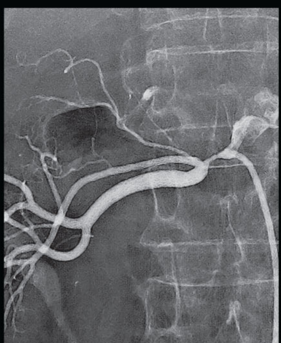
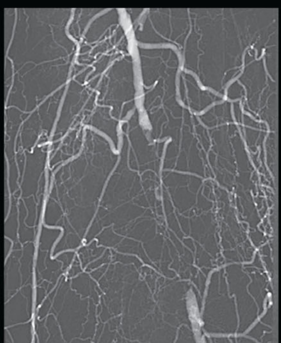
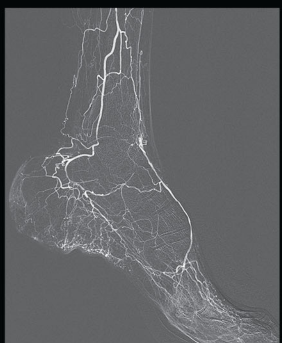
Carotid and Peripheral Vascular Interventions Textbook

Step-by-step technique

Thosaphol Limpijankit


Femoropopliteal Arterial Disease

Thosaphol Limpijankit

INTRODUCTION

Femoropopliteal arterial disease is the most common etiology of intermittent claudication (1,2). Greater than 50% of all peripheral artery disease (PAD) cases affect the femoropopliteal arteries (3). An isolated atherosclerotic stenosis or occlusion of these vessels results in decreased proximal blood flow in the leg, causing ischemic pain confined to the calf. In patients presenting critical limb ischemia (CLI), the occlusive disease of femoropopliteal artery is usually combined with occlusive disease involving the infrapopliteal tibial arteries. In general, two-thirds of symptomatic PAD patients are found to have a multi-segmental disease (4). Unlike the iliac arteries, the disease in the femoropopliteal arteries is normally diffuse disease, long occlusions and extensive calcification. It is predicted that 50% of patients receiving femoropopliteal intervention are found to have chronic total occlusions (CTOs) (5).

Although surgical revascularization is the principle management for femoropopliteal disease, increasingly endovascular intervention is being used as the primary treatment strategy. Over the last decades, new devices and technologies have been continuously developed showing improved long-term patency, including special balloon angioplasty, self-expandable nitinol stents, atherectomy devices, drug-eluting stents, and drug-coated balloons. In addition, with improvements in guidewire crossing techniques, novel crossing devices, and re-entry devices, an increasing number of challenging cases, such as complex lesion or CTOs, may now be managed with endovascular procedure (6). In the future, technological improvements will further improve long-term results in endovascular interventions of femoropopliteal disease.

ANATOMIC CONSIDERATION

The femoropopliteal segment comprises the common femoral artery (CFA), profunda femoris artery (PFA), superficial femoral artery (SFA) and popliteal artery (7). The CFA form as a continuation of the external iliac artery below the inguinal ligament level. The CFA is about 4 cm in length and is located just anterior to the femoral head. Branches emerging from the CFA comprise deep pudendal artery, superficial circumflex artery, and superior epigastric artery (Fig. 12-1). Distal to these small branches, the CFA bifurcates near the bottom of the femoral head into the deep femoral or PFA and SFA. The PFA gives rise to lateral and medial circumflex arteries supplying the femur and hip regions prior to descending far within the thigh compartment then completes as penetrating deep tissue branches. The SFA descends along the thigh anteromedial within the femoral triangle and provides a vital role in supplying the entire lower leg with oxygenated blood. It goes into and along the adductor (Hunter's) canal within the adductor hiatus close by the distal thirds and middle junction of the thigh, and converts into the popliteal artery which runs behind the femur.

One of the distinguishing features of the SFA is the absence of significant branches all along its route. This elucidates this vessel's constant diameter, normally about 6-7 mm. However, a number of small, muscular branches may be seen. The major muscular branches include the sural arteries together with the paired superior, middle, and descending geniculate arteries, which all arise above the adductus canal and form the collateral circulation round the knee. At the distal boundary of the popliteal muscle, the popliteal artery splits into the anterior tibial artery and the tibioperoneal trunk.

The anatomy of the deep femoral or PFA is important since it supplies collateral flow in the SFA CTO. Patients with SFA occlusions located distal to the take-off of the PFA and proximal to the distal reconstitution of the SFA via the profunda collaterals may remain asymptomatic for an extended time period. In contrast, occlusions of the distal SFA involving the popliteal artery may result in rapidly developing and progressing claudication.

