

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 ^[39], 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. ^[36] The superficial veins lie in the subcutaneous tissues, which lies between the dermis and the muscular fascia. ^[36] 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. ^[43, 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 greyscale 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 10**). ^[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 11**). Any vein situated outside of the saphenous compartment cannot be called a saphenous vein. ^[39] Most saphenous tributaries are not contained within the superficial compartment. ^[36]

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 12**). ^[36, 39, 41, 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. ^[41] 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. ^[36, 39, 41, 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. ^[36, 39, 41]

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. ^[36]

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. ^[36, 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. ^[41, 43]

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). ^[36]

Calf

Soleal veins/soleal sinuses: Veins of the soleal muscle 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 13**). They most commonly merge into one trunk and drain into the popliteal vein just before the termination of the SSV, or they may also drain into peroneal or posterior tibial veins or the

tibioperoneal trunk as one or multiple trunks. ^[36] The nonspecific term ‘sural veins’ should not be used to describe soleal or gastrocnemius veins. ^[36]

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 tibioperoneal 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 calf 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 veins at the tibioperoneal trunk before its confluence with the anterior tibial veins 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. ^[36] 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. ^[39] 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 ‘tibio-gastrocnemius 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. ^[39]

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: Representation of lower limb superficial venous anatomy (Note: anatomy may vary from this representation).

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: Superficial 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: Saphenopopliteal Junction (SPJ).	13: Small saphenous vein (SSV).	14: Giacomini vein (variation to cranial extension of the small saphenous vein).
15: Lymph node venous networks (LNVN).	16: Lateral subdermal 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 14).
- 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 15).
- 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]
- There 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 calf. 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, 39, 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 16). [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, and this number increases as the distance between the two valves increases. [70] The proximal tributaries 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 are present 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, 36, 39]

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 17). 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. [36, 39] 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. [39] 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". [40]

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. [36]

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 18). 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 fascia 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 to distinguish below the knee due to the poorly developed saphenous compartment at this site. ^[36, 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 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 18**). 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. ^[36, 51] The pathological LNVN is more common in recurrent veins after surgery (REVAS) with connections to the residual or recurrent varicose network. Following the 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 19**). 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. ^[36] If a Giacomini vein or cranial extension (thigh extension) of the SSV is present, then preterminal valve will usually be located more distally. ^[39]

The SSV terminates at the SPJ where it joins the popliteal vein (Image 20). The SPJ is complex in anatomical connections 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). [39] 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 21). The SSV is occasionally duplicated with two or even three veins of various lengths running in its compartment. [36, 39]

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. [39]

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 then 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. 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. [36, 39, 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 the 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, 89, 72]

Superficial accessory of the small saphenous vein

This vein ascends parallel to the SSV and is located superficial to the saphenous fascia. [36, 68]

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. ^[36]

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. ^[36]

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 and with connections to the deep veins via numerous perforating veins. ^[36, 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 22-24**), 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. ^[36] The medial plantar vein runs along the inner edge of the sole from the end of the plantar arch to the medial malleolus. ^[39] 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. ^[39] Dorsal deep metatarsal veins join medially to form paired dorsalis pedis vein. ^[36]

Superficial veins: The superficial dorsal plexus is clinically important because it is continuous with the superficial veins of the calf 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. ^[39]

Perforating veins (PV)

PVs pierce the muscular fascia, connecting superficial veins with the deep veins. ^[36] 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. ^[36] 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. ^[36, 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]

