommend that to confirm valvular incompetence, venous reflux should be elicited using the following manoeuvres for the following veins:

- Common femoral vein: Valsalva manoeuvre to increase intra-abdominal pressure and/or distal augmentation.
- Saphenofemoral junction): Valsalva manoeuvre to increase intra-abdominal pressure and/or distal augmentation
- Vein segments distal to saphenofemoral junction: Distal augmentation

Distal augmentation is performed using manual or cuff compression distal to the point of examination.

Sonographers should be aware of alternate methods to elicit venous reflux that may be more applicable in different circumstances such as;

- where patient or sonographer comfort is compromised,
- when the patient cannot perform Valsalva,
- the patient has a large body habitus,
- or if venous reflux is suspected but cannot be demonstrated using Valsalva or distal augmentation.

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

Summary statement

Provocation manoeuvres are used to elicit reflux to test the valvular competence by stressing them. Normal valves in the lower limb act as gatekeepers to block blood in the veins from flowing away from the heart, that would otherwise occur due to physiologic pressures. [34] A provocation manoeuvre needs to create a high-pressure gradient across the venous segment under examination in order for reflux to occur, therefore identifying failing or incompetent valves. [34]
Two existing clinical practice guidelines made specific evidence-based recommendations regarding the manoeuvres that should be used. [10, 43] Both recommend that the appropriate manoeuvre for the CFV and the SFJ is Valsalva, and that more distal veins should be assessed with manual or cuff compression. In addition, these manoeuvres should be performed in an upright position. [43]
Findings by Berther et al. [193] support the use of Valsalva to test for reflux in the CFV. The sensitivity of detecting reflux in the CFV was slightly higher using Valsalva (50%) compared to cuff compression (42.9%) in patients with deep vein thrombosis (DVT), and the same for patients with varicose veins (87.5%). This study also partially supports using manual compression for the femoral vein (FV) as sensitivity for detecting reflux in the FV was higher for cuff compression (50%) compared to Valsalva (42.9%) in DVT patients. However, in varicose vein patients, the sensitivity was higher for Valsalva (87.5%) compared to cuff compression (71.4%).
Masuda et al. [195] also compared the cuff compression method against Valsalva across more venous segments including the CFV, FV, deep femoral, the GSV in the upper thigh, popliteal, and posterior tibial veins (PTVs) at the ankle. The results indicated that the Valsalva method is best performed in the RT 15 degrees position as opposed to standing, whereas the cuff technique is more effective in the standing position. A case-by-case analysis identified a large amount of variability between techniques, and inconsistencies could not be used to identify one technique as better than the other. Examination of the PTVs by all methods produced inconsistencies and a low yield of reflux in symptomatic limbs.
Demirpolat et al. [196] compared the efficacy of the Valsalva manoeuvre and cuff compression techniques, both performed in the standing position, in detecting lower extremity deep venous insufficiency (i.e., the FV, popliteal vein) and saphenofemoral insufficiency including the GSV segment near the junction and its caudal segment at the medial aspect of the knee. The study showed that cuff deflation technique was superior for detecting insufficiency at the popliteal vein and caudal segment of the GSV. The Valsalva manoeuvre was superior at the FV.
Yamaki et al. [197] demonstrated that manual and cuff compression can be used interchangeably they found no significant differences in the duration of reflux initiated by both methods at tested sites. This was observed in patients with minor signs and symptoms; at the SFJ, saphenopopliteal junction (SPJ), GSV, as well as in patients with more severe symptoms at the SFJ and SPJ.
Due to the variability of methods and results in research studies, and the variability in individuals, further investigation is needed to determine the best provocation manoeuvres to elicit reflux, including patient positions. Different provocation methods (physiological and non-physiological), including alternate methods are described below.
Alternate provocation manoeuvres may be useful when confirming the presence of reflux proves difficult in symptomatic patients due to technical factors.