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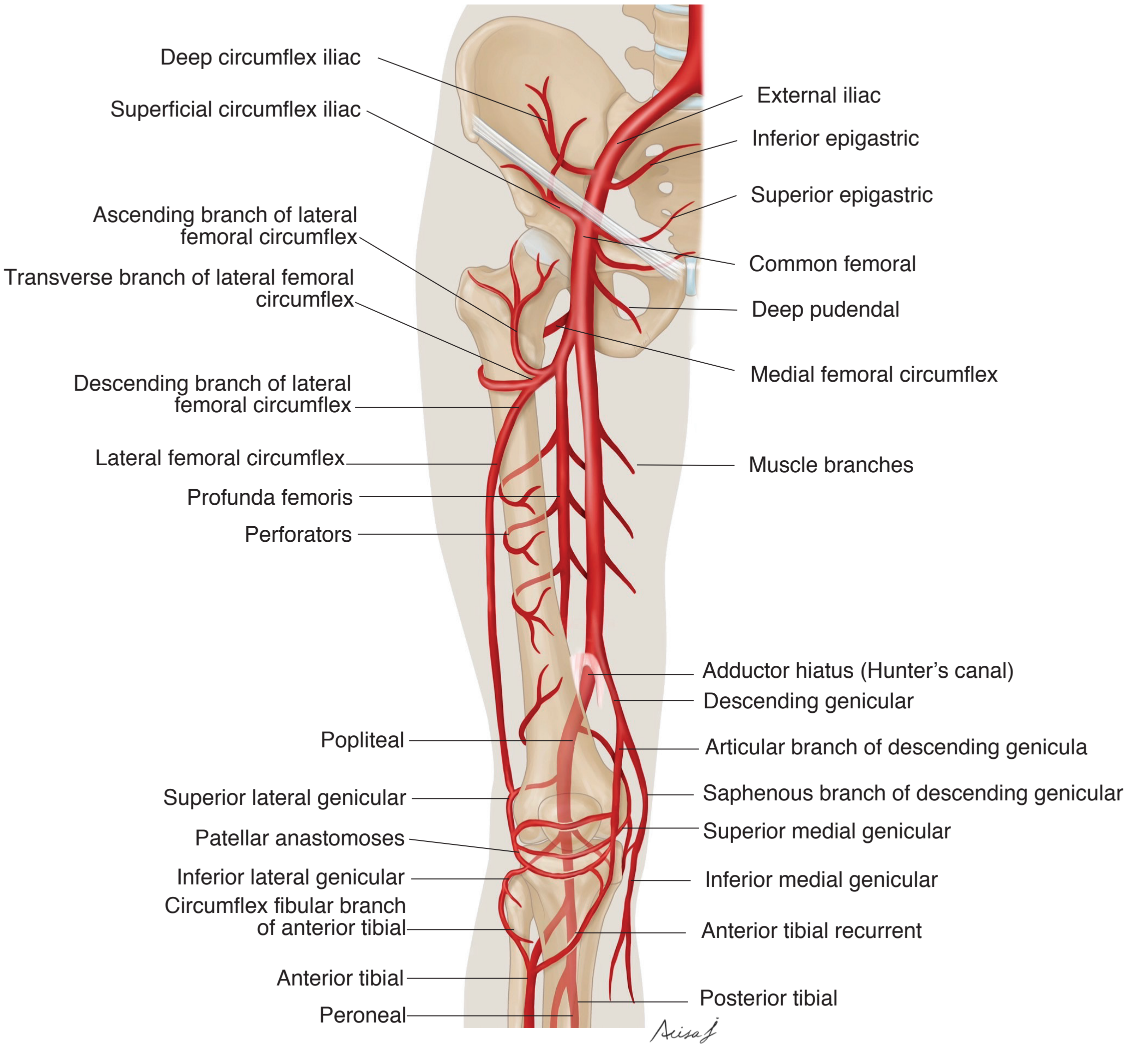

Figure 12-1. Normal anatomy of femoropopliteal artery. (redrawn from https://thoracickey.com/endovascular-treatment-of-femoral-popliteal-arterial-occlusive-disease/)

The PFA emerges from the lateral aspect of the CFA and travels posteriorly, and laterally, to the SFA. It gives off two major branches proximally, the medial and lateral circumflex femoral branches (Fig. 12-1). One of both of these branches may occasionally (i.e., about 15 to 20%) arise directly from the CFA. In its mid- and distal portion, the PFA typically produces three perforating branches to the thigh muscles. Proximally, the medial and lateral circumflex branches and the primary perforating branch have connections with the internal iliac artery branches (i.e., superior and inferior gluteal, and obturator branches). Distally, the lateral circumflex artery and the perforating branches have important connections with the collateral network at the knee joint, which connect with the popliteal and tibial vessels. Through these proximal and distal connections, the PFA produces a vital supply of collateral flow to the foot and leg, in those patients with significant SFA occlusion or stenoses.

COLLATERAL CIRCULATION

The lower extremity has complex and abundant collateral circulation systems which maintain the leg's blood flow when there are obstructions within proximal arteries. The main pathways are provided by branches of the PFA and popliteal arteries:

- SFA occlusion: Collaterals rely depend on the site and length of the occlusion. The PFA is the major conduit to the lower leg, with perforating and lateral femoral circumflex branches (Fig. 12-1) supplying branches of the popliteal, and distal SFA arteries.
- Deep femoral or PFA occlusion: Internal iliac artery branches to lateral and medial circumflex femoral branches of the PFA.
- Popliteal artery occlusion: Sural collateral and geniculate network.

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PATHOGENESIS

Atherosclerosis is the most common pathology of femoropopliteal occlusive disease. Inflammation is important in causing and progression of PAD. Diabetes mellitus and smoking produce oxidative stress, which indirectly and directly induce inflammatory pathways. These two risk factors are related to atherosclerosis in the femoropopliteal segment. Haltmayer et al. discovered no-site specific relationship between cholesterol and hypertension and prevalent PAD, but triglyceride level was only significantly related to PAD for the femoropopliteal segment (8). The marked vulnerability of the femoropopliteal segment for atherosclerosis remains poorly understood. Many factors make this area susceptible to disease. The femoropopliteal segment is fixed between the knee and hip joints, and the SFA endures complex external mechanical stress comprising torsion, bending, compression and flexion (Fig. 12-2). Its distal segment also crosses the adductor canal that additionally magnifies compression with thigh contraction. In addition, the adductor canal is a region with low wall shear stress, which is associated with atherogenesis (9). Repeated injury at this area leads to fibrosis development and calcification of atheromatous plaque that results in CTO which has negative impact on the long-term outcomes of any endovascular procedure. Crossing femoropopliteal CTO is still a problematic endovascular procedure. A normal CTO plaque comprises calcium, extracellular matrix, smooth muscle cells, as well as extracellular and intracellular lipids. A rigid fibrous cap is normally present at both CTO ends with loose or soft lipid tissue, thrombus, and extracellular matrix within the core. CTO lesions frequently show endothelialized microchannels, produced via neovascularization, which cover the blocked segment from proximal to distal cap. The presence of microchannels within the CTO facilitates guide wire passage across occlusion. However, more frequently, there is a compact homogenous fibrous core, which blocks guide wire crossing and subsequent balloon inflation difficult.

