1 Venous anatomy and pathophysiology

The peripheral venous system functions both as a reservoir to hold extra blood and as a conduit to return blood from the periphery to the heart and lungs. Unlike arteries, which possess three well-defined layers, most veins are composed of a single tissue layer. Only the largest veins possess internal elastic membranes, and at best this layer is thin and unevenly distributed, providing little buttress against high internal pressures. The correct functioning of the venous system depends on a complex series of valves and pumps that are individually frail and prone to malfunction, yet the system as a whole performs remarkably well under extremely adverse conditions.

The entire cardiac output volume of 5–10 L/min is received into end-capillary venules for eventual delivery back to the heart and lungs. A large part of this volume passes into the peripheral venous system of the extremities, where it is received against a reverse pressure gradient, then is passed (mostly) uphill against gravity, against fluctuating thoracoabdominal pressures, and sometimes in the face of additional back pressures such as the elevated right atrial pressures of congestive heart failure. All of this return circulation occurs with no obvious motive force. Considered in this light, the venous system seems almost magical in its function.

Primary collecting veins of the lower extremity are passive, thin-walled reservoirs that are tremendously distensible. Most are suprafascial, surrounded by loosely bound alveolar and fatty tissue that is easily displaced. These suprafascial collecting veins can dilate to accommodate large volumes of blood with little increase in back pressure, so that the volume of blood sequestered within the venous system at any moment can vary by a factor of two or more without interfering with the normal function of the veins. Suprafascial collecting veins belong to the superficial venous system. Outflow from collecting veins is via secondary, or conduit, veins that have thicker walls and are less distensible. Most of these veins are subfascial and are surrounded by tissues that are dense and tightly bound. These subfascial veins belong to the deep venous system.

The superficial venous system

The superficial venous system is a tremendously complicated and extremely variable weblike network of interconnecting veins, most of which are unnamed. A few larger superficial veins are fairly constant in location; like the deep veins, these superficial veins serve as a conduit to pass blood centrally and eventually into the deep venous system.

The principal named superficial veins of the lower extremity are the small saphenous vein (SSV), which usually runs from ankle to knee, and the great saphenous vein (GSV), which usually runs from ankle to groin.

The small saphenous vein (Figure 1.1)

The small saphenous vein originates in the lateral foot. It passes posteriorly lateral to the Achilles tendon in the lower

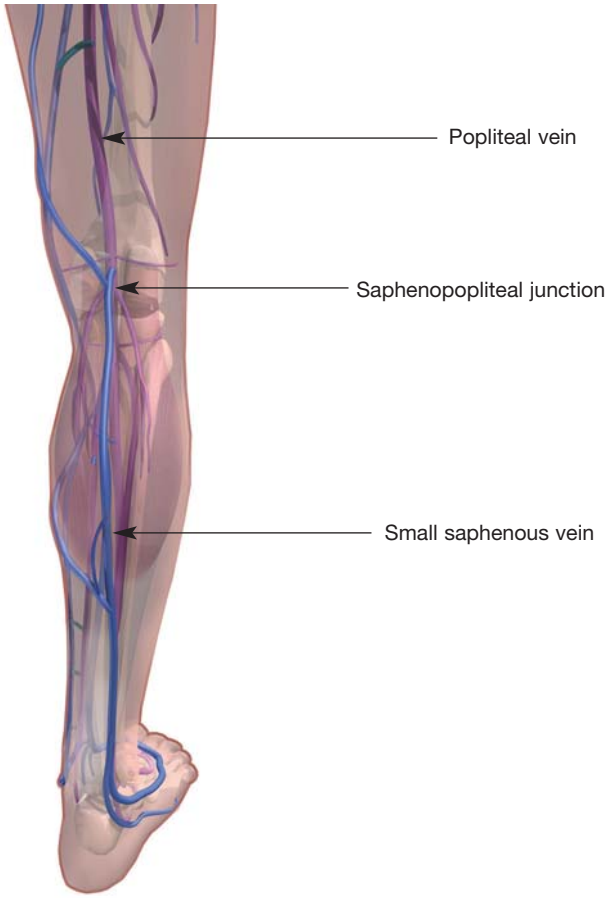

Figure 1.1 Anatomy of the small saphenous vein. (Illustration by Linda S Nye)

calf. The SSV usually lies directly superficial to the deep fascia in the midline as it reaches the upper calf, where it enters the popliteal space between the two heads of the gastrocnemius muscles. In two-thirds of cases, it joins the popliteal vein above the knee joint, and in one-third of cases, it joins with other veins (most often the GSV or the deep muscular veins of the thigh). In some patients, the SSV may have two or three different termination sites.

