Endovascular Therapy for Atherosclerotic Occlusion and Stenosis from the Infrarenal Aorta to the Infrapopliteal Arteries

F. Scott Nowakowski, M.D.[1], and Hank J. Freeman, M.D.[2]

Abstract

Aortoiliac and peripheral vascular disease that cannot be treated medically is generally treated by vascular surgeons and/or interventional radiologists. Advances in technology have allowed endovascular therapy to become a therapeutic option for atherosclerotic disease from the aorta to the femoropopliteal region. Distal peripheral disease is still approached surgically; however, further technological advances may lead to a more active role for endovascular therapy at this level.
Key Words: Peripheral vascular disease, infrarenal aorta, iliac arteries, femoral arteries, popliteal arteries, minimally invasive, vascular surgery, endovascular therapy.

Introduction

Atherosclerosis is the most common disease involving the infrarenal aorta, pelvic and lower extremity vasculature. Many of its consequences can be treated by vascular surgeons and interventional radiologists. Peripheral vascular disease (PVD) affects 2 – 3% of males and 1% of females over the age of 60 (1). Risk factors for this disease include smoking, diabetes, hyperlipidemia, obesity, male sex, and advancing age. Symptomatology of PVD includes intermittent claudication, pain at rest, and non-healing ulcers of one or both of the lower extremities. The initial work-up for patients with suspected PVD entails a detailed history, including symptomatology, prior surgeries, other medical conditions, and social history which may be relevant to the disease. Physical findings may include decreased femoral or distal pulses, ulcerations, cool extremities and skin changes. The results of laboratory tests of blood and urine may reveal contributing etiologies (e.g., hyperlipidemia) as well as other problems, which must be excluded when preparing for possible surgical or endovascular intervention.

Noninvasive testing (e.g., for ankle-brachial pressure indices [ABIs]) is an important next step in the evaluation of PVD. Claudication can be seen in patients with ABIs of less than 0.92. Values less than 0.5 are seen in patients with severe disease and pain at rest; tissue loss is typically noted with values of less than 0.3. Poor prognosis for healing of lower extremity ulcerations is noted when the blood pressure in a lower extremity is 30 mm Hg less than that measured in the arm on the same side of the body (2). Computed tomographic arteriography (CTA) and magnetic resonance arteriography (MRA) are two noninvasive modalities that are growing in popularity as diagnostic tools for aortoiliac disease and PVD (3, 4). These modalities have come close to rivaling arteriography, the gold standard in the assessment of aortoiliac disease. Despite a sensitivity and specificity of MRA approaching 95%, there remains a reluctance to accept this examination because certain information (such as direction of flow beyond occluded segments and post-processing artifacts) may not be acquired (5).

Once it has been established that PVD is responsible for the patient's symptoms, arteriography can be obtained for diagnostic purposes, preoperative planning, and possible interven-

[1]Assistant Professor of Radiology and [2]Diagnostic Radiology Resident, Department of Radiology, Mount Sinai School of Medicine, New York, NY.

Address all correspondence to F. Scott Nowakowski, M.D., Department of Radiology, Box 1234, Mount Sinai School of Medicine, One East 100th Street, New York, NY 10029.

tion. Evaluation of the patient's laboratory values, including blood urea nitrogen (BUN)/creatinine, coagulation studies and platelet count, are essential. Patient preparation for the angiographic procedure includes adequate hydration when possible and the administration of renal-protective agents such as acetylcysteine and fenoldopam to patients with decreased renal function (6). Also, alternative contrast agents such as the low osmolar contrast, CO_2, or gadolinium can be utilized to decrease the nephrotoxicity which may be related to the use of high osmolar contrast agents. Patients with coagulopathies or low platelet count can be given fresh frozen plasma or pooled platelets. If there is a history of adverse reaction to contrast agents, steroids can be administered prior to the procedure.

The interventional radiologist should obtain a focused history, perform a physical examination, and then review all prior diagnostic studies and physical findings with the referring clinician and/or vascular surgeon. The site of the disease should be determined with certainty, since this will guide the approach to arteriography. Informed consent is obtained from the patient for both a diagnostic procedure and possible intervention (percutaneous transluminal balloon angioplasty, stent placement, thrombolytic therapy). Whereas in the past the intervention was often performed independently of the diagnostic procedure, most interventions are now performed at the same sitting.