Another uncommon etiology of femoropopliteal occlusive disease is popliteal artery entrapment syndrome (PAES), in which an abnormally located or enlarged calf muscle compresses the main artery at the back of the knee (popliteal artery) (10). The incidence of PAES is around 0.17%-3.5% of the Unites States general

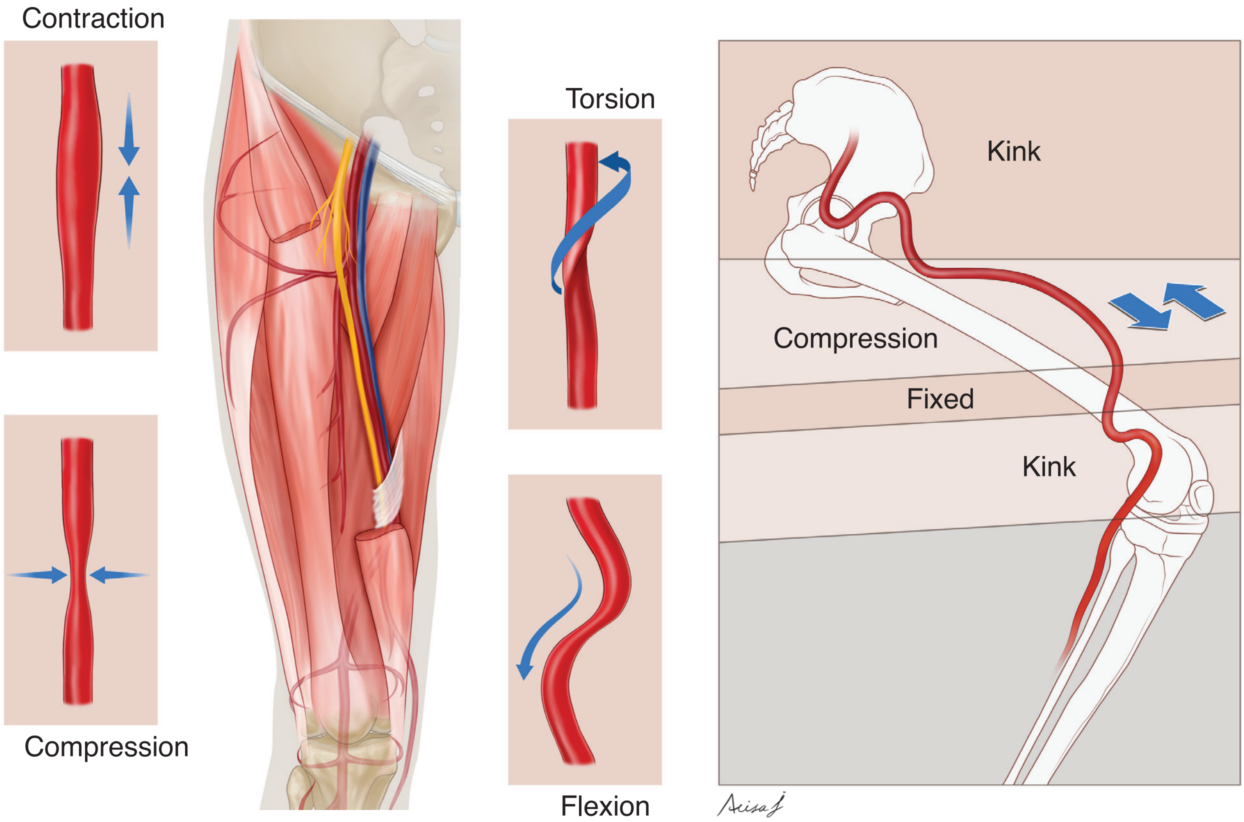

Figure 12-2. Unique mechanical forces on the superficial femoral and popliteal artery cause negatively impact on the long-term outcomes of endovascular intervention.

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population (11). This disorder mainly impacts active young athletes with no prior cardiovascular risk factors' history. Patients usually present complain of intermittent calf and foot pain which happens following exercise and disappears at rest. If left untreated, the PAES may cause distal arterial thromboembolism, popliteal artery thrombosis (PAT), popliteal artery stenosis (PAS), as well as limb amputation. Screening for high-risk patients who need prompt surgical intervention is important to prevent these complications.

CLINICAL PRESENTATION

Intermittent claudication is the most common manifestation of isolated femoropopliteal arterial disease. It is defined as pain, cramping, discomfort or fatigue within the calf muscles which is continually caused by exercise, but rest relieves it within 10 minutes. If the PFA circulation is normal, there is possibility that patients may be asymptomatic or if symptomatic, the claudication is usually relieved with exercise training and intervention is unnecessary. CLI (i.e., ischemic rest pain or non-healing ulceration) is uncommon, and when it occurs, patients always have multi-level arterial occlusive disease involving infrapopliteal tibial arteries. Revascularization of the femoropopliteal arteries to increase proximal in-flow might be enough to alleviate ischemic pain and to promote wound healing.

Peripheral vascular examination should include palpation for all lower extremity pulses as well as auscultation for vascular bruit, especially at the femoral arteries. Absent or diminished pulses of popliteal artery suggests femoropopliteal occlusive disease. In case of tibial vessel involvement, other physical findings at the foot should be examined such as shiny skin, hair loss, muscle atrophy, and non-healing wound or ulcers. Dependent rubor with elevation pallor can appear in advanced disease which is caused by impaired autoregulation within dermal arterioles and capillaries.