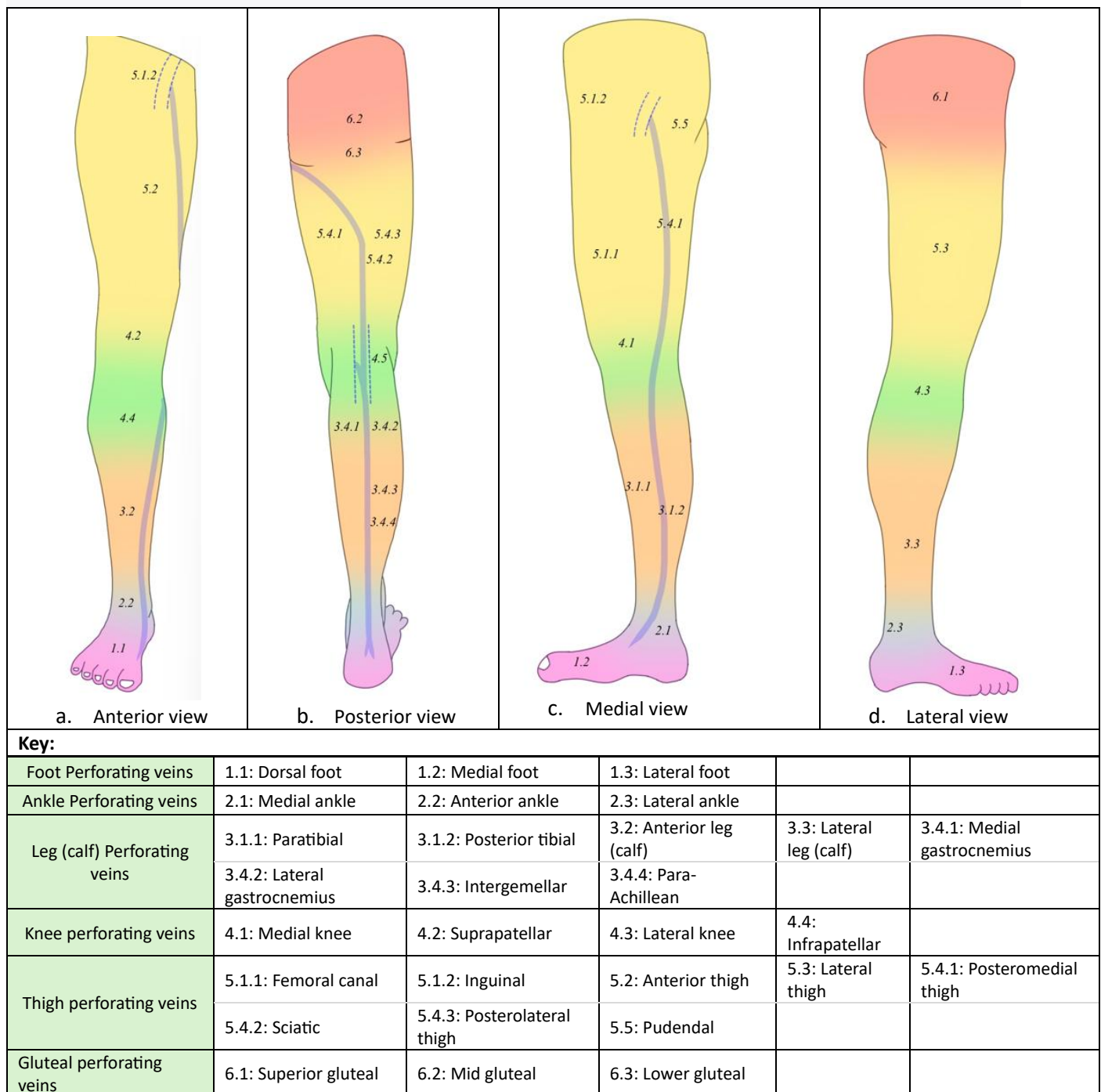
Sonographers should also be aware of bone PVs (intraosseous PVs) that can become incompetent. They allow venous drainage from the interosseous to the extraosseous venous circulation and can be a source of lower limb varicose veins at the anteromedial side of the calf. Incompetent bone PVs can be recognised 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. ^[34]

Figure C2: Topographic representation of regions of groups of perforating veins. [34]

Reprinted from Journal of vascular surgery, 36(2), Caggiati A, Bergan JJ, Gloviczki P, Jantet G, Wendell-Smith CP, Partsch H, International Interdisciplinary Consensus Committee on Venous Anatomical Terminology, Nomenclature of the veins of the lower limbs: an international interdisciplinary consensus statement. 2002, with permission from Elsevier.



Section C. Venous anatomy of the lower limb. 'Duplex ultrasound examination of the lower limb for chronic venous disease: evidence-based guideline for sonographers'

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 Achilleal 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 ' <i>May-Kuster Perforator</i> '. 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 ' <i>Sherman Perforator</i> ' in the lower and mid leg, and ' <i>Boyd Perforator</i> ' 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 ' <i>Cockett Perforator</i> '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 ' <i>Gillot Perforator</i> '. 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 ' <i>mid-calf perforator of May</i> '. Connects the SSV with the muscular veins of gastrocnemius and soleus in the middle of the calf. Para-Achilleal: Formerly known as ' <i>Bassi Perforator</i> '. 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	
Thigh PVs	Infrapatellar	Runs subcutaneously along the posterior aspect of the calf and popliteal area to connect the superficial tributary of the terminal section of the SSV with popliteal veins; sometimes parallel to the SSV and typically forms a separate junction with the popliteal vein usually lateral to the SPJ. Formerly known as ' <i>Thierry Perforator</i> '
	Popliteal fossa	
	Medial thigh	Connects GSV/ASV with FV/CFV
	Femoral canal	Formerly known as ' <i>Hunter Perforator</i> ' in the upper femoral canal and ' <i>Dodd Perforator</i> ' in the lower femoral canal. Connects 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.
Gluteal PVs	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 ' <i>Hach Perforator</i> '. 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
	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.

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