Doppler Ultrasound in Chronic Venous Disease of the Lower Limb: a guide for Dummies to Remain in the Desirable Path

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Learning objectives

After reviewing this educational exhibit you will be able to:

1. Describe the most important classifications of chronic venous disease (CVD) in clinical and vascular surgery; and learn the correct nomenclature used
2. Remember the main anatomical landmarks and their more frequent variants
3. Propose a systematic and efficient scanning protocol
Doppler Ultrasound in Chronic Venous Disease of the Lower Limb: a guide for Dummys to Remain in the Desirable Path

Clínica INDISA, Santiago, Chile

Fig. 1: Doppler Ultrasound in Chronic Venous Disease of the Lower Limb: a guide for Dummys to Remain in the Desirable Path

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Background

Doppler ultrasound is probably the most frequent used exam to evaluate the venous system for management of chronic venous disease (CVD). However, there is no systematic consensus agreement from the different medical societies on how the Doppler ultrasound in CVD is best performed.

Classification

Different classifications and scores have been developed to characterize CVD (VEINTERM, CEAP, VCSS, VDS).

CVD is an spectrum of chronic morphologic and functional venous abnormalities manifested by clinical signs and / or symptoms that can be classified according CEAP (Clinical, Etiological, Anatomical and Pathophysiological) classification. Higher c-classification corresponds to more advanced CVD. The revised Venous Clinical Scoring System (VCSS) is another venous assessment tool utilized to categorize the overall severity of venous disease. Unlike CEAP, VCSS scale is a dynamic tool that provides descriptions of the signs and symptoms of CVD and should be used to assess treatment outcome.

It is necessary to know the nomenclature that is used to describe the deep and superficial territory an how it relates to venous disease, the distribution of the venous system in relation to the deep fascia, if there is communication between the different territories (Deep, Superficial or Perforators) and evidence of the main variants and their relation to main venous trunks which can influence the treatment.

Considering the extent of the territory to be evaluated, it is important to Remain in the Desirable Path and systematically report:

- Determine if there is Retrograde flow (R)
- Diameters of the deep and superficial veins (D)
- Permeability of the venous system (P)
Findings and procedure details

Anatomy

**Great Saphenous Vein (GSV)**

The GSV commences its course anterior to the medial malleolus and passes upwards along the tibial edge of the medial calf to cross the knee and then along the medial thigh to the Saphenous Femoral Junction (SFJ). The GSV has a constant terminal valve 1-2 mm distal to the SFJ, which is usually easily identified on ultrasound (US). There is often another pre-terminal valve a further 2 cm distal, which marks the distal limit of the SFJ area. The most important tributaries join the GSV between the two valves, and these veins are fairly constant and readily identified. These tributaries are proximal or distal. Proximal veins drain venous blood from the abdominal wall and pudendal areas, and from lateral to medial. These are the superficial circumflex iliac, superficial epigastric and superficial external pudendal veins. Proximal veins may be single or multiple and are of clinical importance because they may transmit retrograde flow into the GSV even with a competent terminal valve, reported in 28-59% of cases. Distal merging veins at the SFJ are often relatively large and are typically the lateral accessory anterior saphenous vein (AASV) which is present in 41% of subjects joining the GSV within 1 cm of the SFJ, and the medial posterior accessory saphenous vein (PASV) which may represent the proximal end of the Giacomini vein at a variable distance from the SFJ, often distal to the preterminal valve. In most cases, there is a quite constant lymph node in the angle between the GSV and AASV before they merge and the vein net of lymphatic node that surrounds the AASV may be sometimes large and incompetent, forming a source for reflux into thigh and leg varicose veins.

**The anterior accessory saphenous vein (AASV)**

Close to the SFJ, the GSV medially and the AASV laterally often lie within the same saphenous compartment. Distally, the AASV has its own ‘eye’ and is distinguished from the GSV by the 'alignment' sign, and with an anterolateral course in the thigh.

The AASV is involved in about 14% of patients with varicose veins, and if so then the AASV may be the only proximal source for reflux while the GSV is competent, or alternatively there may be reflux in both the GSV and AASV.

**Relation of fascial compartments to the GSV and anatomical variations in the thigh**

In the thigh, the GSV is contained in its 'saphenous eye'. The fascial compartment is larger and better defined in the thigh than in the leg. Tributaries pierce the superficial
layer of fascia to reach the GSV. Transverse US imaging of the GSV territory in the thigh based on the 'eye' sign has revealed the following anatomical patterns.