The great saphenous vein (Figure 1.2)

The GSV originates in the medial foot and passes anterior to the medial malleolus, then crosses the medial tibia in a posterior direction to ascend medially across the knee. Above the knee, it continues anteromedially, superficial to the deep fascia, and passes through the foramen ovale to join the common femoral vein at the groin crease at a site termed the saphenofemoral junction (SFJ). Large tributaries of the GSV are easily mistaken for the main trunk. Most patients have at least two major tributaries below the knee (the anterior and posterior tributaries, the latter known as the posterior arch vein) and at least two above the knee (the anterior circumflex and posterior circumflex tributaries). These veins usually drain into the GSV distal to the SFJ; however, they may also have a direct connection to the femoral vein. In addition to these veins, there are three pelvic veins that commonly drain into the GSV at the SFJ: the superficial inferior epigastric, the superficial external pudendal, and the superficial circumflex iliac veins. Many patients have a duplicated main GSV trunk in the thigh and some may have three or even four veins, known as anterior or posterior accessory veins, which parallel the main GSV trunk and either reconnect with it usually just above or below the knee or traverse more superficially in the distal thigh.

Perforating veins

Many superficial collecting veins deliver their blood into the great and small saphenous veins, which deliver most of their blood into the deep system through the SFJ and the saphenopopliteal junction (SPJ). However, the SPJ and SFJ are not the only pathways from the superficial system to the deep system. Superficial veins are also connected to a variable number of perforating veins that pass through openings in the deep fascia to join directly with the deep veins of the calf or thigh. Perforating veins usually contain venous valves that prevent reflux of blood from the deep veins into the superficial system. A few named perforating veins are fairly constant in location and are named only as vague groupings. The old nomenclature included Hunter's perforator in the mid thigh, Dodd's perforator in the distal thigh, Boyd's perforator at the knee, and Cockett's perforators in the distal medial calf and ankle and is demonstrated in Figure 1.3. The current nomenclature is noted in Table 1.1.

