9 The Blood Vessels of the Lower Extremity

Chapter Outline

THE ARTERIES

Collateral Circulation

If the arterial supply to the leg is occluded, necrosis or gangrene will follow unless an adequate bypass to the obstruction is present—that is, a collateral circulation. Sudden occlusion of the femoral artery by ligature or embolism, for example, is usually followed by gangrene. However, gradual occlusion such as occurs in atherosclerosis is less likely to be followed by necrosis because the collateral blood vessels have time to dilate fully. The collateral circulation for the proximal part of the femoral artery is through the cruciate and trochanteric anastomoses; for the femoral artery in the adductor canal, it is through the perforating branches of the profunda femoris artery and the articular and muscular branches of the femoral and popliteal arteries.

Femoral Artery Catheterization

A long, fine catheter can be inserted into the femoral artery as it descends through the femoral triangle. The catheter is guided under fluoroscopic view along the external and common iliac arteries into the aorta. The catheter can then be passed into the inferior mesenteric, superior mesenteric, celiac, or renal arteries. Contrast medium can then be injected into the artery under examination and a permanent record obtained by taking a radiograph. Pressure records can also be obtained by guiding the catheter through the aortic valve into the left ventricle.

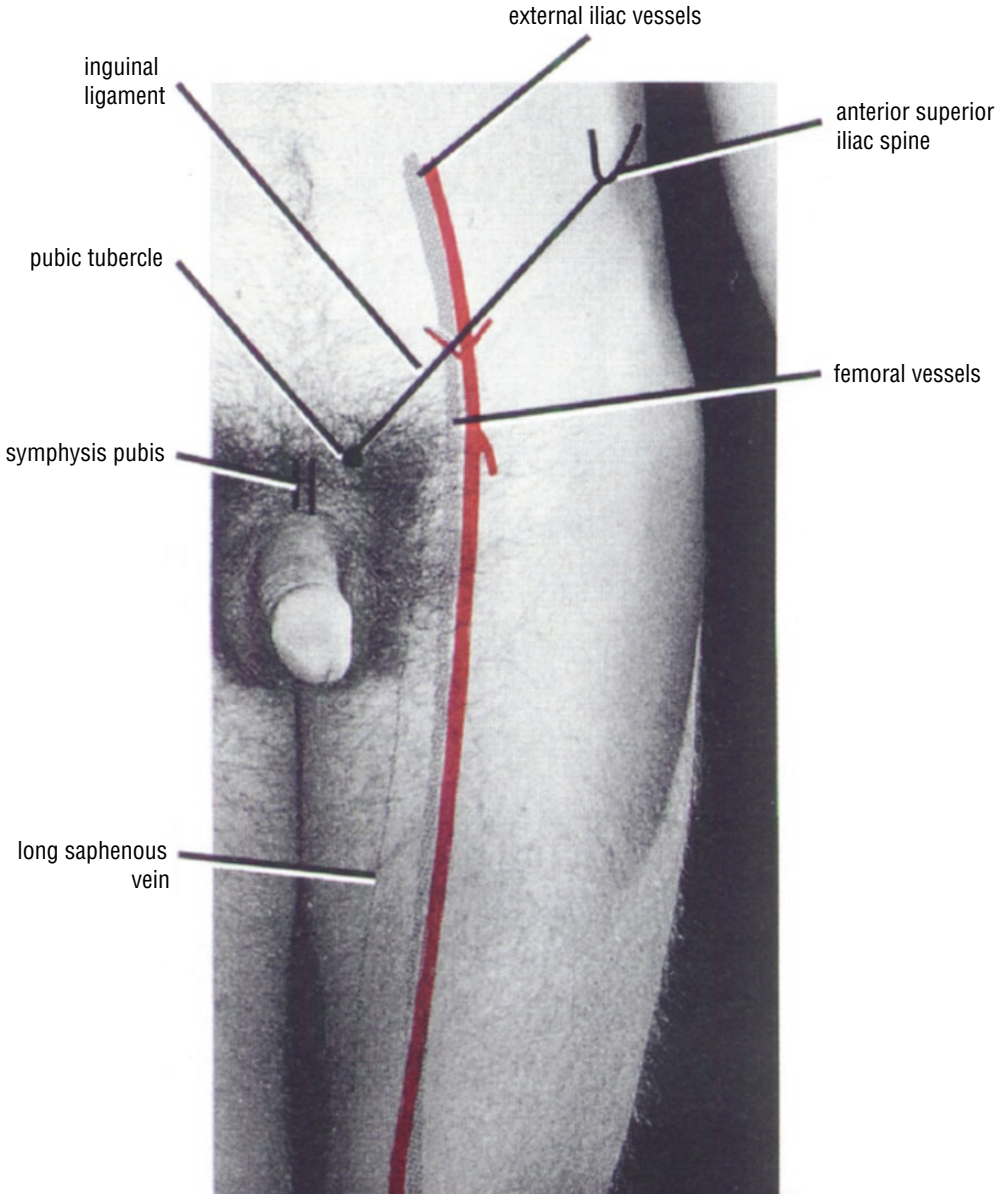
Anatomy of Technique

The femoral artery is first located just below the inguinal ligament midway between the symphysis pubis and the anterior superior iliac spine (CD Fig. 9-1). The needle or catheter is then inserted into the artery. The following structures are pierced:

- Skin
- Superficial fascia
- Deep fascia
- Anterior layer of the femoral sheath

Anatomy of Complications

The femoral vein lies immediately medial to the artery and may be entered in error. The nonpulsatile nature of the vein on palpation should exclude this possibility. Since the hip joint lies posterior to the femoral artery, the erroneous passage of the needle through the posterior arterial wall may cause it to pierce the psoas muscle and enter the joint cavity. Some difficulty may be experienced in passing the catheter up the femoral artery if the artery is tortuous or if there is extensive atherosclerosis of the arterial wall.



CD Figure 9-1 Surface markings of the major blood vessels on the anterior surface of the left thigh.

Traumatic Injury to Arteries of the Lower Limb

Injury to the large femoral artery can cause rapid exsanguination of the patient. Unlike in the upper extremity, arterial injuries of the lower limb do not have a good prognosis. The collateral circulations around the hip and knee joints, although present, are not as adequate as that around the shoulder and elbow. Damage to a neighboring large vein can further complicate the situation and causes further impairment of the circulation to the distal part of the limb.

