Ultrasound Evaluation of Chronic Venous Insufficiency

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Abstract: Chronic venous insufficiency is a common condition caused by valvular incompetence and/or obstruction of the lower extremity venous system. Chronic venous insufficiency presents in a wide range of clinical presentations, ranging from mild pain or edema to the development of varicose veins and nonhealing venous ulcers. Doppler ultrasound is the preferred imaging modality in the assessment of this condition and provides both anatomical and functional information in a noninvasive, cost-effective, and radiation-free manner. Knowledge of the anatomy and nomenclature, pathophysiology, equipment requisites, scanning protocols, relevant findings, and reporting nuances is essential to the creation of an accurate and clinically actionable report. Evaluation of the superficial and deep venous system for degree and extent of reflux is necessary to establish the diagnosis and to institute appropriate treatment.

Key Words: chronic venous insufficiency, ultrasound venous incompetence, chronic venous disease, reflux.

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Chronic venous insufficiency (CVI) encompasses a group of disorders caused by retrograde blood flow (venous reflux) and/or obstruction to normal flow dynamics in the lower extremity veins. Chronic venous insufficiency is a public health problem with important quality-of-life and socioeconomic consequences. Chronic venous insufficiency has an estimated prevalence of 27% of the adult population. Risk factors for CVI include deep vein thrombosis, genetic predisposition, age, female gender, occupations that involve prolonged standing, multiparity, and obesity, among others.[1–5] The incidence of varicose veins is higher in women (2.6% annually) than in men (1.9%)[4]; this difference is believed to be secondary to venous dilation due to the hormonal effects of progesterone.

Under physiological conditions, the superficial venous system drains the superficial tissues and periodically empties blood into the deep venous system through perforator veins, establishing a flow pattern from superficial to deep and from caudal to cephalad (Fig. 1), which is enabled by valves that prevent prolonged retrograde flow (Fig. 2). Several mechanisms including venous remodeling due to chronic hemodynamic stress, valve agenesis, prior episode of deep venous thrombosis, and venous obstruction may result in valvular dysfunction. The widely accepted retrograde theory of venous reflux postulates that valve dysfunction of the deep and/or superficial veins (regardless of the underlying cause) leads to prolonged retrograde venous flow, resulting in venous hypertension. The increased hydrostatic pressure in the lower extremity tissues and transudation of blood products into the soft tissues leads to hypoxia, inflammation, and cellular toxicity.[6] These in turn may lead to a wide spectrum of clinical manifestations, ranging from mild symptoms and signs such as aching, heaviness, and warmth, to severe trophic skin alterations, development of varicose veins (Fig. 3), and hard-to-treat venous ulcers.[1–5] In addition, CVI may present with leg throbbing, cramping, and edema.

Ultrasound (US) is the only imaging modality used in the workup of most patients with CVI.[7] Doppler examinations are noninvasive and provide real-time anatomical and hemodynamic information, allowing localization of the level and source of reflux. In addition, US is used in treatment planning, guiding the use of minimally invasive treatments and follow-up of patients. In this review, we provide an overview of the anatomy and current nomenclature, scanning protocol, interpretation, and reporting of lower extremity venous Doppler reflux studies.

ANATOMY AND NOMENCLATURE

The lower extremity veins are classified into 3 types: superficial veins, deep veins, and perforator veins according to their relationship with the muscular fascia and with other veins[8] (Fig. 4). To reduce potential confusion, a standardized nomenclature has been developed for the lower extremity veins,[9] which we reference for this manuscript.

Superficial Venous System

Superficial veins lie outside of the muscular fascia and are part of the superficial venous system. These include multiple interconnected veins that drain into 2 main trunks: the great saphenous vein (GSV) and the small saphenous vein (SSV). One must avoid using older terminology such as "greater saphenous vein," "long saphenous vein," "lesser saphenous vein," and "short saphenous vein."[10] These 2 veins are often recognizable on US due to their typical location, size, and biconvex encasement by the saphenous fascia in its superficial aspect and the muscular fascia in the deeper aspect (saphenous compartment), which has been referred to as the "Egyptian eye" or "Horus's eye" appearance on transverse US imaging (Fig. 5).