Vascular access for the diagnostic procedure is usually obtained via the common femoral artery, using either the Seldinger technique or a single-wall needle. The puncture site is usually determined based on prior knowledge of disease or physical findings (e.g., stronger common femoral artery pulse). Occasionally, when femoral access is not feasible (e.g., bilateral common femoral artery occlusions), a left high brachial artery approach can be used. Rarely, a translumbar route to the aorta is utilized for a diagnostic study. Diagnostically, it is important for the interventionalist to perform a study yielding as much information as possible, while being mindful of the contrast burden being administered to the patient. This includes obtaining multiple projections (anteroposterior, lateral and bilateral 30 degree obliques of the pelvic vasculature) and pressure measurements across questionable lesions to assess for hemodynamic significance (7). Administration of vasodilators intra-arterially (25 mg talazoline, 100–200 μg nitroglycerine or 30 mg papavarine) can be performed in an attempt to better define the hemodynamic significance of an equivocal lesion. Usually a gradient greater than 5–10 mm Hg at rest and greater than 15–20 mm Hg following administration of one of the aforementioned drugs is considered hemodynamically significant. It must be noted, however, that pressure gradients proximal to an occlusion can be surprisingly low or near normal (i.e., measuring across a common iliac stenosis proximal to a superficial femoral artery occlusion). Also, reactive hyperemia induced by these drugs can be used to facilitate the visualization of diseased trifurcation vessels below the calf.

Focal Aortic Stenosis / Occlusion

Focal aortic stenosis / occlusion is a relatively uncommon form of peripheral vascular disease seen predominantly in younger patients who smoke (8) (Figs. 1, 2). The characteristic lesions may produce claudication and distal ischemic symptoms but often manifest as Leriche syndrome (infrarenal aortic occlusion), which can produce the triad of buttock claudication, impotence and absent femoral pulses. In the past these lesions were treated primarily via surgery, but advances in endovascular techniques have made percutaneous transluminal angioplasty (PTA), with or without subsequent stent placement, the current treatment of choice.

Technically, once the appropriate common femoral artery has been accessed and a vascular sheath placed, the lesion should be carefully traversed with an atraumatic floppy-tipped wire to avoid subintimal passage. A directional catheter can be used to negotiate difficult lesions. Although prior to PTA, thrombolytics were commonly used for aortic and iliac occlusions, these agents are much less likely to be used now, unless there is frank evidence of fresh thrombus (9). Once across the lesion, heparin (3000–7000 U IV) is administered by some physicians, depending on factors such as slow flow associated with marked stenosis. A marking pigtail catheter can then be passed over the guidewire and a diagnostic aortogram can be performed to discern the aortic diameter and the appropriate choice of balloon catheter. The aorta can be dilated to a diameter which does not exceed that measured just proximal or distal to the lesion. Aortic stretching beyond its normal size during angioplasty is thereby minimized. Depending upon the size of the lesion, a single PTA catheter, or two PTA catheters with the second introduced via a contralateral common femoral artery puncture, can be utilized to