DIAGNOSTIC TESTS

Noninvasive vascular studies are used in many purposes, including 1) to confirm PAD diagnosis in patients with equivocal history or physical findings, 2) to grade the severity and to determine the level of stenosis or occlusions, 3) to follow the progression of disease, and 4) to monitor the result of percutaneous and surgical revascularization therapy. The ankle-brachial index (ABI) is both a reproducible and inexpensive way of evaluating lower extremity hemodynamics. The ABI is the ratio of the highest systolic pressure within each leg, taken at the posterior tibial and dorsalis pedis arteries with a Doppler probe with the higher of the left or right arm brachial artery pressure. ABI ratio less than 0.9 are indicative of diagnosis of PAD and values below 0.5 indicate severe PAD. When ABI has confirmed PAD, it is required to delineate the diseased lesion and assess revascularization therapy options. Several methods have been applied to define the location of the affected arteries. Each method has its strengths and limitations.

Segmental limb pressure and pulse volume recordings

The location and extension of PAD may additionally be defined by using segmental limb pressure measurements, recorded by a doppler instrument using plethysmographic cuffs covering the brachial arteries and different points on the lower limb, which need to include the upper thigh, the lower thigh, the upper calf just below the knee, and the ankle. A pressure gradient of more than 20 mm Hg between the lower thigh and the upper calf suggests distal SFA or popliteal artery disease. As noted, patients with well-formed collateral flows might not show a significant pressure gradient. Besides segmental limb pressure, pulse volume recordings (PVRs) can evaluate changes within each limb's volume, in various leg segments, within every cardiac cycle. Using segmental limb pressures and PVRs measurements together, the accuracy rate is 95% in detecting and localizing occlusive disease compared with angiography (12).

Arterial duplex ultrasonography

Duplex ultrasonography (DUS) is a precise method of determining the location and degree of stenosis of femoropopliteal disease. The DUS combines doppler velocities and doppler waveform analysis. Doppler waveforms may change from a typical triphasic pattern to a biphasic and, finally, monophasic presentation in significant PAD patients (Fig. 12-3). DUS is increasingly used to assess the hemodynamic effects of localized stenoses and peripheral arterial anatomy with high sensitivity and specificity. However, the accuracy of the study is highly operator dependent.

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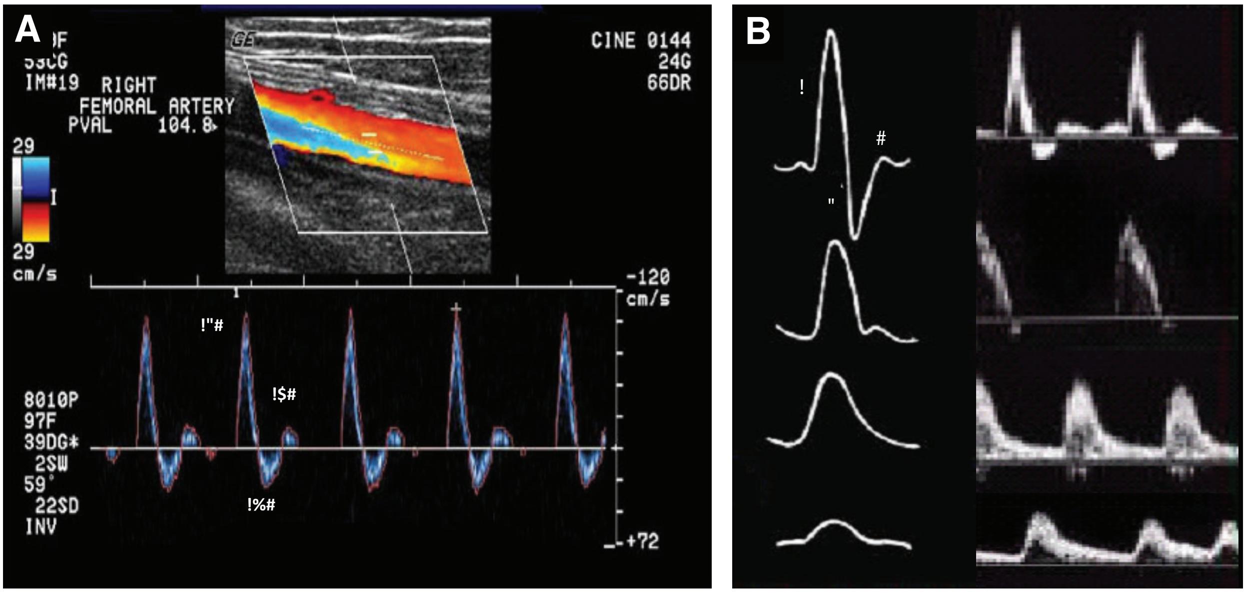

Figure 12-3. Duplex ultrasonography to determine the location and degree of stenosis. A: Doppler wave form of a patent right femoral artery showing triphasic pattern. B: Different doppler wave forms changing from a typical triphasic pattern to a biphasic, and finally monophasic presentation in a significant stenotic lesion.

Computed tomography angiography (CTA)

Lower extremity CTA is not the primarily preferred diagnostic test, but it can be helpful for planning revascularization strategies and offers quicker image acquisition capabilities compared with magnetic resonance angiography (MRA) (13). CTA creates images of vascular structures using cross-sectional plains which may be reconstructed into 3-dimensional angiographic-like images. Importantly, CTA visualizes calcification clearly (Fig. 12-4 A), which is beneficial when considering revascularization strategies. At femoropopliteal segments, the sensitivity, specificity, and accuracy rates are 96%, 85%, and 92%, respectively (14). Since it requires large volumes of iodinated contrast media, CTA is unsuitable for renal insufficient patients. Another disadvantage is radiation exposure.