**Relation of fascial compartments to the GSV and anatomical variations at the knee**

It may be difficult to recognise the GSV and its fascia forming the 'saphenous eye' near the knee using US, GSV can be confused with a number of subcutaneous tributaries and perforating veins confined within a small region. GSV can be identified from transverse US images by the **tibio-gastrocnemius angle sign** between the distal third of thigh and proximal third of calf.

This US sign has been described in subjects with and without varicose veins. Five patterns (A-E) have been reported:

(A) The GSV is visible and no large tributary is seen.

(B) The GSV is visible but there are one or more tributaries below the knee the most typical being the posterior arch or 'Leonardo' vein.

(C) 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 erroneously assumed to be the GSV itself. The GSV is always present in the knee area in all of the three patterns described above (A-C) though sometimes smaller than its normal or varicose tributaries. In contrast the middle portion of the GSV is barely visible or not visible at all (hypoplastic or absent) for a variable length in about 30% of cases with the 'missing' portion bypassed by a subcutaneous tributary.

Two patterns are observed:

(D) 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.

(E) This is similar to 'D' but the absent portion of the GSV is very short and just below rather than across the knee.

This classification of GSV patterns at the knee cannot be applied in 3% of cases. The study reported above showed that varicose veins were present in 34% of limbs where the GSV was present throughout the thigh and calf (types A-C) and in 56% of limbs with the patterns where a segment of GSV was missing at the knee (types D and E).

**Relations between the GSV and tributaries**
The GSV both in the leg and in the thigh is often accompanied by parallel veins of different length that are so large that they may be confused with the GSV itself or considered to be 'double' saphenous veins.

US imaging shows that these veins are not a duplication of the GSV but are tributaries lying subcutaneously that may then pierce the superficial fascia to enter the saphenous compartment. The relationship between the GSV and these subcutaneous tributaries may be classified as three anatomical patterns, each with a specific US appearance:

Type 'I': the saphenous trunk is present with a normal diameter throughout the length of the saphenous compartment and there are no large parallel tributaries.

Type 'h': the saphenous trunk is present throughout the saphenous compartment, and there is also a tributary vein that may be even larger than the GSV

Type 'S': a superficial tributary ascends and pierces the superficial fascia continuing as the GSV within its compartment, while distal to this point the GSV is absent or only barely visible on ultrasound imaging (absent or hypoplastic).

**Anatomy of the small saphenous vein**

The small saphenous vein (SSV) begins behind the lateral malleolus as a continuation of the lateral marginal foot vein. It ascends the posterior aspect of calf and frequently finishes at the popliteal vein. The SSV lies for its entire length in an interfascial compartment defined by the deep muscular fascia and superficial fascia. The distal compartment appears on a transverse US scan as an 'eye' similar to that for the GSV in the thigh. The proximal 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 SSV is occasionally duplicated with two or even three veins of various lengths running in its compartment.

**The saphenopopliteal junction-anatomical variations**

There are three patterns at the SSV termination:

(A) The SSV joins the popliteal vein at the saphenopopliteal junction (SPJ) and joins deep veins at a higher level through its thigh extension (TE) or joins GSV via Giacomini vein (A1) and (A2).

(B) The SSV continues upwards as TE or GV, but it also connects with popliteal vein through an 'anastomotic' tiny vein.

(C) There may be no connection to deep veins so that the SSV continues proximally as the TE or vein of Giacomini.
The SPJ is most often situated within 5 cm of the popliteal skin crease. However, its level is variable, most often at 2-4 cm above the knee crease, 25% are higher. A higher location of SPJ is common in healthy subjects, whereas in case of incompetence of the SPJ this is located in the vast majority of the cases within the popliteal fossa. The terminal part of the SSV includes two valves: the terminal one, which is in close proximity with the popliteal vein and the pre-terminal one, which is usually located below the depart of Giacomini vein or of the TE of SSV.

Gastrocnemius veins may join the popliteal vein, upper SSV, or their confluence at the SPJ. The SSV may merge with the gastrocnemius veins before joining the popliteal vein, 30% of limbs.