Anatomy of Complications of Arterial Injury

A single perforating injury to an artery in the lower limb may also perforate an accompanying vein and establish an acute **arteriovenous fistula.** This complication is common in regions where large vessels run close together, such as the femoral artery and vein in the femoral triangle and the subsartorial canal, and the popliteal artery and vein behind the knee. Such a shunt produces a continuous machinery-like murmur over the fistula with the later development of varicosities and edema of the distal part of the limb.

Anatomically, a true aneurysm is one whose wall contains all three layers of the arterial wall, namely, the intima, media, and adventitia. A **false aneurysm,** sometimes called a **pulsating hematoma**, is one whose wall contains only the tunica adventitia. An arterial perforation may lead to a false aneurysm that becomes walled off by the adventitia and surrounding tissues. Pressure on neighboring nerves may give rise to neurologic symptoms.

Compartmental Syndromes

Delay in the diagnosis and repair of injured arteries, especially when accompanied by vein damage, may lead to muscle necrosis and compartmental edema. The compartment syndromes are discussed on CD Chapter 13.

Occlusions of the Popliteal, Anterior, and Posterior Tibial Arteries

Popliteal artery occlusion occurs just below the beginning of the artery (just below the opening in the adductor magnus muscle). In some cases the occlusion extends distally to involve the origins of the anterior and posterior tibial arteries and even the peroneal artery. Symptoms include intermittent claudication, night cramps, and rest pain caused by ischemic neuritis. Signs include impaired or absent arterial pulses, lowered skin temperature, color changes, muscle weakness, and trophic changes.

Intermittent Claudication and Arterial Occlusive Disease of the Lower Extremity

Atherosclerosis of the lower limb arteries is common in men. Ischemia of the muscles produces a cramp-like pain with exercise. **Intermittent claudication** is a condition characterized by calf muscle cramping pain on exertion that is relieved by rest. Thrombosis in a diseased segment of the artery may lead to a sudden worsening of the symptoms and even cause nocturnal ischemic pain. The common sites for occlusion are the femoral, popliteal, and tibioperoneal arteries. If the obstruction occurs more proximally in the aorta or iliac arteries, impotence is common.

Femoropopliteal and Femorotibial Bypass for Lower Extremity Vascular Insufficiency

Bypasses have been used with success in patients with severe distal extremity ischemia. In the presence of gangrene or severe rest pain, the distal limb has been successfully salvaged. A reversed ipsilateral autogenous saphenous vein, a contralateral saphenous vein, or a cephalic vein graft has been used to connect the proximal femoral artery or popliteal artery to the distal popliteal or tibial or peroneal arteries.