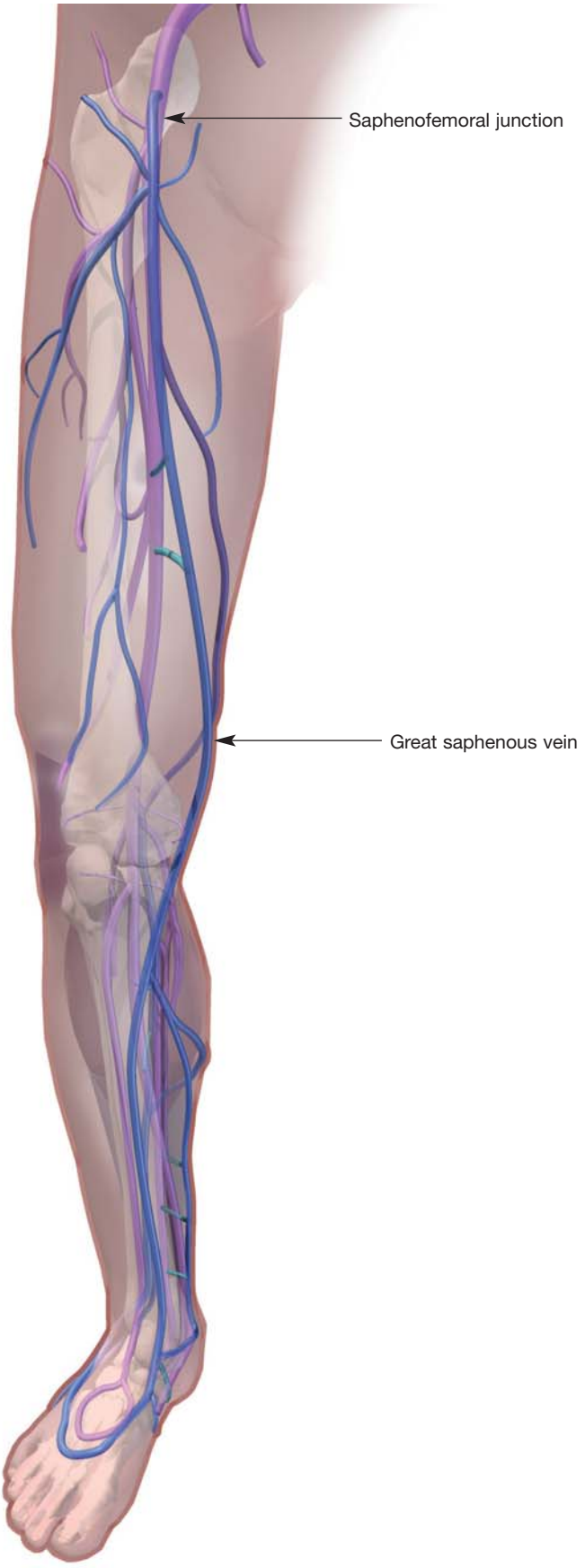

Figure 1.2 Anatomy of the great saphenous vein. (Illustration by Linda S Nye)

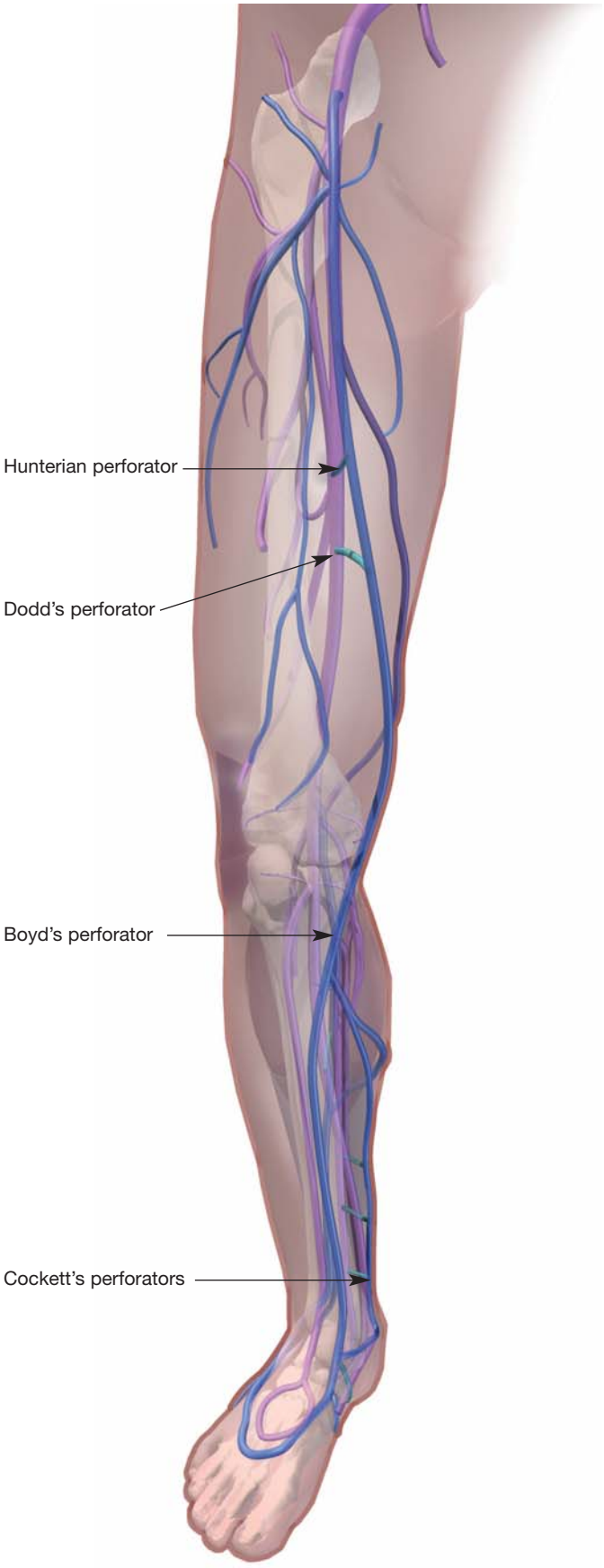

Figure 1.3 Major named perforating veins of the leg. (Illustration by Linda S Nye)