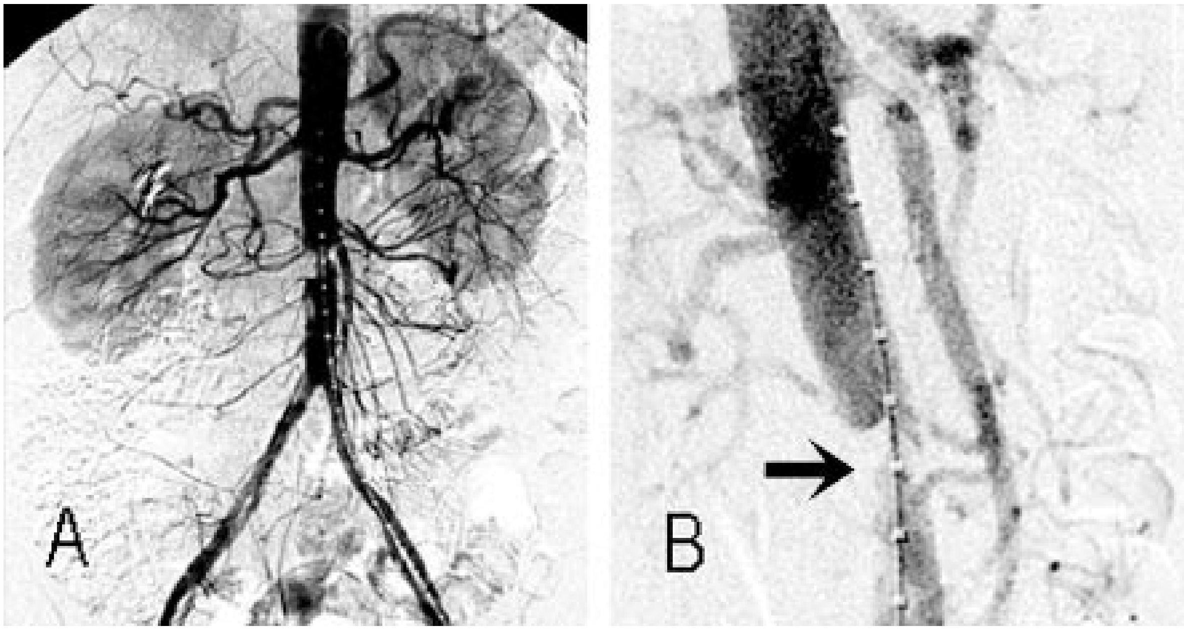

Fig. 1. (A) Tight focal abdominal aortic stenosis in patient with Leriche syndrome. A systolic pressure gradient of 67 mm Hg was present. **(B)** Lateral aortogram (arrow) reveals the extent of the disease in the AP dimension.

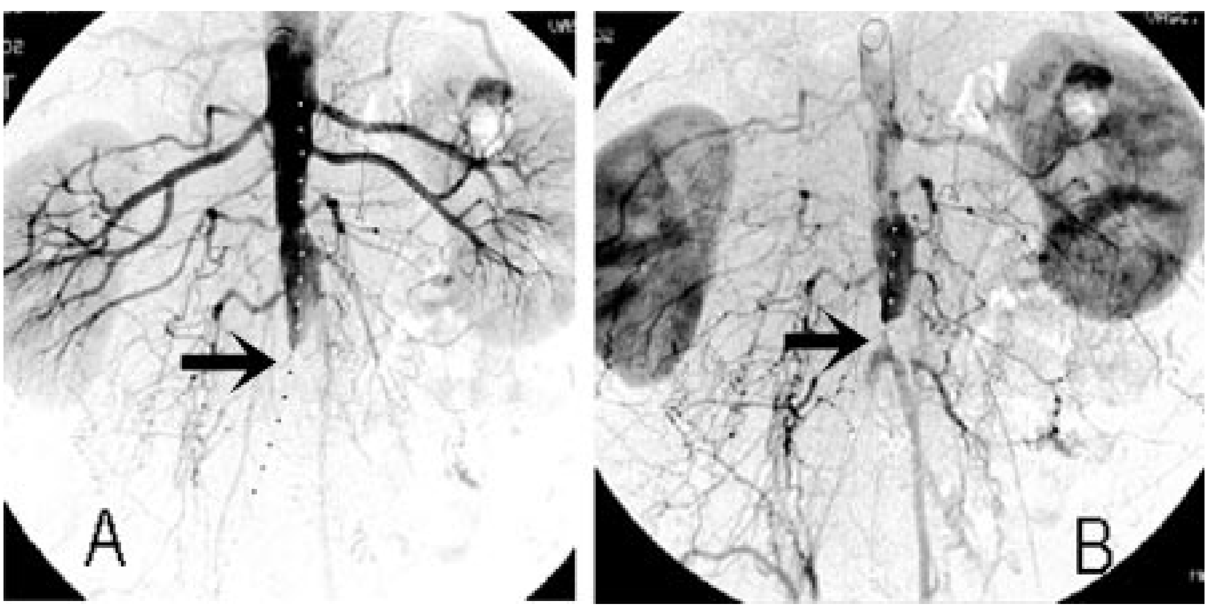

Fig. 2. (A) Early phase of abdominal aortogram revealing tight focal stenosis of the distal abdominal aorta (arrow) in patient with Leriche syndrome. **(B)** Later phase of aortogram reveals tight focal aortic stenosis with patent common iliac arteries bilaterally filling predominantly via collateral circulation (arrow).

dilate the aorta. After follow-up aortography to assess aortic patency and exclude residual stenosis or flow-limiting dissection, pressures can be measured across the newly dilated lesion to assess for hemodynamically significant gradients. Failure of PTA is an indication for aortic stent placement.