Great Saphenous Vein

The GSV originates medially on the foot and ascends anterior to the medial malleolus and the anteromedial aspect of the leg and thigh until it reaches the groin, where it drains via the

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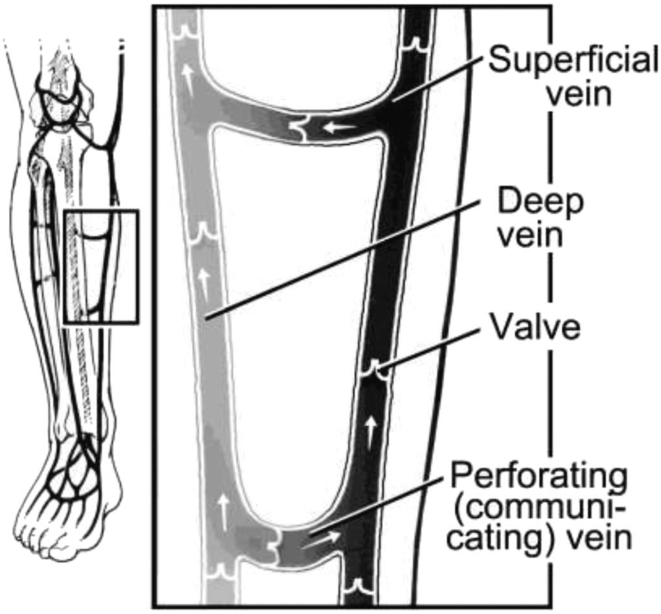

FIGURE 1. Types of veins. Under physiological conditions, the superficial venous system drains into the deep system through direct connection or through perforator veins. In the context of valvular incompetence (the lower perforator vein in the diagram), perforator.

saphenofemoral junction (SFJ) into the common femoral vein (CFV). The GSV resides in its own fascial compartment, the saphenous compartment. If the GSV leaves its own fascia during its course in the thigh, it should be documented in the report as it may have a bearing on treatment options. True duplication of the GSV is quite uncommon with a reported incidence of 1% and should be only termed as such when both veins are within the same saphenous compartment. More commonly, in approximately 26% of lower extremities, accessory veins are observed, which run in parallel to the saphenous vein but lie outside the saphenous compartment.[8] The SFJ (Fig. 6) is limited proximally by

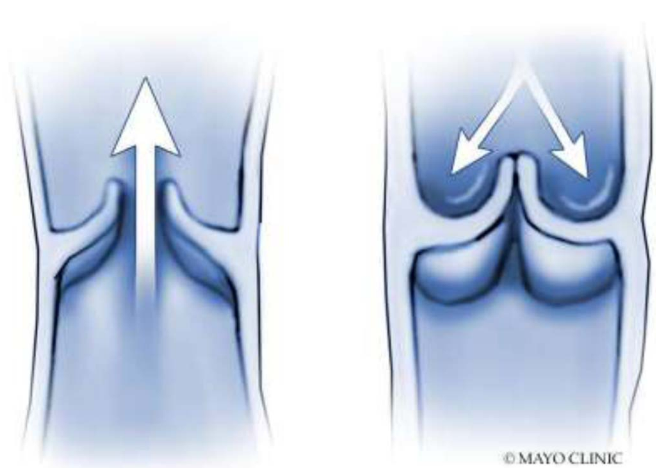

FIGURE 2. Normal valvular function. When muscles around the veins squeeze, blood is pushed up through the valves. When muscles relax, the valves close. This stops blood from flowing backward.

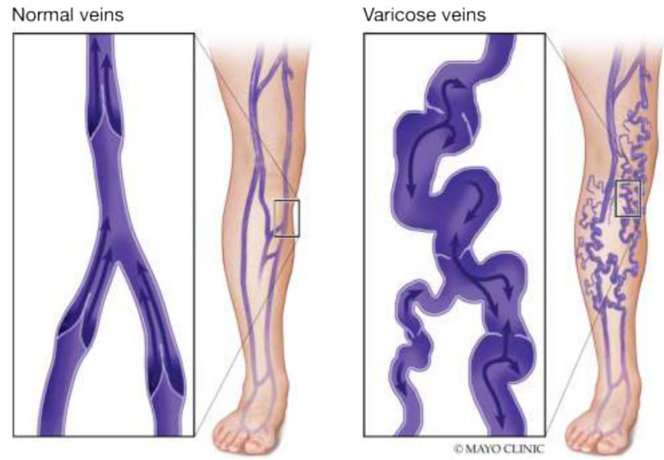

FIGURE 3. Varicose veins. As venous hydrostatic pressures increase in CVI, the vein wall undergoes remodeling, leading to venous dilatation and tortuosity, promoting even more valvular dysfunction and retrograde flow.

the ostium and the terminal valve and distally by the subterminal valve. Several small venous branches may be identified at the level of SFJ, which may potentially serve as collateral pathways and lead to recurrent CVI after treatment. For example, a common cause of early recurrence after endothermal ablation is from reflux in nonablated groin tributaries.[11]

Small Saphenous Vein

The SSV originates laterally on the foot and ascends posterior to the lateral malleolus, through midline of the posterior calf until it drains, commonly via the saphenopopliteal junction (SPJ) into the popliteal vein at the level of the popliteal fossa or distal thigh (Fig. 7). In approximately one third of cases, there is an anatomical variant in which the SSV drains directly into the GSV through the intersaphenous vein, previously known as the vein of Giacomini.[12,13] Currently, this anatomical variation is called cephalic extension of the SSV. The SSV may also directly drain into the deep venous system through a perforator vein.[14]