Lumbar Sympathectomy and Occlusive Arterial Disease

Lumbar sympathectomy may be advocated as a form of treatment in occlusive arterial disease of the lower extremity to increase the blood flow through the collateral circulation. Preganglionic sympathectomy is performed by removing the upper three lumbar ganglia and the intervening parts of the sympathetic trunk.

Aneurysms of the Lower Extremity

These occur much less frequently than abdominal aortic aneurysms and are usually caused by atherosclerosis. Most patients are over 50 years of age, and the common sites are the femoral and popliteal arteries. The diagnosis is usually made by finding an expansile swelling along the course of the artery. Patients may present in the emergency department with complications, which include sudden embolic obstruction to arteries distal to the aneurysm or sudden thrombotic occlusion of the aneurysm. Pressure on neighboring nerves may give rise to symptoms; for example, an enlarging popliteal aneurysm may press on the tibial nerve,

causing pain in the foot. Rupture of femoral or popliteal aneurysms is rare.

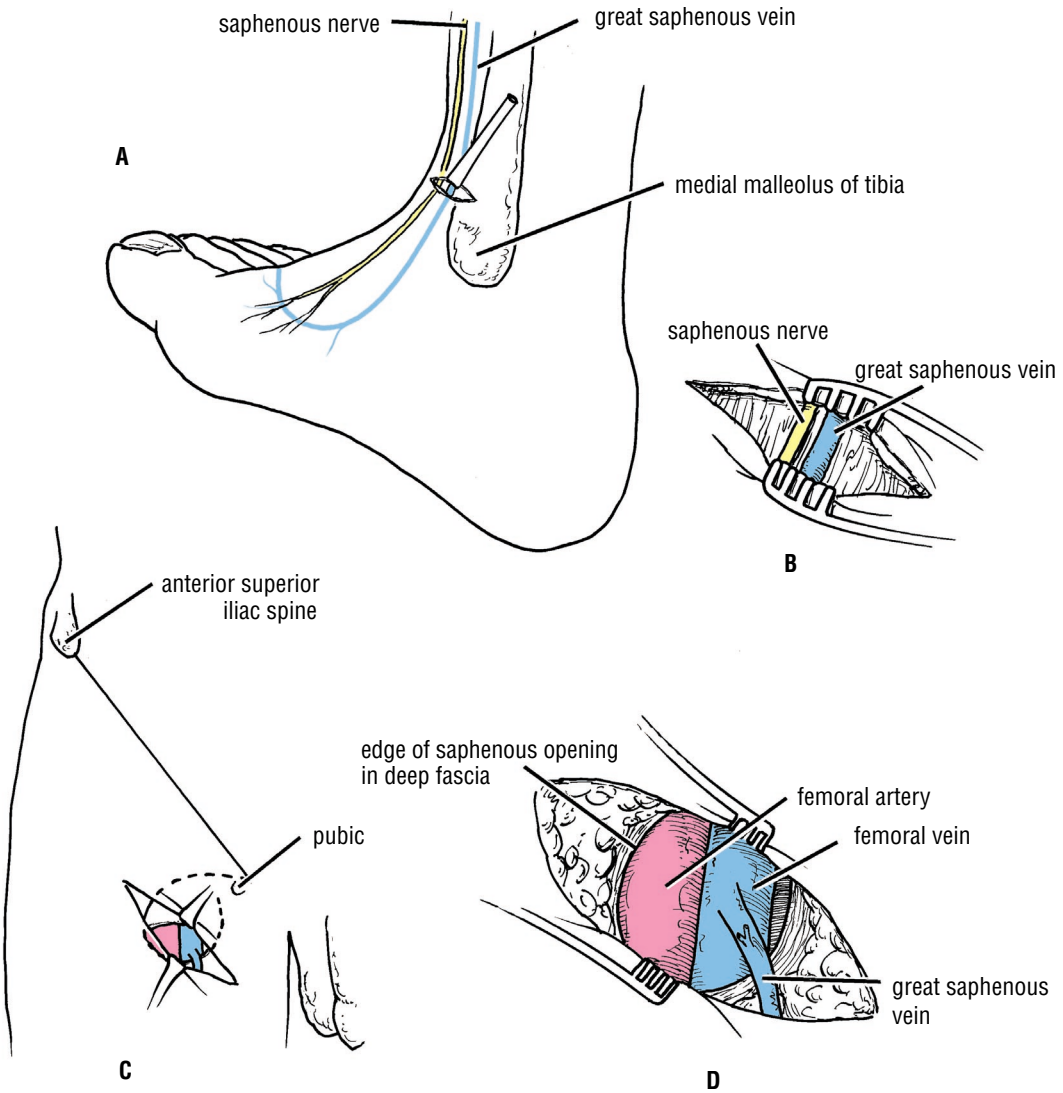
THE VEINS

Great Saphenous Vein Variation and Venous Vein Cutdown

Occasionally the great saphenous vein at the medial malleolus is replaced by several small veins instead of a single large one. This possibility is of great clinical importance when performing a venous cutdown