**Thigh extension (TE) of the SSV**

In 1873, Giacomini described the TE and its frequent connection to the GSV. Further anatomical dissections confirmed that the SSV usually extends into the thigh. The anatomy of the TE has been confirmed by US. The TE of the SSV lies deep to the fascia on the back of the thigh. The distal TE is recognised on US by its intrafascial position into a triangleshaped compartment that resembles the saphenous compartment for the SSV, and is defined by the semitendinosus muscle medially, the long head of the biceps muscle laterally and the superficial fascia that stretches over the intermuscular groove.

Various terminations have been described. The proximal TE may:

(A) continue straight up into the gluteal area as a single vein or divided in many deep and superficial branches, (B) join the deep femoral veins as a posterior or posterolateral thigh perforator, (C) divide into many muscular or subcutaneous branches of the posterior thigh

(D) connect to the posterior thigh circumflex vein which then passes to the GSV in the medial thigh, this complex of veins (TE of SSVC posterior thigh circumflex vein) being termed the vein of Giacomini.

In many cases, the proximal limit of the TE is a combination of the above terminations. The **TE and Giacomini vein may transmit reflux** from proximal incompetent veins (e.g. GSV, perineal veins, thigh perforators) to the SSV, or, vice versa, may transmit an 'ascending reflux' from SPJ upwards to GSV and/or varicose veins of the posterior aspect of the thigh.

**Arrangement of the SSV and its tributaries**
Subcutaneous tributaries of the SSV and TE are recognised because they perforate the superficial fascia to enter the saphenous compartment and join the SSV or TE trunk. One particular tributary that deserves separate description is the so-called ‘popliteal fossa perforating vein’ and was described first by Dodd. This vein 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.

**Anatomy of perforating**

Perforating veins connect deep veins with superficial veins and may be single- or multiple-branched; US anatomy is characterized by their penetration through the muscular fascia. Perforating veins are numerous and very variable. More than 40 constantly present perforating veins have been described. Descriptive terms designating location should be used. Perforators are grouped on the basis of their topography.

Perforators of the foot (venae perforantes pedis) are divided into dorsal, medial, lateral and plantar foot perforators.

Ankle perforators (venae perforantes malleolaris) are designated as medial, anterior and lateral ankle perforators.

Perforators of the leg (venae perforantes cruris) are divided into four main groups:

(a) Medial leg perforators are designated as paratibial or posterior tibial. Paratibial perforators (formerly Sherman perforators in the lower and mid leg and Boyd perforators in the upper leg) connect 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 perforators (formerly Cockett perforators) connect the posterior arch vein with the posterior tibial veins. They should be named topographically as upper, middle, and lower.

(b) Anterior leg perforators pierce the anterior tibial compartment fascia to connect anterior GSV tributaries to the anterior tibial veins.

(c) Lateral leg perforators connect veins of the lateral venous plexus with the peroneal veins.

(d) Posterior leg perforators are divided into medial gastrocnemius perforators in the medial calf, lateral gastrocnemius perforators in the lateral calf, intergemellar (soleal) perforators connecting the SSV with soleal veins (formerly the mid-calf perforator of May), and para-Achillean perforators connecting the SSV with the peroneal veins (formerly perforator of Bassi).

**Scanning protocol**
Considering the extent of the territory to be evaluated, it is important to systematically report and Remain in the Desirable Path (P: permeability, R: retrograde flow and D: diameters): consider P and R in the proximal deep veins (common femoral, femoral and deep femoral) and distal (popliteal, tibioperoneum, peroneal, tibialis anterior and posterior), and P and R and D corresponding to SV and D both proximal (saphenofemoral and saphenous junction) and distal (saphenopopliteal junction and saphenous).
**Fig. 2:** Anatomy. A) Surface distribution of major superficial veins. B) AASV, anterior accessory saphenous vein; C) GSV, great saphenous vein; D) TE, thigh extension of the small saphenous vein

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**Fig. 3:** Anatomy. A) Saphenous Femoral Junction (SFJ). B) Normal great saphenous vein in thigh C) "The eye sign" is always present and allows the saphenous vein to be clearly identified and distinguished from parallel subcutaneous tributaries.

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Fig. 4: Anatomy: Relation of fascial compartments to the GSV and anatomical variations at the knee. Explanation in text. B and C) Varicose veins in the knee periphery

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**Anatomy.** Relationship between the GSV and tributaries: I, h and S type configurations. B) H configuration is shown.