Deep Venous System

Deep veins are defined as veins that lie below the muscular fascia and form the deep venous system. These veins usually run parallel to the arteries and include the common femoral, femoral, profunda femoris, popliteal, anterior tibial, posterior tibial, peroneal, and muscular veins, including the gastrocnemius and soleus veins. At the groin level, there is a single CFV in the majority of individuals. The femoral and popliteal levels may be duplicated in up to 25% of cases. At the calf level, duplication is the norm for deep veins, and sometimes up to 3 veins can accompany each corresponding artery (Fig. 8). The deep veins share a common name with the adjacent artery with one notable exception: the femoral vein that runs alongside the superficial femoral artery. The term femoral vein is used instead of the previously used "superficial femoral vein" to avoid the risk of a thrombus within this vein being misconstrued as being within the superficial system, potentially leading to nontreatment of deep venous thrombosis in the vein.[15]

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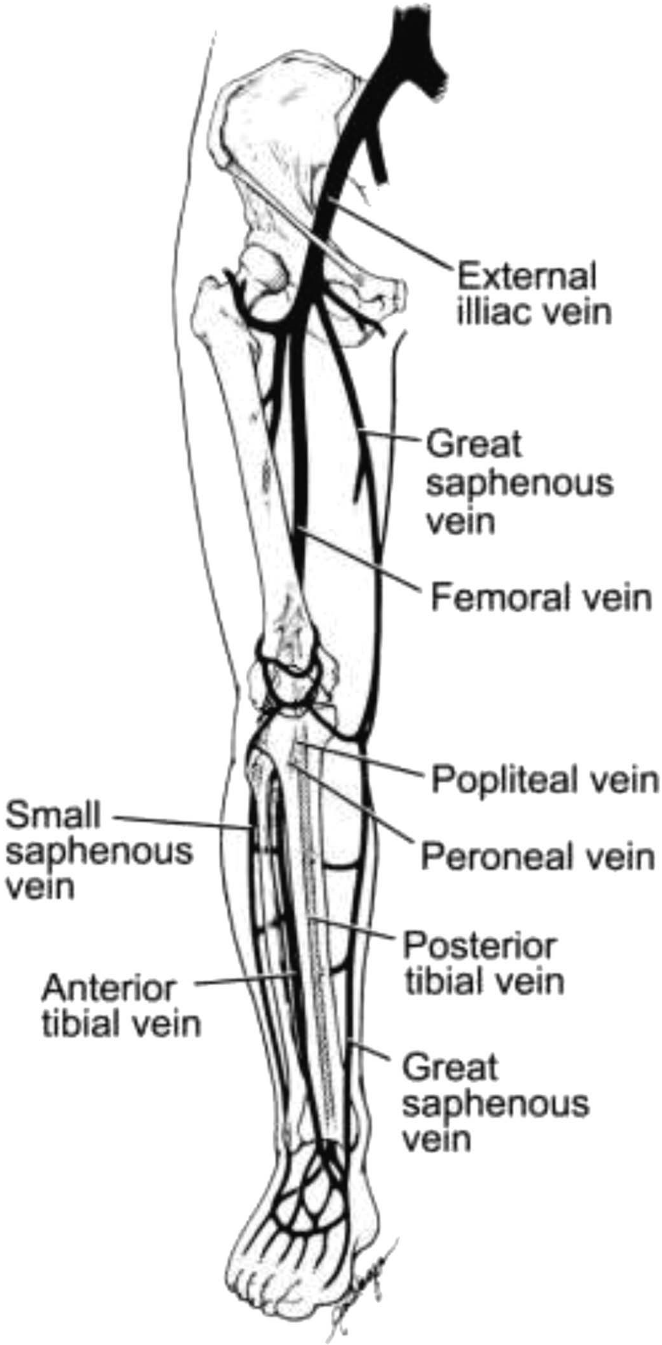

FIGURE 4. Major veins of the leg. The deep venous system encompasses external iliac vein, femoral vein, popliteal vein, anterior tibial veins, posterior tibial veins, and peroneal veins. The superficial venous system drains into the deep system and encompasses GSV and SSV.

Perforator Veins

Perforator veins traverse ("perforate") the muscular fascia and drain blood from the superficial to deep venous systems (Figs. 9, 10, 11). There are multiple perforator veins with considerably greater anatomic variability when compared with the superficial and deep venous systems. There is a clear shift away from using older eponyms to anatomical names for the perforator veins. The most important perforator veins include the following:

- Medial thigh perforators, which connect the GSV to the femoral vein (previously termed Hunterian perforators in the proximal thigh, and Dodd perforators in the distal thigh);
- Paratibial perforators, which connect the GSV to the posterior tibial or popliteal veins (previously termed Boyd perforators); and
- Posterior tibial perforators that connect the posterior accessory GSV to the posterior tibial vein (previously termed Cockett perforators).