Great Saphenous Vein Cutdown

Exposure of the great saphenous vein through a skin incision (a "cutdown") is usually performed at the ankle (CD Fig. 9-2). This site has the disadvantage that phlebitis (inflammation of the vein wall) is a potential complication. The great saphenous vein also can be entered at the groin in the femoral triangle, where phlebitis is relatively rare; the larger diameter of the vein at this site permits the use of large-diameter catheters and the rapid infusion of large volumes of fluids.



CD Figure 9-2 Great saphenous vein cutdown. **A and B.** At the ankle. The great saphenous vein is constantly found in front of the medial malleolus of the tibia. **C and D.** At the groin. The great saphenous vein drains into the femoral vein two fingerbreadths below and lateral to the pubic tubercle.

Anatomy of Ankle Vein Cutdown

The procedure is as follows:

1. The sensory nerve supply to the skin immediately in front of the medial malleolus of the tibia is from branches of the saphenous nerve, a branch of the femoral nerve. The saphenous nerve branches are blocked with local anesthetic.
2. A transverse incision is made through the skin and subcutaneous tissue across the long axis of the vein just anterior and superior to the medial malleolus (see CD Fig. 9-2). Although the vein may not be visible through the skin, it is **constantly** found at this site.
3. The vein is easily identified, and the **saphenous nerve** should be recognized; the nerve usually lies just anterior to the vein (see CD Fig. 9-2).

Anatomy of Groin Vein Cutdown

1. The area of thigh skin below and lateral to the scrotum or labium majus is supplied by branches of the ilioinguinal nerve and the intermediate cutaneous nerve of the thigh. The branches of these nerves are blocked with local anesthetic.
2. A transverse incision is made through the skin and subcutaneous tissue centered on a point about 1.5 in. (4 cm) below and lateral to the pubic tubercle (see CD Fig. 9-2). If the femoral pulse can be felt (may be absent in patients with severe shock), the incision is carried medially just medial to the pulse.
3. The great saphenous vein lies in the subcutaneous fat and passes posteriorly through the saphenous opening in the deep fascia to join the femoral vein about 1.5 in. (4 cm), or two fingerbreadths, below and lateral to the pubic tubercle. It is important to understand that the great saphenous vein passes through the saphenous opening to gain entrance to the femoral vein. However, the size and shape of the opening are subject to variation.

The Great Saphenous Vein in Coronary Bypass Surgery

In patients with occlusive coronary disease caused by atherosclerosis, the diseased arterial segment can be bypassed by inserting a graft consisting of a portion of the great saphenous vein. The venous segment is reversed so that its valves do not obstruct the arterial flow. Following removal of the great saphenous vein at the donor site, the superficial venous blood ascends the lower limb by passing through perforating veins and entering the deep veins.

The great saphenous vein can also be used to bypass obstructions of the brachial or femoral arteries.

Intraosseous Infusion in the Infant

This technique may be used for the infusion of fluids and blood when it has been found impossible to obtain an intravenous line. The procedure is easy and rapid to perform as follows:

- With the distal leg adequately supported, the anterior subcutaneous surface of the tibia is palpated.
- The skin is anesthetized about 1 in. (2.5 cm) distal to the tibial tuberosity, thus blocking the infrapatellar branch of the saphenous nerve.
- The bone marrow needle is directed at right angles through the skin, superficial fascia, deep fascia, and tibial periosteum and the cortex of the tibia. Once the needle tip reaches the medulla and bone marrow, the operator senses a feeling of "give." The position of the needle in the marrow can be confirmed by aspiration. The needle should be directed slightly caudad to avoid injury to the epiphyseal plate of the proximal end of the tibia. The transfusion may then commence.

Varicose Veins

A varicosed vein is one that has a larger diameter than normal and is elongated and tortuous. Varicosity of the esophageal and rectal veins is described elsewhere. This condition commonly occurs in the superficial veins of the lower limb and, although not life threatening, is responsible for considerable discomfort and pain.

Varicose veins have many causes, including hereditary weakness of the vein walls and incompetent valves; elevated intraabdominal pressure as a result of multiple pregnancies or abdominal tumors; and thrombophlebitis of the deep veins, which results in the superficial veins becoming the main venous pathway for the lower limb. It is easy to understand how this condition can be produced by incompetence of a valve in a perforating vein. Every time the patient exercises, high-pressure venous blood escapes from the deep veins into the superficial veins and produces a varicosity, which might be localized to begin with but becomes more extensive later.