Although primary aortic stenting has been advocated as an alternative to surgery for focal aortic disease (10) (Figs. 3, 4), studies comparing PTA with aortic stenting (generally balloon-expandable stents) have yielded conflicting results (11,12). Recently, self-expanding stents (Wallstent [Boston Scientific, Watertown, MA], SMARTstent [Cordis Corporation, Miami, FL]) have been utilized to treat these lesions. Long-term results are not yet available to assess the efficacy of this technique, although anecdotal reports are encouraging.

Fig. 3. Abdominal aortogram following placement of self-expanding stent in same patient as in Fig. 1. Final systolic pressure gradient was less than 5 mm Hg.

The initial approach to stenting is similar to that for PTA. Once the appropriate-size stent is chosen, road-mapping can be employed for exact stent placement. The lesion is commonly pre-dilated with an 8 – 10 mm balloon catheter. For distal aortic lesions which may or may not extend into the iliac system, bilateral stents extending into the common iliac arteries can be deployed. Balloon-expandable stents are deployed via the “kissing balloon / stent” technique, in which simultaneous deployment is performed (Fig. 5). Self-expanding stents can be deployed simultaneously or sequentially (with the contralateral catheter utilized to inject contrast, to ensure exact initial stent placement). Extreme caution is essential to ensure that the initial stent is not dislodged upon exchange and positioning of the second stent. Following treatment of these lesions, either by PTA or stent, physical findings such as diminished peripheral pulses or non-healing ulcers should show marked improvement. For patients whose physical examination results worsen or who develop increased lower extremity symptomatology, additional images are imperative to assess for possible dissection and thromboembolism prior to removal of the vascular sheaths.

Aortoiliac Stenosis / Occlusion

Aortoiliac atherosclerotic disease resulting in hemodynamically significant stenoses and/or occlusion are readily treated via endovascular therapy. Recent studies have indicated the advantage of endovascular therapy over surgery for certain types of lesions (13). PTA is the treatment of choice for a single stenosis of the common iliac artery (CIA) or external iliac artery (EIA), either unilateral or bilateral, of less than 3 cm in length. Surgery, when compared to PTA, is recommended for diffuse disease involving the CIA, EIA or common femoral artery (CFA), bilateral EIA occlusions, unilateral occlusion involving both the CIA and EIA, diffuse disease involving the aorta and bilateral iliac arteries, or iliac stenoses in patients with abdominal aortic aneurysm. According to the Trans Atlantic Inter-Society Consensus (TASC), definitive recommendations must await more evidence regarding the outcomes of treatment of lesions such as unilateral and bilateral CIA occlusions, unilateral EIA occlusion (or stenosis extending into the CFA), single stenoses 3 – 10 cm in length (not extending into the CFA), two stenoses each less than 5 cm long (not extending into the CFA), and bilateral stenoses 5 – 10 cm long (not extending into the CFA) (13). The Cardiovascular and Interventional Radiological Society of Europe (CIRSE) has noted that before firm recommendations can be made on the aforementioned “gray area” lesions, more evidence must be obtained (13), even though these lesions are more commonly being treated with endovascular therapy and endovascular stents with reasonable technical success.

Recent studies have displayed the significance of elastic recoil in the iliac arteries following PTA of stenoses, suggesting that vascular stents, by limiting elastic recoil, are an important tool in maintaining patency following endovascular procedures (14). TASC agrees that for some lesions that were previously in the gray area of treatment options and for selected patients for whom surgery was previously thought to be the treatment of choice, vascular stent placement can improve immediate hemodynamic results. Kandarpa et al. (15), expanding on that conclusion, consider endovascular therapy to be the treatment of choice for a single stenosis up to 10 cm in length, and for two stenoses each less than 5 cm in length for lesions of the CIA or EIA (not extending into the CFA), and for unilateral occlusions of the CIA. Vascular stents have also been successfully utilized in treat-

Fig. 4. (A) Early phase of oblique abdominal aortogram in same patient as in Fig. 2 prior to stent deployment, revealing tight focal aortic stenosis (arrow) with extensive collateral flow reconstituting the iliac vessels. **(B)** Oblique abdominal aortogram revealing widely patent abdominal aorta following deployment of self-expanding stents into the iliofemoral system. Final pressure gradient from the aorta to the external iliac arteries was less than 10 mm Hg. Common femoral artery pulses, barely palpable prior to the procedure, were 2+ following stent placement.