Table 1.1 Perforating veins (PV) of the leg

Foot perforators	Dorsal foot or intercapitular PV Medial, lateral, plantar foot PV
Ankle perforators	Medial ankle, lateral ankle, anterior ankle PV
Leg (calf) perforators	Paratibial, posterior tibial PV (formerly Cockett's perforators) Anterior leg, lateral leg PV Posterior leg PV (medial and lateral gastrocnemius, Intergemellar, para-achillean PV)
Knee perforators	Medial knee PV (formerly Boyd's perforator) Suprapatellar, lateral knee, infrapatellar, popliteal fossa PV
Thigh perforators	Medial thigh PV (formerly Hunter's perforator) (PV of the femoral canal or Inguinal PV) Anterior thigh, lateral thigh PV Posterior thigh PV (posteromedial, sciatic, posterolateral PV) Pudendal PV
Gluteal perforators	Superior gluteal, midgluteal, lower gluteal PV

The deep venous system (Figure 1.4)

All venous blood is eventually received by the deep venous system on its way back to the right atrium of the heart. In most cases, there are five major named members of the deep venous system: three below and two above the knee. The principal deep venous trunk of the leg is called the popliteal vein (PV) from below the knee until it passes upward and anteriorly through the adductor canal in the distal thigh, where it is called the femoral vein (FV) for the remainder of its course in the thigh. Although historically called the "superficial femoral vein," this deep vein should be referred to simply as the femoral vein in order to clarify its position within the deep venous system.

Deep veins of the calf

In the lower leg, three pairs of deep veins exist: the anterior tibial vein (ATV), draining the dorsum of the foot; the posterior tibial vein (PTV), draining the medial aspect of the foot; and the peroneal vein, draining the lateral aspect of the foot. From the ankle, the anterior tibial vein passes upward anterolateral to the interosseous membrane, the posterior tibial vein passes upward posteromedially beneath the medial edge of the tibia, and the peroneal vein passes upward posteriorly through the calf. Venous sinusoids within the calf muscle coalesce to form soleal and gastrocnemius intramuscular venous plexi, which join the peroneal vein in mid calf. In most patients, each