**Fig. 5:** Anatomy. Relationship between the GSV and tributaries: I, h and S type configurations. B) H configuration is shown

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Fig. 6: Anatomy. Great saphenous vein varices in the thigh.

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Anatomy. The saphenopopliteal junction—anatomical variations. In this case the V of Giacomini is shown.
Fig. 7: Anatomy. The saphenopopliteal junction-anatomical variations. In this case the V of Giacomini is shown

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Reflex (R) evaluation:
This identification is accomplished by a combination of visual inspection and Doppler US. Three different maneuvers can be attempted to elicit reflux:

1. **Augmentation**: The leg is squeezed from below, directing flow toward the heart. If blood flows back toward the feet for more than 0.5 seconds following augmentation, the examination is positive for reflux.

2. **Valsalva maneuver**: Reflux can be assessed in the thigh after the Valsalva maneuver because the resultant increased intra-abdominal pressure causes retrograde flow through incompetent valves. Although this technique is sensitive, it works well only in the upper thigh.

3. **Direct or retrograde compression**: Direct compression above the point of Doppler interrogation propels blood toward the feet in the setting of an incompetent valve.

**Upper figure**: Valsalva maneuver with competent valve

**Down figure**: Valsalva maneuver with incompetent valve showing reflux at the great saphenous vein

Fig. 8: Reflux (R) evaluation: This identification is accomplished by a combination of visual inspection and Doppler US. Three different maneuvers can be attempted to elicit reflux:

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**Fig. 9:** Veins Diameters (D) evaluation: The great saphenous vein (GSV) join the common femoral vein (CFV) just superior to its bifurcation. It measures about 3 to 5 mm in the saphenofemoral junction, tapering to 1 to 3 mm at the ankle. The small saphenous vein (SSV) extends from the ankle along the posterior aspect of the calf to insert at variable levels into the popliteal vein. The diameter tapers from 2 to 4 mm proximally, and 1 to 2 mm distally. Diameters are important because they can be use as an autologous vein grafting and also for venous insufficiency diagnosis.

Upper fig: GSV diameter up to 7 mm.
**Fig. 10**: Incompetent Perforators (P)Veins evaluation. Perforator veins were identified as deep fascia gaps at cross-sectional imaging of the medial, posterior, and anterolateral portions of the calf and thigh.

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**Fig. 11**: Permeability (Pe) evaluation Compression protocol in all the deep and superficial veins, searching for lack of compression of the veins, echogenic endoluminal thrombus.

Upper fig: Superficial femoral vein compressible. Down fig: Popliteal vein not compressible with endoluminal thrombus

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Permeability evaluation:

a) **COMPRESION**: Venous ultrasound in grey scale. Common femoral vein completely compressible, en escala de grises.

b) **COLOR DOPPLER AND SPECTRAL CURVE**: Show correct morphology and fascicle.

c) Not compressible vein with ecogenic endoluminal content, compatible with venous thrombosis.

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**Fig. 12: CVD**

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Diameter evaluation

a) **Great Saphenous Vein**: grey scale and color doppler, great saphenous junction is considered normal at 5mm and 3mm in the thigh

b) **Lesser Saphenous Vein**: grey scale. Below knee medition is normal in 4mm.

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**Fig. 13: CVD**

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Perforators evaluation: are those that cross the fascia from superficial to deep. The perforator is determined to be insufficient if the flow is inverse to that expected, as shown in a), b) and c) where flow from deep to superficial is observed, demonstrated with flow to the transducer (red).

Fig. 14: CVD

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Reflux evaluation: with Valsalva, augmentation or extrinsic compression

SUPERFICIAL VENOUS SYSTEM
a) Competence of Great saphenous vein valves
b) Evidence of retrograde reflux after Valsalva.

DEEP VENOUS SYSTEM
a) Superficial femoral vein without evidence of reflux.
b) Reflux after Valsalva in the superficial femoral vein

**Fig. 15: CVD**

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Conclusion

The study of CVD of lower extremities can be long and tedious, even for experienced sonographers, so it is important to have a systematic approach to the study and analysis of different veins.

In order to achieve an adequate evaluation we must maintain an order and keep in mind to Remain in the Desirable path and always evaluate:

- Determine if there is **Retrograde flow (R)**
- **Diameters** of the deep and superficial veins (D)
- **Permeability** of the venous system (P)
References