CLINICAL ASSESSMENT AND SEVERITY GRADING

The CEAP (Clinical, Etiologic, Anatomic and Pathophysiologic) classification system is a comprehensive and objective method with a stated purpose of standardizing the classification and treatment of diverse manifestations of patients with CVI. The clinical score "C" is based on clinical examination and is assigned a value ranging from C0 (no visible or palpable signs of venous disease), C1 (telangiectasias or reticular veins), C2 (varicose veins), C3 (edema), C4 (skin changes), C5 (healed), and C6 (venous ulcers).[9,16] Doppler US evaluation is indicated before treatment for all patients with C2 or higher disease and in patients with telangiectasias (C1) along the distribution of the great and SSVs.

The Revised Venous Clinical Severity Score is a severity grading system that assigns scores of 0 through 3 for each of 10 clinical parameters, for a minimum score of 0 and a maximum score of 30. In contrast to the CEAP system, which is a relatively static classification system, the Revised VCSS system is considered to be more "dynamic" in assessing disease severity and the efficacy of intervention.

EQUIPMENT AND SCANNING PROTOCOL

Color and spectral Doppler US are essential in the assessment of venous reflux disease alongside grayscale US. A high-frequency linear transducer (5–18 MHz) is used to assess the superficial venous system, due to its improved spatial resolution. The same transducer may also be used for assessment

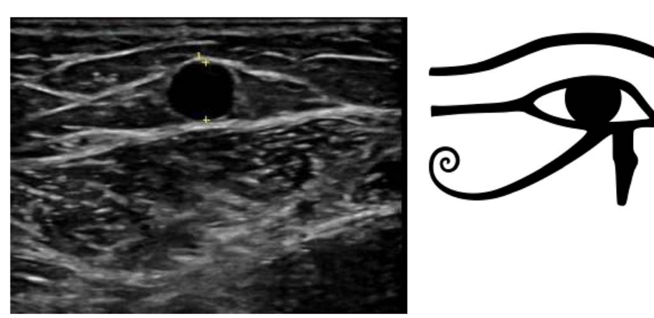

FIGURE 5. A, The GSV lies within its compartment enclosed by the saphenous fascia. By scanning the vessel in transverse plane, the fascia and the vein adopt the so-called Eye of Horus appearance, a typical depiction of ancient Egyptian art. B, Eye of Horus, Wikimedia Commons.

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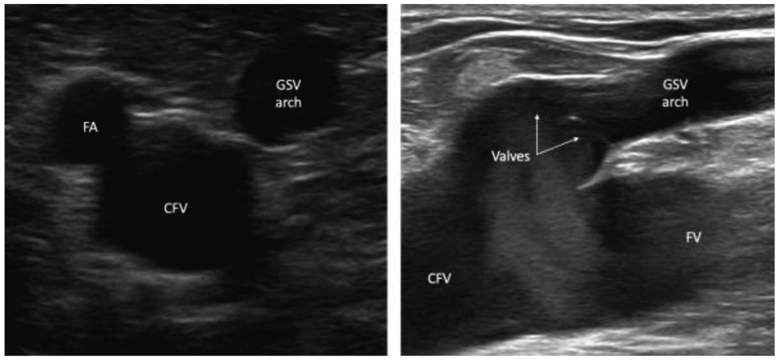

FIGURE 6. Saphenofemoral junction. Axial grayscale image at the level of the SFJ. This is colloquially known as the "Mickey Mouse" view, in which the femoral artery (FA) and the GSV arch are the ears and the CFV corresponds to the face. Longitudinal grayscale image at the level of the SFJ. Sometimes, the terminal valves of the GSV arch can be visualized as thin mobile echogenic lines. FV, femoral vein.

of deep venous system, but in patients with a large body habitus or markedly edematous extremities, a lower frequency curved array transducer may be needed. Although not routinely examined, if there is concern for pathology in the iliac veins and inferior vena cava, curved array transducers are needed.

As with all US studies, the operator begins the study by confirming the patient's identity, ordered examination, and explaining the study procedure and the expected scan time duration. One must obtain a brief history noting any specific site of symptoms and take particular note of the site(s) of varicose veins and skin changes on a focused physical examination (Table 1). The latter is especially important as it will allow the operator to improve the sensitivity of the examination for the detection of refluxing superficial veins, enlarged venous branches communicating directly with varicose veins, and pathological perforator veins. Unlike other US examinations, adequate lighting in the room helps tailor the protocol in these examinations.