The successful operative treatment of varicose veins depends on the ligation and division of all the main tributaries of the great or small saphenous veins, to prevent a collateral venous circulation from developing, and the ligation and division of all the perforating veins responsible for the leakage of high-pressure blood from the deep to the superficial veins. It is now common practice to also remove or strip the superficial veins. Needless to say, it is imperative to ascertain that the deep veins are patent before operative measures are taken.

Varicose Leg Ulcers

These occur in the region of the medial malleolus, are caused by venous skin stasis, and may be a complication of

varicose veins; many are caused by postthrombotic incompetent perforating veins in the region.

A venous ulcer must be distinguished from an **arterial ulcer** caused by atherosclerosis of the skin arteries. An arterial ulcer tends to occur on the lateral side of the distal leg, and the leg is often pulseless and cool. A venous ulcer occurs on the medial side of the distal leg because skin venous stasis tends to be more severe on the medial side in the presence of varicose veins. The explanation for the laterally placed arterial ulcer is that the skin over the lateral malleolus receives a poorer arterial supply than that over the medial malleolus.

Traumatic Bleeding from a Varicosed Vein

Profuse bleeding from a pierced varicosed vein may cause a patient to seek medical treatment. Pressure over the vein, proximal to the injury, should stop the blood escaping. The varicosed veins have incompetent valves and venous blood is merely draining downward by gravity from the abdominal veins. Raising the leg to a level above the heart should also stop the bleeding.

Superficial Thrombophlebitis

Thrombosis of the superficial veins of the lower limb is often associated with varicose veins. The condition is painful, and the thrombosed vein is tender to touch; the overlying skin is reddened and edematous. The thrombus is usually strongly adherent to the wall of the vein so that emboli are rarely formed. However, should the thrombosis extend to the deep veins through a perforating vein, embolic formation in the deep vein can be a serious, although rare, complication.

Deep Thrombophlebitis

Thrombosis of the deep veins can occur at any time, but significant predisposition is immobility of the lower limbs in bed or in a splint. The common site where the process starts is the veins draining the soleus muscle in the calf. It must be assumed that the pressure of the bed on the calf veins damages the tunica intima, and this together with certain predisposing factors, such as surgical trauma, malignant disease, pregnancy, or estrogen therapy, initiates thrombus formation. Once formed, the thrombus may extend proximally into the popliteal and femoral veins and even higher into the iliac veins. The symptoms include discomfort and tightness in the calf, especially when the patient is using the calf muscles, as in standing and walking. Tenderness of the calf muscles may be apparent, and edema of the ankles, pretibial area, or thigh may be present. The superficial veins may be dilated and more obvious than normal. The great danger of deep vein thrombosis is the high incidence of pulmonary embolism. A secondary problem is residual chronic venous insufficiency of the lower extremities.

Deep Vein Thrombosis and Long-Distance Air Travel

Passengers who sit immobile for hours on long-distance flights are very prone to deep vein thrombosis in the legs. Preventative measures include stretching of the legs every hour to improve the venous circulation.

Femoral Vein Catheterization

Femoral vein catheterization is used when rapid access to a large vein is needed. The femoral vein has a constant relationship to the medial side of the femoral artery just below the inguinal ligament and is easily cannulated. However, because of the high incidence of thrombosis with the possibility of fatal pulmonary embolism, the catheter should be removed once the patient is stabilized.