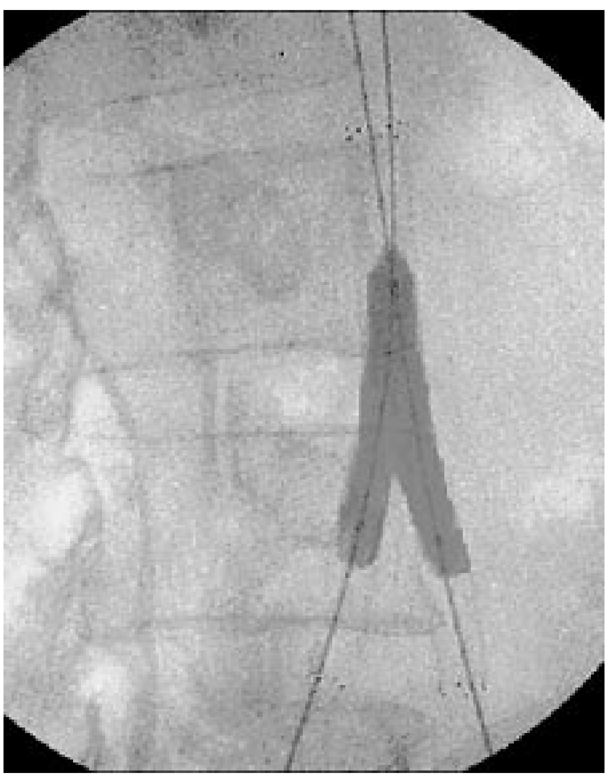

Fig. 5. "Kissing balloon" technique reducing the residual waist in two previously placed self-expanding stents (same patient as in Fig. 4).

ing PTA-induced flow-limiting dissections, thus making endovascular therapy more attractive for lesions for which dissection was a concern.

Vascular stents have also altered thinking regarding the approach to chronic aortoiliac occlusions (Fig. 6). Surgery had always been the mainstay in the past, since PTA of these lesions generally yielded poor results. Studies comparing stents to PTA, however, have shown the benefits of stenting these lesions (16, 17). Although results from recent studies such as the Dutch Iliac Stent Trial reveal the hemodymamic and clinical success rates of primary stent placement, compared to primary angioplasty followed by selective stent placement, to be nearly identical at two years, mild lesions were predominantly treated in this study (18). It is thought unlikely that more severe lesions would respond in a similar fashion. Whereas low-dose thrombolysis of occluded iliac lesions was once utilized prior to stenting, recent studies indicate that primary stent placement can be safe and efficacious without prior thrombolytic therapy (18) and should be the treatment of choice for chronic iliac artery occlusion.

The technical approaches for aortoiliac PTA and stenting are similar to those for focal aortic

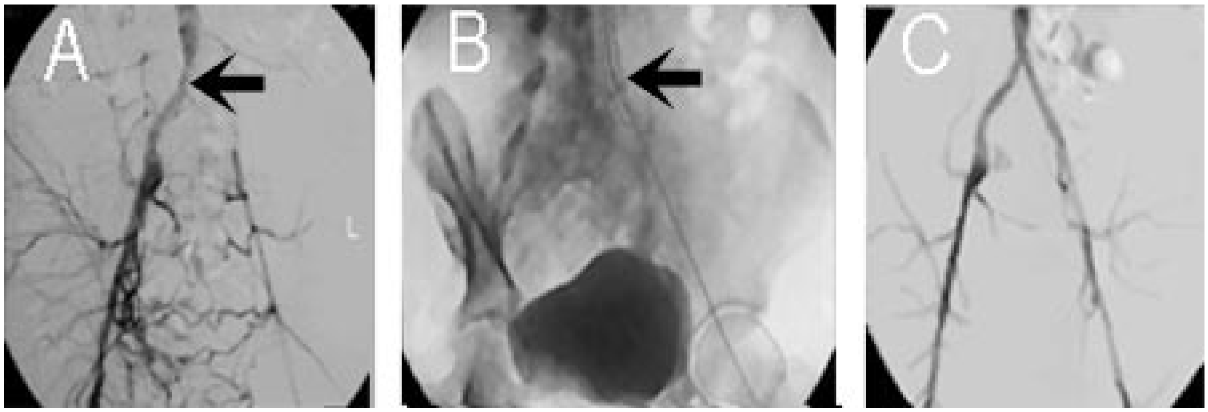

Fig. 6. (A) Pelvic arteriography revealing left common iliac occlusion with reconstitution of the external iliac artery via collateral circulation (arrow). **(B)** Oblique view of the pelvis showing the self-expanding stent successfully deployed across the common iliac occlusion following careful manipulation across the lesion (arrow). **(C)** Final pelvic arteriogram reveals widely patent left common iliac artery following self-expanding stent deployment.