To detect the expected low-velocity flow in veins, color and spectral Doppler settings must be appropriately optimized with a low pulse repetition frequency, low wall filter, and a correctly steered, small sample box. If the US equipment has optimized presets for the evaluation of venous insufficiency, these should be used.

FIGURE 7. Saphenopopliteal junction. The SSV arch empties into the proximal popliteal vein (PV). In this case, the arch is dilated in the context of known CVI.

The patient should be properly positioned with the limb in a dependent position, preferably by standing and bearing weight on the contralateral extremity. As the examination may take a considerable amount of time to be done, standing position support will enable patients to be more comfortable, reduce the risk of falls, and help patients needing assistance. In patients who are unable to stand, 45 degrees reverse Trendelenburg position may be used for the examination. Alternatively, for evaluation of the calf veins only, a sitting position may be used.

The GSV is evaluated with the knee mildly flexed and the leg in a partially abducted and externally rotated position. The SSV is scanned with the knees slightly flexed with the muscles relaxed. The study generally begins in the groin region from the GSV at the SFJ ("Mickey Mouse sign") (Fig. 6) and the SSV from the SPJ to the ankle.

The size of the superficial veins should be measured. Although size is not reliable in differentiating competent versus incompetent veins,[2] an abrupt change in vein size can provide a useful clue to the presence of incompetent valves, refluxing venous branches, or incompetent perforator veins. Compressibility of the veins should be performed to exclude the presence of thrombus. Transverse grayscale images must be documented without and with transducer compression at the very least within the CFV, SFJ, mid femoral vein, GSV, popliteal vein, SSV, and any other areas of suspected reflux. Transverse grayscale images of diameter measurement at the SFJ, GSV in proximal thigh, GSV at knee, and SSV at SPJ or proximal calf should be documented.[17] Measurements of vein diameter should be done from anterior to posterior vein walls with the extremity in a dependent position. One must take care not to externally compress the vein when taking measurements.

Next, assessment for reflux should be done in the superficial and deep venous systems (Fig. 12). This may initially be done with color Doppler and augmentation maneuvers, which is followed by prolonged flow reversal in case of valve incompetence. Augmentation maneuvers typically include direct compression of the extremity inferior to the evaluated site. Valsalva maneuver may be used for the upper thigh region but is less

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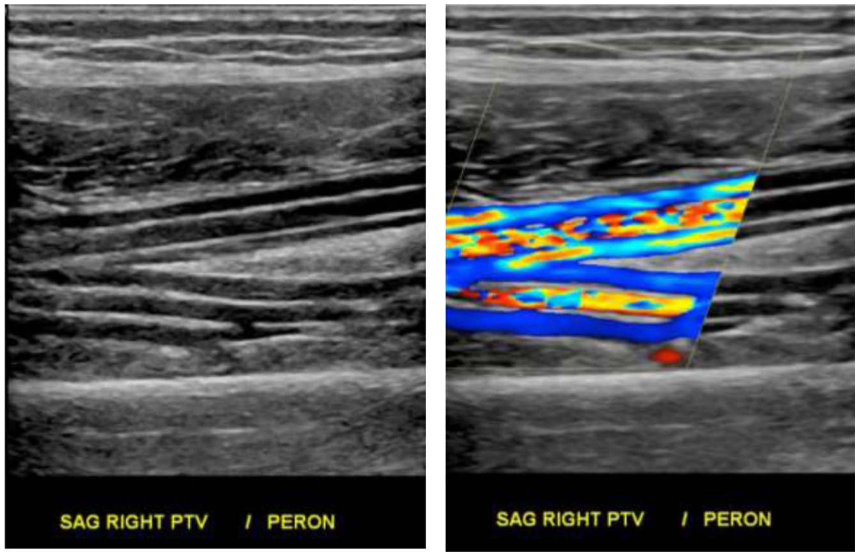

FIGURE 8. Deep system. Sagittal view of posterior tibial veins and peroneal veins at calf level. In gray scale, a group of 3 anechoic vessels can be seen, as the pair of veins accompanies the corresponding artery. Color Doppler shows that the middle vessel corresponds to the artery in each case.

reliable below the knee. Other maneuvers include direct compression just above the level of the transducer to generate retrograde flow and isometric contraction of calf muscles. Accessory equipment designed to provide an automatic augmentation maneuver are commercially available and may be preferred by some operators for their convenience, but these are no more effective when compared with manual compression.[18,19]

Color Doppler is helpful during real-time scanning as it lays out a roadmap for focused spectral Doppler evaluation.