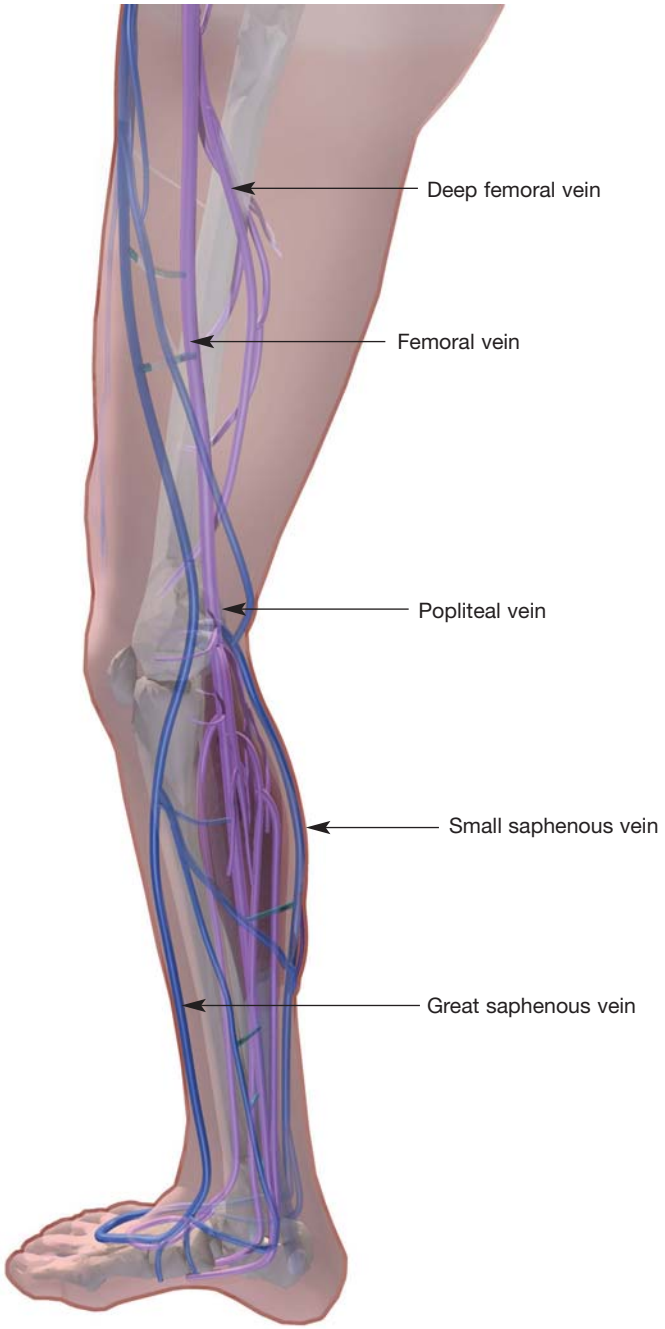

Figure 1.4 The deep venous system of the leg. (Illustration by Linda S Nye)

one of these is actually a pair of veins flanking an artery of the same name; thus, there are actually six named deep veins below the knee in a typical patient. Just below the knee, the four anterior and posterior tibial veins join with the two peroneal veins to become the single large popliteal vein.

Deep veins of the thigh

The popliteal vein courses proximally behind the knee and then passes anteromedially in the distal thigh through the adductor canal, at which point it is called the FV. The PV and the FV are one and the same, and this is the largest and longest deep vein of the lower extremity. The deep femoral vein (DFV) is a short, stubby vein that usually has its origin in terminal muscle tributaries within the deep muscles of the lateral thigh, but may communicate with the popliteal vein in up to 10% of patients. In the proximal thigh, the FV and the DFV join together to form the common femoral vein (CFV), which passes upward above the groin crease to become the iliac vein.

The calf muscle pump

The passage of blood upward from the feet against gravity depends on a complex array of valves and pumps. Muscle pumps of the calf and foot provide the motive force for venous return. This is frequently called the calf muscle pump or musculovenous pump and is thought to function as the peripheral heart. The calf muscle pump is easy to understand by simple analogy to the common hand-pump bulb of a sphygmomanometer. Before pumping starts, the pressure is neutral and equal everywhere throughout the system. When the hand bulb is squeezed, the intake valve is forced closed and the outflow valve is forced open. Air is pumped into the cuff at high pressure. When the hand bulb is allowed to relax, the bulb re-expands. The inflow valve opens to allow refilling of the bulb.

Each segment of the calf muscle pump works in the same way as the hand bulb of the sphygmomanometer. Inflow to a segment of deep vein is through intake valves from perforating veins as well as from the deep vein segment below. Outflow is through an outflow valve to the deep vein segment above. Squeezing of the vein segment occurs when muscle contraction increases the pressure within a fascial muscle compartment. Just like a sphygmomanometer, the calf muscle pump can achieve pumping pressures of several hundred mmHg before valve failure occurs.

Venous dysfunction

Venous dysfunction develops when venous return is impaired for any reason, and can arise from abnormalities within the deep veins, superficial veins, or a combination. It can result from primary muscle pump failure, from venous obstruction (thrombotic or nonthrombotic), or from venous valvular incompetence, which may be segmental or may involve the entire length of the vein. Immediately after ambulation, the normal pressure within the veins of the lower extremity is extremely low. Normal inflow to the lower extremity veins is purely via arterial inflow; the normal venous system will be more or less refilled after 3–5 minutes of standing. When the entire venous system is filled, the valves float open and venous pressure rises to a maximum exactly equal to the height of the standing column of venous blood from right atrium to foot. This condition triggers an urge to move the legs, activating the muscle pumps and emptying the leg veins.