disease. The initial approach to the lesion (ipsilateral or contralateral) depends on prior knowledge of the lesion (via physical examination, symptoms, ABI, noninvasive imaging) and physician preference. Common and external iliac disease can be approached via either an ipsilateral or a contralateral approach. If the angle of the aortic bifurcation is not too acute, a contralateral approach is sometimes preferred, since treating potential downstream complications such as embolism is not feasible from an ipsilateral approach. Also, thrombolytic therapy for *in situ* thrombosis after PTA or stent deployment may worsen bleeding complications at the downstream puncture site (19). An "up and over" sheath can be placed; it conveys the additional convenience of the capability of "puffing" contrast through the side port of the sheath for exact balloon or stent placement and the ability to do post-procedure runs immediately, without employing catheter exchange. An ipsilateral retrograde approach is still the preferred access for many physicians, since it provides a direct, "straight-line" approach to the lesion. An ipsilateral approach is also utilized when an acute aortic bifurcation is present.

Balloon-expandable stents have traditionally been the preferred choice in stenting of aortoiliac disease. Most studies in the literature have involved this type of stent. More recently, however, self-expanding stents have been utilized in the aortoiliac system with a great deal of success (17, 20). These stents are particularly useful in markedly tortuous iliac vessels and can conform to various vessel dimensions and diameters within the same patient, especially when particularly long lesions are stented. Following deployment, PTA of residual stenoses secondary to extrinsic compression upon the stent can be performed. It is important to stay within the confines of the stent when performing PTA, since angioplasty of normal vessel beyond the stent may lead to intimal hyperplasia just proximal or distal to the stent. More studies on self-expanding stents need to be performed to ascertain their long-term efficacy in aortoiliac occlusive disease.

Femoropopliteal Disease

There are a number of factors that distinguish atherosclerotic disease of the femoropopliteal system from isolated aortoiliac disease. Occlusions tend to be more common than stenoses. Also, patients with femoropopliteal disease are more likely to have comorbidities such as coronary artery disease (21). Thus, when feasible, endovascular therapy would be preferred to surgery for these patients, who are at relatively high risk. Also, preservation of autologous vein, usually used in lower extremity bypass grafts for possible future coronary artery bypass grafting, is a potential benefit of performing endovascular therapy.

Balloon angioplasty has been the preferred endovascular treatment for solitary stenoses of the superficial femoral artery (SFA) less than 10 cm in length, tandem lesions less than 3 cm long, and lesions just proximal to planned distal bypass procedures (not involving the SFA origin or extending into the popliteal artery). PTA has also been shown to be safe and effective for SFA occlusions less than 3 cm in length. The addition of stents for the aforementioned lesions as well as solitary SFA occlusions less than 10 cm and tandem occlusions less than 3 cm in length improves initial success and patency rates, but has been shown to confer no benefits in long-term patency (Fig. 7). It has therefore been recommended that stent placement be reserved for PTA failures secondary to elastic recoil or flow-limiting dissection, or for limb salvage (13, 22).

For lesions below the inguinal ligament, either a contralateral retrograde or an ipsilateral antegrade access is utilized, again based on prior knowledge of the lesions and physician preference. A contralateral approach is sometimes preferred, to avoid any potential complications to inflow such as dissection or hematoma formation, which may occur from an ipsilateral antegrade puncture. Left high brachial approach and ipsilateral retrograde popliteal approach have been described, but are rarely used. The general principles for PTA and stenting mentioned in previous sections also apply to the femoropopliteal region. Extra care must be employed in this region, as passage of wires into the infrapopliteal region may initiate spasm and subsequent thrombosis in these sensitive vessels. Multiple lesions should be approached in a proximal-to-distal fashion.