The Valsalva manoeuvre (physiological):

This technique requires clear instruction to the patient and their cooperation. [48] The patient should be encouraged to Valsalva forcefully and rapidly (within 0.5 seconds) and for a sustained period of time (at least three seconds) to increase the intra-abdominal pressure. [45] If performed in veins distal to competent veins it may elicit a false-negative result. [48]

Simulated Valsalva (physiological):

This may be used if the patient finds it difficult to perform an adequate Valsalva. [48] The patient should be instructed to take a deep breath and hold, during which the sonographer pushes on the patient's abdomen with their free hand by

firmly leaning into the patient. The patient is instructed to resist or guard against the pressure, creating a simulated Valsalva manoeuvre. [48]

Distal augmentation, manual or with pressure cuff (non-physiological):

Perform by applying compression over and distal to the examined vein with gradual, firm and prolonged pressure to create orthograde (normal direction, feet to heart) flow. The compression is then rapidly released to detect any insufficiency in the examined vein. [45] This technique ensures that a large volume of venous blood is emptied out of the calf in order to create a high-pressure gradient on release. The pressure can be applied either by manual compression or by using an automated cuff applied on the lower leg or foot which the operator can inflate with the push of a button. The cuff inflates to a desired peak pressure and then rapidly deflates. [34] Sonographers will have a personal preference in using manual compression or a cuff. The cuff method allows for standardisation and sonographers may find it easier to remain in an ergonomic position using a pneumatic cuff device, [86, 113] however some sonographers may find the cuff cumbersome, particularly in the presence of venous ulcers.

The strength and duration of augmentation as well as the speed of release can have an influence whether reflux is or is not observed and for what duration. Augmentation at the foot or ankle can be less effective due the low venous volume at these sites. To maximise the sensitivity of detecting reflux, augmentation should be applied at a site over the examined vein, and just distal to the vein segment being tested. Increased pressure may be also useful to push a greater volume of blood in an orthograde direction through the vein.

Alternate reflux provocation methods:

Alternate reflux provocation methods can be used when reflux in varicose veins cannot be elicited by the above methods. More research is needed to determine the efficacy of these alternate provocative manoeuvres. If reflux still cannot be provoked, this may be due to other variables such as the diameter of the re-entry vein. [45]

- *Cremona manoeuvre (physiological):* A modified Valsalva manoeuvre, the patient is instructed to blow through a straw with the other end closed. This action leads to increased thoraco-abdominal pressure and push the flow to go backwards. A technique akin to the Cremona manoeuvre was demonstrated by Deb Coghlan (vascular sonographer, Precision Vascular Imaging) during the 18th International Union of Phlebology (UIP) conference in 2018. [198] In this method, a patient was directed to place his/her thumb in the mouth and exhale forcefully onto it.
- *Double hands distal augmentation (non-physiological):* Squeeze the leg using two hands (with the help of an assistant). [45] Distal compression at the calf is appropriate for proximal veins, and distal compression of the foot is appropriate for distal calf veins. [81]
- *Elevation-dependency manoeuvre (physiological):* The patient is placed supine with raised legs for 20 seconds to empty the vein. The patient then is asked to stand and the vein is re-examined during venous re-filling without provocation manoeuvre. [45]
- *Paraná manoeuvre (physiological):* The sonographer asks the patient to shift their weight slightly forwards, which applies pressure to the sacrum. In response, the patient involuntarily tenses the triceps surae muscle (i.e., gastrocnemius and soleus) to maintain balance. The activated muscle pump causes a strong, physiological, orthograde flow in the calf veins. This manoeuvre is challenging, as the sonographer has to move their left hand from the keyboard to the patient. The movement of the patient increases the chances of image blurring, and some patients may find it difficult to keep their balance. Additionally, the manoeuvre can cause them to move back and forth incessantly, which continuously activates the muscle pump in an uncontrolled manner. [108]
- *Wunstorf manoeuvre (physiological):* also known as the toe elevation manoeuvre, is a physiological method that patients can perform independently without the need for an examiner's assistance. During the procedure, the examined leg should remain as still as possible. Venous flow can be elicited by either raising the toes (dorsiflexion of the forefoot) or clawing the toes (plantarflexion of the forefoot). The elevation of the toes or forefoot leads to highly effective orthograde blood flow, which can be measured all the way up to the CFV and is often detectable in the trunks of the saphenous veins. [45, 81, 108]
- *Proximal augmentation (non-physiological):* involves applying manual compression above the transducer level. This technique induces valvular closure by generating a pressure wave directed towards the valves, similar to Valsalva. While this method has demonstrated comparable outcomes in detecting venous reflux when compared to both Valsalva and distal augmentation, its accuracy and reliability, particularly for the assessment of the superficial venous system, have yet to be determined. [199, 200]