Anatomy of the Procedure

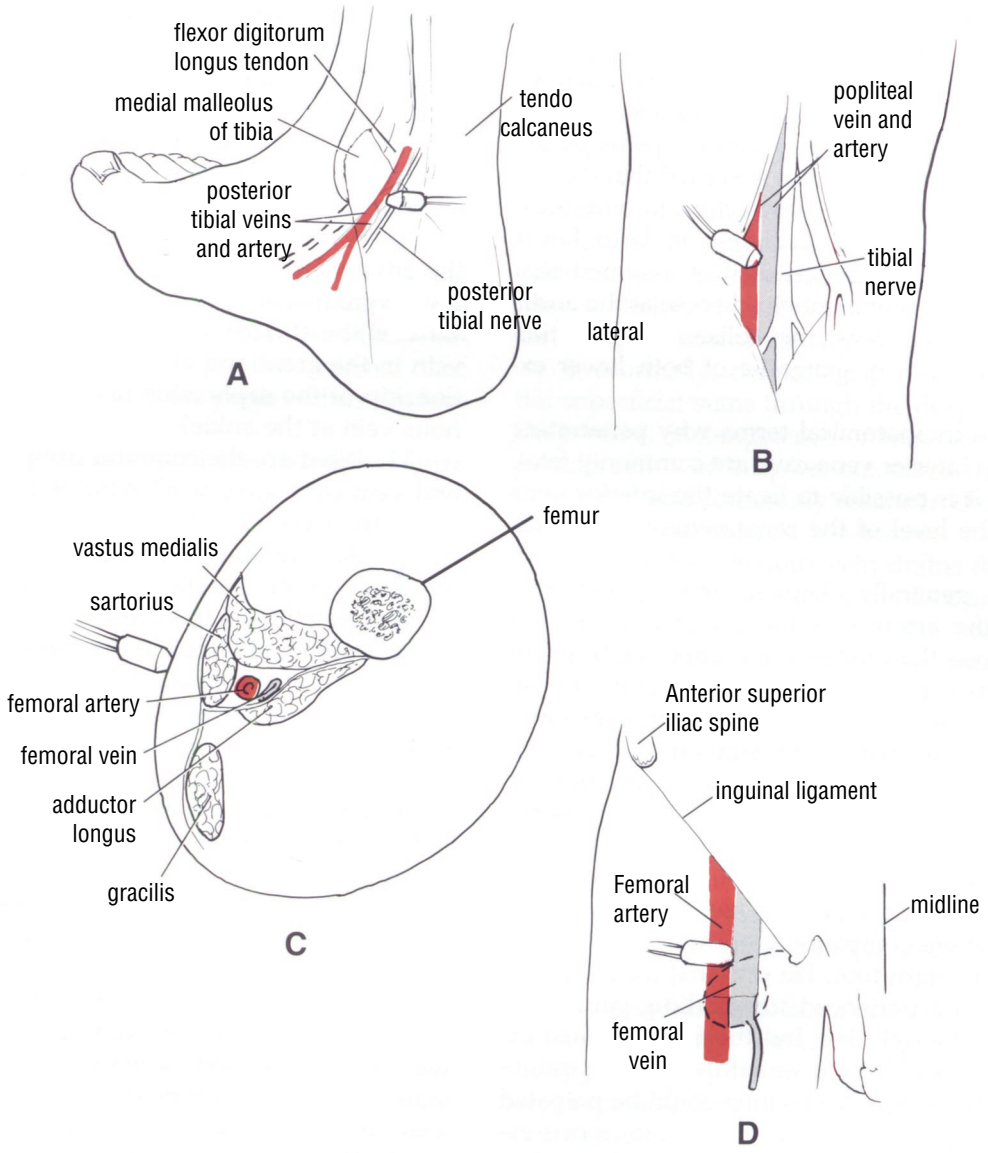
1. The skin of the thigh below the inguinal ligament is supplied by the genitofemoral nerve; this nerve is blocked with a local anesthetic.
2. The femoral pulse is palpated midway between the anterior superior iliac spine and the symphysis pubis, and the femoral vein lies immediately medial to it.
3. At a site about two fingerbreadths below the inguinal ligament, the needle is inserted into the femoral vein.

Doppler Ultrasound Examination of Venous Flow in the Lower Extremity

Posterior tibial veins: The probe is applied to the skin just posterior to the medial malleolus of the tibia. Here the posterior tibial veins accompany the posterior tibial artery between the tendon of the flexor digitorum longus and the posterior tibial nerve (CD Fig. 9-3).

Popliteal vein: The probe is applied to the skin over the popliteal space with the knee partly flexed to relax the deep fascia. The flow signal is best heard over the vein just lateral to the popliteal artery (see CD Fig. 9-3).

Femoral vein: The probe is placed over the vein at midthigh as it lies in the subsartorial canal with the femoral artery (see CD Fig. 9-3). The probe can also be applied higher up on the skin covering the femoral triangle just below the inguinal ligament. Here the femoral vein lies medial to the femoral artery (see CD Fig. 9-3). The pulse of the femoral artery can easily be felt at the midpoint between the anterior superior iliac spine and the symphysis pubis.



CD Figure 9-3 Doppler ultrasound of venous blood flow in the lower limb. **A.** Posterior tibial veins at the ankle. **B.** Popliteal vein behind the knee. **C.** Femoral vein and the subsartorial (adductor) canal in the midthigh. **D.** Femoral vein just below the inguinal ligament.