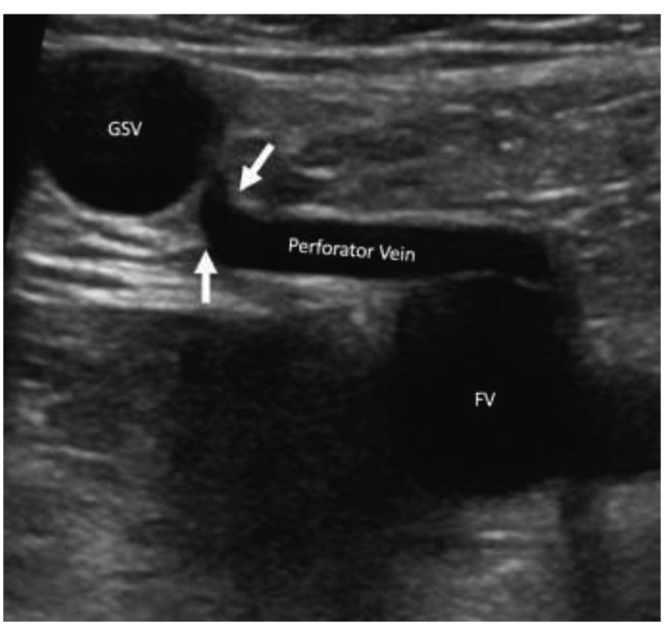

FIGURE 9. Perforator veins. Axial grayscale image at the mid-thigh. A perforator vein connecting the femoral vein (FV) with the GSV can be seen. Note how the perforator vein transverses the fascia (white arrows) that surrounds the GSV.

The documentation of reflux and measurement of reflux time should be done using spectral Doppler in the longitudinal plane. Spectral waveforms must be acquired with the extremity in a dependent position and show baseline flow, response to augmentation maneuver, and the duration of retrograde flow.

As per the IAC standards, at a minimum, spectral Doppler of the CFV, SFJ, GSV at proximal thigh, GSV at knee, femoral vein at mid-thigh, popliteal vein, and SSV at SPJ or at proximal calf should be performed (Table 2).[17]

Further, it is important to compare the extent of cardiac and respiratory phasicity between the femoral veins, as there is loss of normal phasicity in case of proximal obstruction.[20] Although an exhaustive search for perforator veins is not typically performed, one must pay careful attention to perforator veins in regions where there is an abrupt change in the size of the saphenous veins and near a venous ulcer. The size of the perforator vein is measured at the level where it enters the fascia. In addition to noting the incompetent perforator, its distance from the base of the foot should be measured.

Finally, one may need to adjust the local protocol in conjunction with the vascular surgeons and other specialists of the institution where the treatment will be carried out.

A complete venous Doppler examination includes the assessment for deep venous thrombosis. Compression of deep veins should be performed, as noncompressible venous segments are the single best sign of DVT.[21] Sequela of prior DVT or postthrombotic chronic changes can present with CVI. Deep veins must be assessed for areas of wall thickening, calcification, vein narrowing, occlusion, or collateral venous pathways development.[2]

SONOGRAPHIC AND DOPPLER FINDINGS IN DEEP AND SUPERFICIAL PERIPHERAL VENOUS INSUFFICIENCY

The main finding to be identified using Doppler US is the presence of reflux in the examined vein segment, which is

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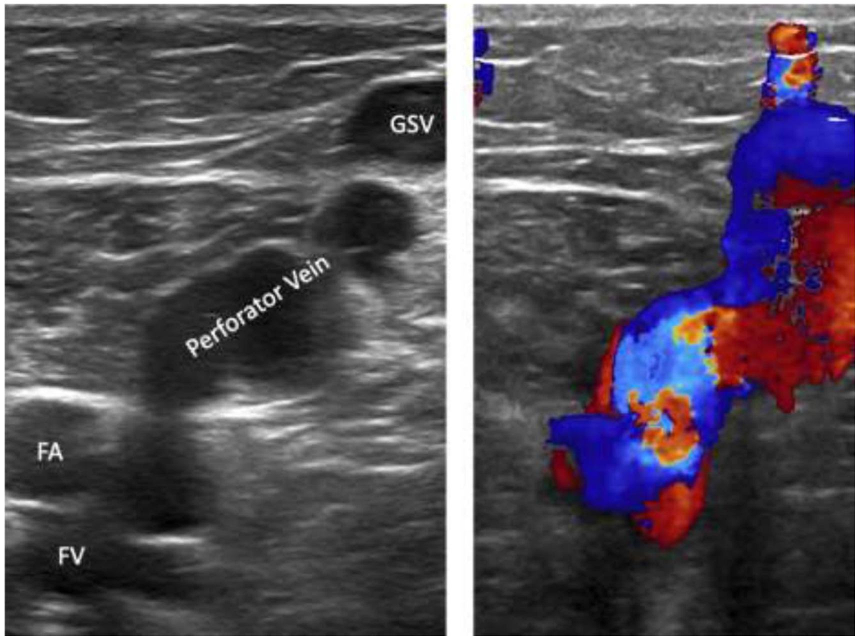

FIGURE 10. Perforator veins. Incompetent perforator vein connecting the femoral vein (FV) with the GSV. FA, femoral artery. By using augmentation maneuver, flow from deep to superficial (abnormal) can be seen. Some segments that show flow from superficial to deep (normal) are a consequence of vein tortuosity.

defined as abnormally prolonged retrograde flow after an augmentation maneuver[5,22,23] (Fig. 12).