Magnetic resonance angiography

Non-contrast MRA which relies on inflow can overestimate the degree of stenosis. Contrast-enhanced MRA is better in determining and assessing the severity of stenosis and can help in decision between surgical and endovascular revascularization (13). In addition, MRA can give helpful information such as the reconstitution of blood flow distal to the occlusion, the vessel runoff beneath the knee and also the anatomy of the aortoiliac bifurcation for crossover technique. Currently, MRA imaging is complementary and supplants the current gold standard of digital subtraction angiography (DSA). The limitation of MRA is lacking visualization of vascular calcifications (Fig. 12-4 B), which is a possible impediment when considering revascularization options. In addition, MRA has some limitations in patients with metallic clips, prosthetic implantation, implantable defibrillators and permanent pacemakers.

Digital subtraction angiography

DSA provides an improved overall arterial tree visualization and a more accurate assessment of stenosis. DSA is the standard method for diagnosing PAD and is normally applied for delineating the location and extension of arterial pathology before a revascularization procedure. The major advantage is the capability to selectively assess individual vessels to obtain physiologic information such as pressure gradients, and to function as a percutaneous intervention platform. The disadvantages are its invasiveness using ionizing radiation, arterial puncture, with potential nephrotoxicity from iodinated contrast agents.

INDICATIONS

Based on 2016 AHA/ACC guidelines on the management of patients with lower extremity PAD (15), indications for revascularization have been reserved for only a subset of symptomatic PAD patients, including those with:

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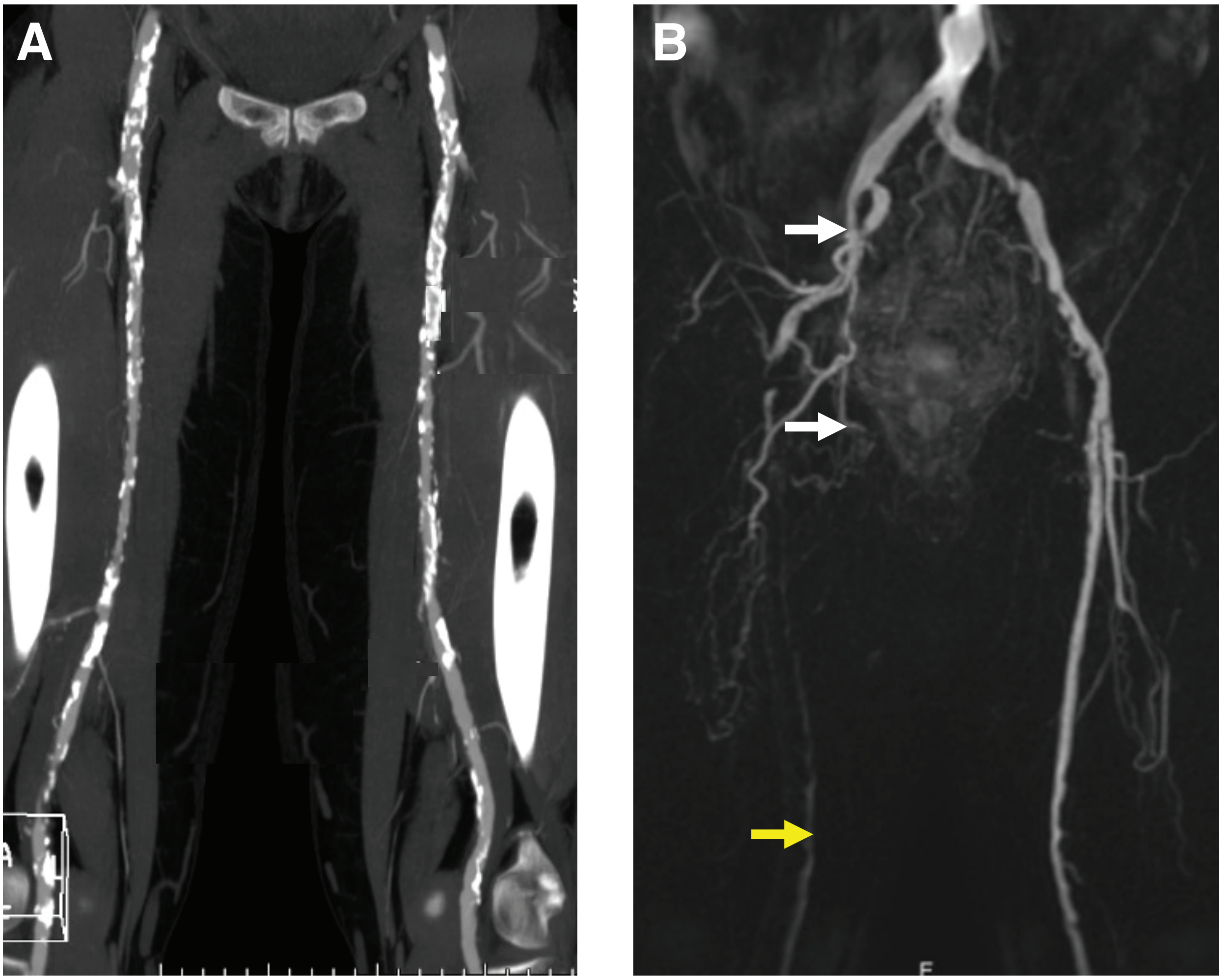

Figure 12-4. Comparison between computed tomography angiography (CTA) and magnetic resonance angiography (MRA). A: CTA of bilateral superficial femoral arteries showing calcification clearly. B: MRA of aortoiliac and infrainguinal vessels showing a long occlusion of right iliac, common femoral, and superifical femoral artery (white arrows) with reconstitution of blood flow distal to the occlusion (yellow arrow). Unlike CTA, MRA is lacking visualization of vascular calcification.