Venous Tone in Hypovolemic Shock

In extreme hypovolemic shock, excessive venous tone caused by the contraction of the smooth muscle in the vein walls may inhibit the venous flow and thus delay the introduction of intravenous blood into the vascular system.

Arterial Palpation

Every health professional should know the precise position of the main arteries within the lower limb, for he or she may be called on to arrest a severe hemorrhage or palpate different parts of the arterial tree in patients with arterial occlusion.

The **femoral artery** enters the thigh behind the inguinal ligament at a point midway between the anterosuperior iliac spine and the symphysis pubis (see text Fig. 9-2 and CD Fig. 9-1). The artery is easily palpated here because it can be pressed backward against the pectineus and the superior ramus of the pubis.

The **popliteal artery** can be felt by gentle palpation in the depths of the popliteal space provided that the deep fascia is fully relaxed by passively flexing the knee joint (see text Fig. 9-7).

The **dorsalis pedis artery** lies between the tendons of extensor hallucis longus and extensor digitorum longus, midway between the medial and lateral malleoli on the front of the ankle (see text Fig. 9-9).

The **posterior tibial artery** passes behind the medial malleolus and beneath the flexor retinaculum; it lies between the tendons of flexor digitorum longus and flexor hallucis longus. The pulsations of the artery can be felt midway between the medial malleolus and the heel (see text Fig. 9-14).

It should be remembered that the dorsalis pedis artery is sometimes absent and is replaced by a large perforating branch of the peroneal artery. In the same manner, the peroneal artery may be larger than normal and replace the posterior tibial artery in the lower part of the leg.

Clinical Problem Solving Questions

Read the following case histories/questions and give the best answer for each.

A 47-year-old woman complaining of a dull, aching pain in the lower part of both legs visited her physician. She stated that the pain was particularly severe at the end of a long day of standing at her work. On examination, the patient was found to have widespread varicose veins in both legs.

1. The following symptoms and signs supported the diagnosis **except** which?
   A. The patient stated that the skin down the medial side of the leg was irritated especially in dry weather.
   B. If the patient coughed in the standing position, a fluid thrill was transmitted from the abdomen to the hand palpating the veins.
   C. The skin showed marked discoloration over the medial malleoli and was dry and scaly.
   D. The patient had a large family of six children and the varicose veins showed improvement during each pregnancy.
   E. The great and small saphenous veins in both legs were enlarged and elongated.

A 65-year-old man told his physician that he could walk only about 50 yd (46 m) before a cramp-like pain in his left leg forced him to rest. After a thorough physical examination, a diagnosis of severe intermittent claudication of the left leg was made.

2. The following findings in this patient supported the diagnosis **except** which?
   A. His femoral pulses were normal in both legs.
   B. The popliteal, posterior tibial, and dorsalis pedis pulses were present in the right leg and completely absent in the left leg.
   C. Arteriography revealed a blockage of the left femoral artery at the level of the adductor tubercle.
   D. The lower part of the left leg was receiving its blood supply through the muscular and genicular branches of the femoral artery and the muscular and genicular branches of the popliteal artery.
   E. The collateral circulation in the left leg was adequate to prevent gangrene but was insufficient to supply oxygen to the active leg muscles.
   F. The perforating branches of the profunda femoris artery did not participate in the collateral circulation around the blocked femoral artery.

A 58-year-old businessman flew to Korea from New York by plane. Except for infrequent visits to the toilet, he remained in his seat sleeping or reading. Toward the end of the long flight, he experienced mild cramp-like pain in his right calf. On feeling his leg, he found it to be tender but thought nothing more about it. On reaching his destination, he was walking down the ramp from the plane when he suddenly collapsed with severe pain in his left chest and was experiencing extreme respiratory distress. The airport physician made the diagnosis of pulmonary embolism, secondary to deep vein thrombosis of the right calf.

3. The blood clot (embolus) reached the left lung via the following blood vessels **except** which?
   A. The right popliteal vein
   B. The right common iliac vein
   C. The inferior vena cava
   D. The pulmonary trunk
   E. The left pulmonary vein

4. A 65-year-old man was seen in the emergency department complaining of the onset of a sudden pain in his right foot. He said that for the past 6 months he had experienced some aching pain in the lower part of the right leg, but the foot pain had occurred quite suddenly and was different. On examination, a tender pulsatile swelling could be palpated in the right popliteal space. In anatomic terms explain the chronic aching pain in the right lower leg. What is your explanation for the sudden onset of pain in the right foot?