The time threshold used for diagnosis of abnormal reflux is 0.5 seconds in the superficial and perforator veins, whereas it is 1.0 second in the larger femoral and popliteal veins. Brief retrograde flow after augmentation maneuvers is expected under physiological conditions: this flow provides the force that pushes and closes venous valves when they are working properly. One must understand all the components of both normal and abnormal venous flow curves after augmentation maneuvers. When compressing the soft tissues below the level of the transducer, blood moves toward the heart, which is observed as increased flow velocity. After peak anterograde flow with

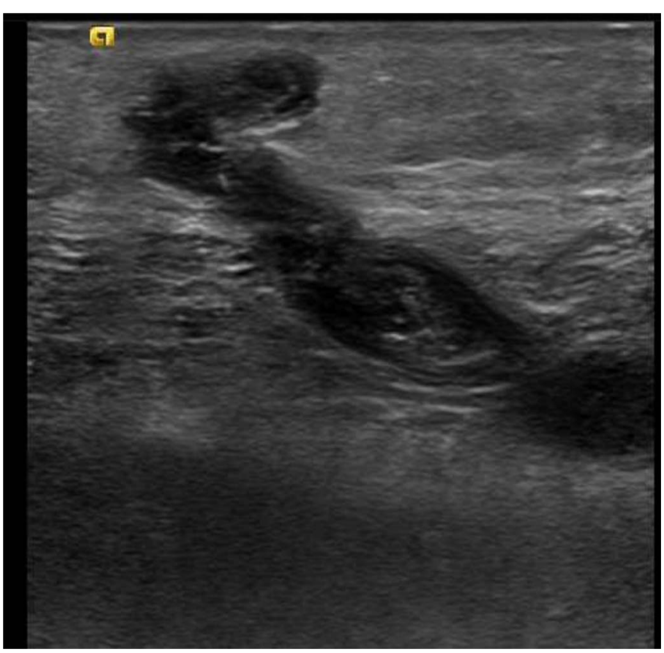

FIGURE 11. Thrombosed perforator vein. Perforator veins are prone to thrombosis. In that case, its course can be more clearly seen, traversing the fascia and connecting the deep and superficial venous systems.

TABLE 1. Checklist for Performing Venous Reflux Study

Questions to ask patient		What are your symptoms (pain, varicose veins, ulcer)?
		How long have you had symptoms?
		Where are your worst varicose veins?
		Have you received any treatments for this condition before?
		Have you ever been diagnosed with venous thrombosis?
Examination	Deep veins	CFV
		Femoral vein
		Profunda femoris
		Popliteal vein
		Tibioperoneal trunk
		Anterior tibial
		Posterior tibial
		Peroneal
		Intramuscular veins: soleus, gastrocnemius
	Superficial veins	GSV
		SSV
		Accessory saphenous veins, if present
	Perforator veins	If enlarged or refluxing
		If communicating with varicose veins
		If in close proximity to a venous ulcer

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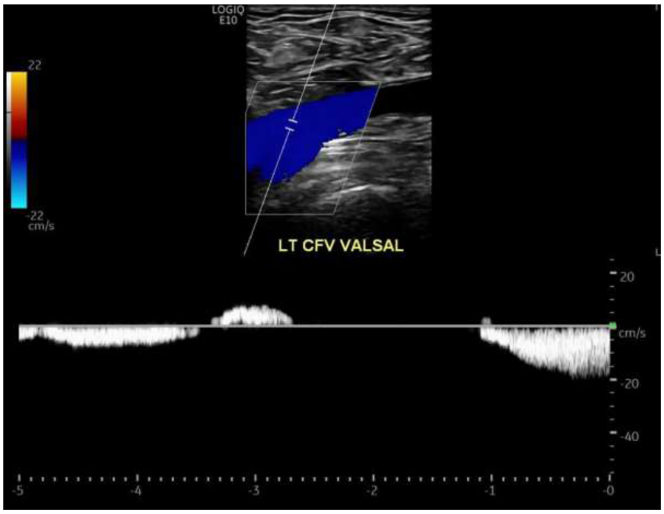

FIGURE 12. Common femoral vein evaluation using Valsalva maneuver. The Valsalva maneuver raises intra-abdominal pressure, and there is brief retrograde flow (in this case toward the transducer) that is halted by the functioning valves. As soon as the maneuver subsides, normal anterograde venous flow is re-established.