- Persistent lifestyle-limiting claudication with insufficient response to guideline-directed medical therapy (GDMT), including structured exercise therapy (Class IIa, LOE A).
- CLI (e.g., non-healing ulcer or gangrene), revascularization should be conducted whenever practical to minimize the loss of tissue (Class I, LOE B-NR)
- Staged approach for endovascular procedures is reasonable for ischemic rest pain patients (Class IIa, LOE A)

Endovascular procedures are practical as a revascularization choice for patients who have hemodynamically significant femoropopliteal disease and lifestyle-limiting claudication. The persistent life-style limiting claudication includes impeded activities of recreational and/or vocational and/or daily living because of claudication. For asymptomatic patients with PAD and in patients without significant translesional pressure gradient, endovascular procedures should not be conducted in PAD patients just to prevent or to prophylaxis progression to CLI (Class III, LOE B-R).

PATIENT SELECTION

Preoperative assessment includes angiography to define location and severity of vascular occlusion together with guiding the choice of the appropriate revascularization strategy. Decision making for treating with surgery or endovascular intervention relies on the degree of disabling symptoms, the presence of comorbid illness, and the anticipated short-and long-term outcomes. In general, patients with mild non-disabling claudication should be placed on conservative treatment

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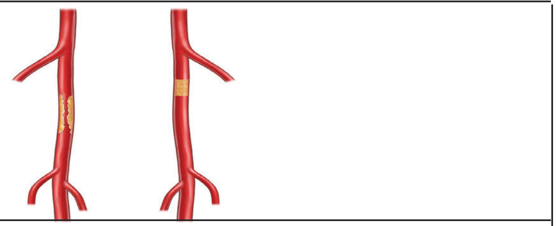
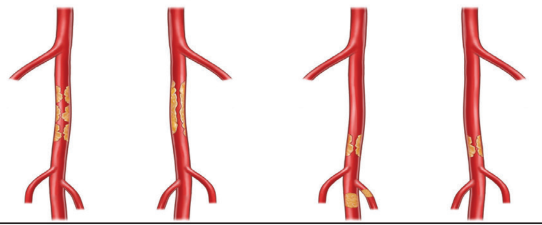
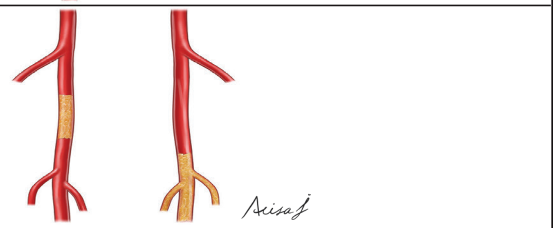
with an exercise program to augment collateral flow rather than undergoing intervention therapy for femoropopliteal disease. Fewer than one-fourth of these patients will progress to the stage of developing more disabling symptoms or a threatened limb, which mandate therapy.

Once revascularization is indicated, deciding whether to choose a surgical or an endovascular approach is based on the TASC II recommendation. The TransAtlantic Inter-Society Consensus (TASC) (16) has classified femoropopliteal disease into four types (i.e., A-D) based on the number of lesions, lesion length, and the presence of stenosis or occlusion (Fig. 12-5). The classification has defined lesion length as follows: focal (<10cm), intermediate (10-20 cm), and diffuse (>20 cm). This classification also proposed treatment strategies and recommendations for the management of the lesions. Type A and type B are advised for initial endovascular revascularization, type D lesions advised for surgical revascularization and type C for either approach depending on factors such as physician experience, the patient status, and technical resources available. In patients with comorbidities and high risk for surgery, an endovascular approach should be applied irrespective of anatomy. Patients with rest pain or disabling claudication and having multiple levels of disease may receive a staged approach with an endovascular-first approach as one stage. In-flow disease may be corrected first, and out-flow disease may be corrected in a staged manner, when needed. Patients whose veins have been harvested for prior coronary artery bypass surgery without suitable remaining autologous veins to apply for conduits, should be considered for endovascular revascularization.

For non-operable severe claudication patients because of unfavorable anatomy or medical comorbidities, only medication treatment is appropriate. Amputation can ameliorate ischemic rest pain and is required when gangrene and significant tissue loss is present.

Figure 12-5. The TransAtlantic InterSociety Consensus (TASC) II classification for the management of femoropopliteal lesions. (Redrawn from Jaff MR, White CJ, Hiatt WR, et al. An update on methods for revascularization and expansion of the TASC lesion classification to include below-the-knee arteries. *J Endovasc Ther.* 2015;20:465-478, with permission from SAGE Publications.)

TASC A lesions • Single stenosis ≤10 cm in length • Single occlusion ≤5 cm in length	
TASC B lesions • Multiple lesions (stenoses or occlusions), each ≤5 cm • Single stenosis or occlusion ≤15 cm not involving the infrageniculate popliteal artery • Heavily calcified occlusion ≤5 cm in length • Single popliteal stenosis	
TASC C lesions • Multiple stenoses or occlusion totaling >15 cm with or without heavy calcification • Recurrent stenoses or occlusions after failing treatment	
TASC D lesions • Chronic total occlusions of CFA or SFA (>20 cm, involving the popliteal artery) • Chronic total occlusion of popliteal artery and proximal trifurcation vessels	

CFA, common femoral artery; SFA, superficial femoral artery.

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STEP-BY-STEP TECHNIQUE

VASCULAR ACCESS

The selection of access location is left to the operator's discretion. The most common vascular access for femoropopliteal intervention is the CFA. Most interventionists are usually familiar with the CFA puncture. However, it may be challenging in patients with diminished or absent palpable pulse, calcified CFA disease, obese patients, and high bifurcation. In these difficult cases, fluoroscopy-guided puncture or using ultrasound-guidance should be used to reduce multiple punctures and the complication rates. The suitable point for puncture is the inner lower third of the femoral head, because the femoral head contributes a solid surface to support CFA compression which is required for hemostasis. Besides CFA access, in selected cases, radial or brachial artery (antegrade approach) or popliteal or pedal artery (retrograde approach), can be used for an additional access (Fig. 12-6). Table 12-1 summaries the vascular access sites commonly used for femoropopliteal intervention and its features.