5. Explain the significance of the valved perforating veins of the lower limbs. What is the surface marking of the small saphenous vein at the ankle?
6. What is the surface marking of the femoral artery? Name the structures that are pierced by the insertion of a catheter into the femoral artery. What is the relationship of the femoral artery to the femoral vein and the hip joint?
7. Compare in anatomic and practical terms the advantages and disadvantages of cutting down on the great saphenous vein at the groin and ankle. What is the surface marking of the great saphenous vein in the groin and at the ankle? What is the relationship of the saphenous nerve to the great saphenous vein at the ankle?
8. What are the common complications of femoral vein catheterization? What is the surface marking of the femoral vein?

Answers and Explanations

1. **D** is the correct answer. During the later months of pregnancy, the enlarged uterus presses on the inferior vena cava and impedes the venous return from the lower limbs. This condition results in a worsening of preexisting varicosed veins.
2. **F** is the correct answer. The profunda femoris artery arises from the femoral artery about 1.5 in. (3.8 cm) below the inguinal ligament. It plays a major role in the formation of the collateral circulation around the knee joint.
3. **E** is the correct answer. The embolus does not enter the left pulmonary vein. The embolus ascends the venous system via the popliteal, femoral, external iliac, and common iliac veins and inferior vena cava to reach the right atrium of the heart. It then passes into the right ventricle, pulmonary trunk, and left pulmonary artery to finally reach the small or medium-sized branches of the left pulmonary artery, where it becomes lodged and obstructs the circulation.
4. The chronic aching pain in the right lower leg could be explained by the pressure of the expanding popliteal aneurysm on the tibial nerve (see text Fig. 9-7) in the popliteal space. The sudden onset of severe pain in the foot could be explained by the lodging of an embolus in one of the arteries in the foot. The embolus could have originated as a thrombus in the wall of the popliteal aneurysm.
5. Normally, the valved perforating veins drain the superficial veins through the deep fascia into the deep veins. Incompetence of these important veins permits reflux of deep venous blood into the superficial veins and commonly results in the formation of local superficial varices.

   The small saphenous vein drains the lateral end of the dorsal venous arch of the foot and ascends in the superficial fascia **posterior** to the lateral malleolus of the fibula. Here the position is constant and it can be readily seen.
6. The femoral artery enters the thigh beneath the inguinal ligament at a point midway between the anterior superior iliac spine and the symphysis pubis (see CD Fig. 9-1).

   The following structures are pierced by a catheter entering the femoral artery in the thigh just below the inguinal ligament: (a) skin, (b) superficial fascia, (c) deep fascia, and (d) anterior layer of femoral sheath.

   The femoral vein lies along the medial side of the femoral artery within the femoral sheath. The cavity of the hip joint lies posterior to the femoral artery, separated by the psoas muscle and the fibrous joint capsule.
7. The advantages of great saphenous vein cutdown at the ankle are (a) the position of the vein in front of the medial malleolus is constant, and (b) apart from the presence of the saphenous nerve, there are no other anatomic structures to damage—the cutdown is made over bone. The disadvantages are (a) phlebitis is a common complication, and (b) the small diameter precludes the rapid instillation of large volumes of fluid; in young children the small diameter of the vein sometimes make it difficult to identify.

   The advantages of great saphenous cutdown in the groin are (a) the larger diameter of the vein at this site permits the rapid instillation of large volumes of fluid, and (b) there is easier recognition of the vein at this site. The disadvantages of the groin site are (a) the great saphenous vein lies in thick subcutaneous fat about 1 1/2 in. below and lateral to the pubic tubercle; its identification may prove difficult in obese patients; and (b) other important structures may be damaged, including the femoral artery and vein, if the procedure is carried out by an inexperienced individual.

The saphenous nerve usually lies just anterior to the great saphenous vein as it ascends anterior to the medial malleolus of the tibia (see CD Fig. 9-2).

8. The common complications of femoral vein catheterization are (a) thrombophlebitis of the femoral vein, especially if the catheterization is prolonged (since the catheter entering the saphenous vein at the groin also goes into the femoral vein, there is risk of phlebitis with saphenous catheterization as well); (b) hematoma formation if the procedure is poorly carried out and the vein wall is torn; (c) infection of the hip joint if an infected catheter pierces the femoral vein completely or misses the vein and traverses the psoas muscle and the anterior part of the capsule of the hip joint; and (d) damage to the femoral nerve, which normally lies some distance laterally to the femoral artery (midpoint between the anterior superior iliac spine and the pubic tubercle).

The surface marking of the femoral vein is just medial to the pulsating femoral artery below the inguinal ligament. If the artery is pulseless, the position of the artery may be determined as being midway between the anterior superior iliac spine and the symphysis pubis; the vein lies just medial to it (see text Fig. 9-1).