compression, the flow returns to the baseline, until it stops moving. At this point, because of gravity, blood starts to move inferiorly. In physiological conditions, this retrograde flow will push the venous valves to their closed position and flow will quickly cease. In patients with CVI due to malfunctioning valves, retrograde flow due to gravity will persist. Patients with clinically evident CVI will often show retrograde flow for several seconds (Fig. 13). Further, although the actual reflux times are mentioned in radiology reports, from a clinical standpoint, venous reflux is a normal versus abnormal phenomenon. The actual measured reflux times (provided it is abnormal) does not correlate well with a given patient's symptoms.[24]

Another important imaging finding in CVI is venous size. With the chronic increase in venous hydrostatic pressure, there is vein wall remodeling, and the vein size increases accordingly. An increased vein size further worsens venous incompetence by preventing previously normal-sized valves from opposing each other. A GSV size greater than 7 mm is said to be a good predictor of superficial venous insufficiency (note: certain third-party payers cover CVI treatment only in the context of a specific minimum diameter for GSV or SFJ). Further, an abrupt change in vein diameter can provide an important clue to the presence of an incompetent perforator vein, or a large draining venous channel. Finally, a very small caliber segment of the superficial veins may preclude treatment using endovascular methods.

In patients with CVI, it is important to assess the extent of venous thrombosis, whether acute or chronic, superficial, or deep. In fact, the wall changes occurring after venous thrombosis are one of the mechanisms that damage venous valves. In the acute phase, endoluminal echogenic material, luminal expansion, and lack of compressibility are the hallmark findings. In the superficial veins, increased echogenicity in adjacent adipose tissues may result from the local inflammatory changes of thrombophlebitis. The chronic phase is characterized by a reduced vein caliber associated with vein wall thickening, endoluminal calcifications, and possible permanent obstruction.

TABLE 2. Minimum Documentation Requirements of Veins According to IAC Guidelines

Transverse grayscale images without and with transducer compression	CFV
	SFJ
	Mid femoral vein
	GSV
	Popliteal vein
	SSV
	Additional images to document areas of suspected reflux and as required by the protocol
Diameter measurements on transverse grayscale images	SFJ
	GSV at proximal thigh
	GSV at knee
	SSV at SPJ; if not visualized there, SSV at proximal calf
Spectral Doppler waveforms images	CFV
	SFJ
	GSV at proximal thigh
	GSV at knee
	Femoral vein at mid-thigh
	Popliteal vein
	SSV at SPJ; if not visualized there, SSV at proximal calf
	Additional images to document areas of suspected reflux

REPORTING

Structured reporting is particularly helpful in communicating the results of CVI US examinations. Use of templates

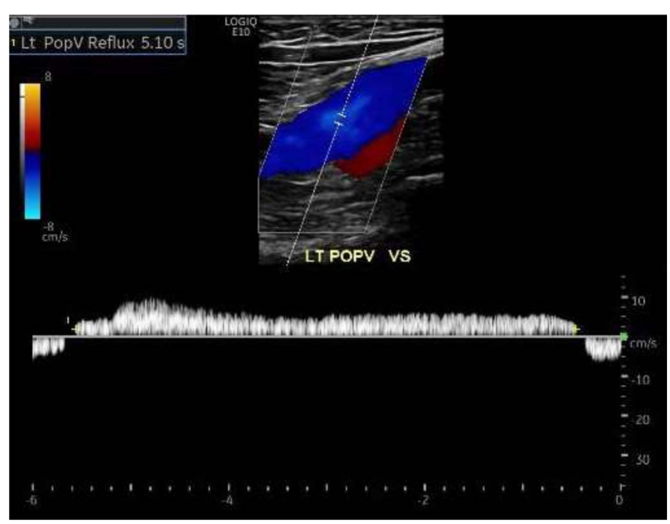

FIGURE 13. Popliteal vein insufficiency. During Valsalva maneuver, there is prolonged retrograde flow (in this case toward the transducer), which lasts for more than 1 second. As venous valves are not working properly, there is no way to stop the flow going in reverse direction.

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and schematic images of lower extremity anatomy enables clear communication with the treating physician. Reports should include details on superficial and deep venous system anatomy, caliber of important venous segments, and measured retrograde flow duration. Other findings such as anatomic variants and thrombosis are also included.

CONCLUSIONS

Chronic venous insufficiency is a common disorder with significant morbidity that can be accurately evaluated using US. Careful attention to detail and an understanding of the clinical context is essential to the performance of an accurate study and creation of a clinically actionable radiology report. It is essential for radiologists to be aware of normal and variant venous anatomy, currently preferred nomenclature, and the clinical context to interpret these studies.

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