CONTRALATERAL FEMORAL (CROSSOVER)

Arterial access may be obtained contralateral or ipsilateral to the target lesion. Commonly, contralateral vascular access is preferable. This approach allows a suitable working length for imaging and treating sequential lesions located within the distal external iliac, femoral and popliteal arteries, and also it is frequently used for below-knee interventions. This approach is associated with less access-related complications while allowing the easier application of closure devices when indicated.

When contralateral access is gained, a guide wire is forwarded retrograde along the iliac arteries and aorta using fluoroscopic guidance. For SFA angioplasty, the sheath sizes may vary between 4- and 7-French (Fr). When in placed, the vascular sheath needs flushing with heparinized saline. Through the vascular sheath, a diagnostic catheter (e.g., Judkins right (JR), internal mammary (IM), Sos Omni, Simmons, or Cobra) is advanced over a 0.035", angle-tip angled Glidewire® (Terumo) into the distal abdominal aorta. Then DSA of the aorta with the iliac arteries is then performed, except when this area has been already surveyed by MRA or CTA. This angiography helps to assess the inflow and to facilitate crossing the aortic bifurcation into contralateral limb.

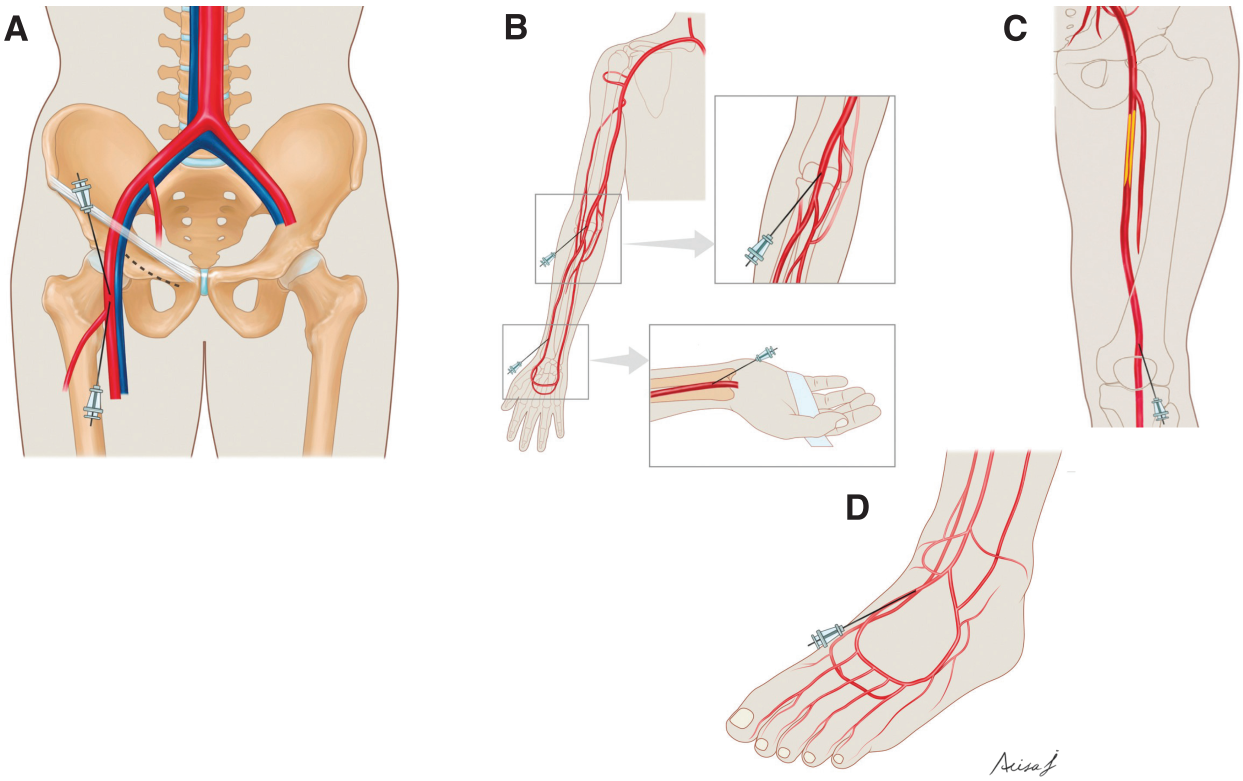

Figure 12-6. Vascular access for femoropopliteal intervention. A: Common femoral artery (retrograde and antegrade access); B: Brachial and radial artery (retrograde access); C: Popliteal artery (retrograde access); D: Dorsalis pedis or tibial artery (retrograde access).

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After finishing DSA, the catheter is torqued towards the ostial contralateral iliac artery, the Glidewire® is then forwarded distally to the CFA level enabling suitable length to forward a selective catheter within the distal external iliac artery. In difficult anatomy, roadmap function with fluoroscopy may be used to facilitate during the Glidewire® navigation.

As compared to antegrade common femoral approach, this retrograde access is much easier to achieve, more familiar with less subsequent vascular complications. This approach also permits to treat contralateral common femoral and ostial SFA disease. The disadvantages of this approach are less catheter and wire support and trackability as it is working from a distance, technical difficulty with calcified and/or angulated aortoiliac bifurcations, and not feasible with previous aorto-bifemoral bypass or aortoiliac kissing stents.

Table 12-1. Summary of potential access sites for femoropopliteal and lower extremity endovascular intervention.

Access site	Target vessels	Advantages	Disadvantages
Contralateral femoral (crossover)	- Contralateral distal common iliac, external and internal iliac - Contralateral femoral, popliteal and below-knee vessels	- Lower bleeding risk than antegrade femoral approach - Permits approach to contralateral common femoral and ostial SFA disease	- May not be technically feasible with angulated and/or calcified aortoiliac bifurcations, or with prior aorto-bifemoral bypass, kissing stents - Less catheter and wire trackability and support than antegrade femoral access
Antegrade common femoral (ipsilateral)	- Ipsilateral non-ostial SFA, popliteal, and below-knee	- More catheter and wire support and better manipulation for distal disease, total occlusions - No need to crossover in angulated and/or calcified aortoiliac bifurcations	- Higher vascular complication rate - Not technically feasible for very obese patients - Needs learning curve - Early thrombotic occlusion of the target lesion caused by flow reduction during manual compression for hemostasis
Retrograde popliteal	- All ipsilateral vessels proximal to distal SFA - Ostial SFA occlusion with no stump	- Good support - Potentially useful if unable to cross or re-entry SFA occlusion from above	- Higher vascular complication rate - Nerve injury - Not convenient for a patient in prone position
Retrograde dorsalis pedis, tibial	- Tibial vessels, popliteal, SFA	- Potential useful if unable to cross femoropopliteal and infrapopliteal tibial stenosis from above	- Obtaining access often technically challenging, needs skill and ultrasound guidance - Limited experience - Injury or occlusion of target vessel for bypass graft
Radial	- Aorta - Proximal iliac vessels - CFA and proximal SFA	- Lowest vascular complication rate of all access sites	- Distance from target vessels limits ability to reach infra-iliac lesions - Limited to 6-Fr sheath size - Subclavian and aortic tortuosity may limit catheter manipulation
Brachial	- Aorta - Iliac vessels, CFA, proximal-to-mid SFA	- Permits larger diameter sheaths than radial artery	- Substantially increased vascular complication rate compared to the radial approach
Axillary	- Aorta - Iliac vessels - Proximal-to-mid SFA	- Ability to reach more distal lesions than with radial or brachial access	- Vascular complications - Brachial plexus injury

CFA, common femoral artery; SFA, superficial femoral artery.

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ANTEGRADE COMMON FEMORAL

In select cases, such as a calcified and/or angulated aortoiliac bifurcation, antegrade common femoral access is preferred. This method requires positioning a sheath within the CFA which is pointed distally (toward the ipsilateral foot), and depicts an alternative technique for managing lesions distal to the CFA (such as mid to distal SFA, popliteal, and below knee) and in patients who have aortoiliac bifurcation anatomy that precludes the crossover technique. The antegrade approach may also permit easier guide wire torquability and pushability and improved catheter support, particularly when dealing with a more complex disease, such as heavily calcified disease or total occlusion of tibial vessels or the distal SFA. In patients with ostial or early proximal SFA lesion, this approach is contraindicated owing to insufficient room for a sheath placement.

This technique involves accessing the CFA cranial to the bifurcation of SFA and PFA, in an antegrade approach. Right and left-handed operators need to stand by the right and left side of the catheterization table, respectively. A 4-Fr or 5-Fr micropuncture set should be routinely used. Using the head of femur as a landmark, the CFA is punctured above the bifurcation under fluoroscopic guidance. This will result in a skin puncture site that is significantly higher than that used for the retrograde approach. The angle of needle should be fairly vertical (75° approximately) and sometimes in obese patients, the artery has to be accessed from the lateral aspect. Once the needle is in the CFA, the 0.018" wire is forwarded using fluoroscopy within the SFA and a standard 6-Fr short sheath is placed. If the wire is advanced into the PFA, it should be redirected into the SFA before inserting a short sheath. If the attempts at redirecting the guide wire into SFA are unsuccessful, the needle should be withdrawn, pressure held and a reassessment of puncture site made. Usually, the initial puncture was "too-low" or caudal, so the second attempt should be higher. Once the guide wire is advanced into the SFA, a skin nick with adequate track should be made. The sheath is advanced under fluoroscopy. Since there can be stenosis in the proximal femoral artery, an 11 cm sheath usually is optimal. The guide wire should never be completely removed, since the sheath may kink, making re-access difficult and dangerous.

Antegrade femoral access is more technically demanding compared with the retrograde femoral approach and needs a considerable learning curve. The complications of this approach include vascular complication at the puncture site (e.g., retroperitoneal hemorrhage) especially in an obese patient, and early thrombotic occlusion of the target lesion caused by post-interventional flow reduction during manual compression for hemostasis.

POPLITEAL RETROGRADE

The ipsilateral popliteal retrograde access is rarely used and reserved for CTOs of the SFA which cannot be crossed from above, because the distal "cap" for the occluded arterial segment can be punctured easier using a guide wire compared with the proximal cap of the occlusion. Using ultrasound to identify the accurate position of the popliteal artery prior to obtaining access is recommended and can minimize the occurrence of nerve injury and vascular complications.

After failure from contralateral femoral or antegrade femoral approach, the sheath is secured and draped under a sterile towel. The patient is placed in a prone position and then the popliteal fossa is prepped and draped. The level of the femorotibial joint space is fluoroscopically identified. The skin is anesthetized at approximately 3 cm superior to the joint space, because at this point the degree of overlapping of the popliteal artery, popliteal vein (lateral) and popliteal nerve is minimal. Using ultrasound guidance or contrast injection from above, the popliteal artery is punctured using a 4-Fr to 5-Fr micropuncture needle. Then, a 0.018" wire is advanced, and a sheath is inserted. Most popliteal arteries are sufficiently large to accommodate a 6-Fr sheath. The disadvantages of this access are vascular complication or nerve injury that might occur more frequently because of small vessel size and the lack of familiarity with this access.

BRACHIAL OR RADIAL APPROACH

Obtaining an access by the radial or brachial may serve as an alternative technique to image or to perform intervention when severe aortoiliac or bilateral CFA disease is present and mitigates the usual femoral approach. As a result of the high risks for local vascular complications associated with brachial access, using the radial artery has grown more popular and familiar among interventional cardiologists. Since there are long guiding catheters (120 or 150 cm) and long shaft (200 cm) of balloon and stent delivery systems [Radial to peripheral (R2P™) products,

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