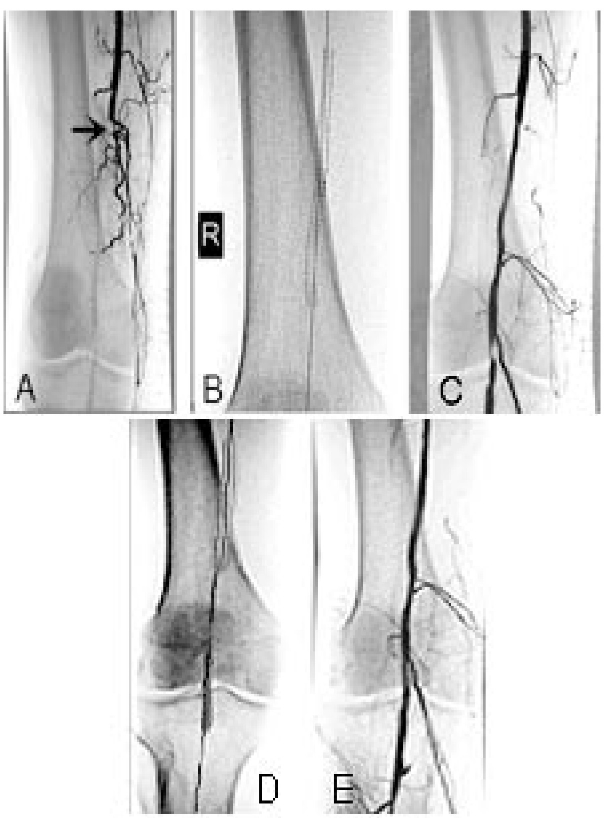

Fig. 7. (A) Early phase of arteriogram revealing distal superficial femoral artery (SFA) occlusion (arrow) with reconstitution of the distal SFA / proximal popliteal artery via collateral circulation. **(B)** Self-expanding stent was successfully deployed across the superficial femoral artery occlusion. **(C)** Arteriogram reveals widely patent superficial femoral artery following stent deployment. A previously noted popliteal artery stenosis is more apparent on this study. **(D)** Balloon angioplasty of the popliteal artery stenosis seen in C is performed following deployment of the more proximal SFA stent. **(E)** Final arteriogram reveals widely patent distal SFA and popliteal artery following stent deployment and PTA, respectively.

The use of other techniques for femoropopliteal revascularization have had mixed results. The use of atherectomy devices and polytetrafluoroethylene (PTFE)-covered stent-grafts has yielded disappointing patency rates (23, 24). Subintimal angioplasty has revealed successful results but has failed to gain popularity. Self-expanding nitinol (nickel titanium polymer) coil stents have been shown to be safe and effective in PTA failures and are of particular use in the distal SFA and popliteal artery because of their unique longitudinal flexibility (25). Laser-assisted angioplasty has been successfully utilized in the recanalization of infrainguinal occlusions averaging approximately 20 cm in length (26). The results following the of drug-eluting stents seem to encourage the most optimism, as preliminary studies have shown a six-month restenosis rate of 0% when using these stents to treat obstructive SFA disease (27). However, more evidence must be obtained regarding the efficacy of these modalities in the treatment of infrainguinal disease.

Infrapopliteal Disease

Patients with infrapopliteal disease, like those with femoropopliteal disease, tend to have comorbidities such as hypertension, cardiac disease, chronic renal insufficiency and cerebral vascular disease. A majority of these patients are diabetics. The role of endovascular therapy in the treatment of infrapopliteal disease has traditionally been limited. Recent studies, however, have shown the benefit of infrapopliteal PTA for limb salvage in critical limb ischemia (28).

Technologic advances such as floppy-tipped steerable guidewires (0.014–0.018 inch) and low-profile balloons (2–4 mm) have increased the efficacy of infrapopliteal procedures; the resulting limb salvage rates are now comparable to rates with surgical techniques, for selected patients. The use of intra-arterial nitroglycerine (and often the addition of sublingual nifedipine) in these vessels, which are particularly sensitive to spasm, is essential. An intravenous or intra-arterial bolus of heparin, 5000–7000 U, is generally administered. Techniques such as passing a safety wire down the adjacent vessel when performing PTA at a branch point can help avoid occlusions of nonstenosed vessels by dissection or displacement of intimal plaque. Technical success rates, (with “success” defined as successful balloon angioplasty or stent deployment), have been high, with the greatest clinical results noted when straight-line blood flow to the foot has been restored (29).

Summary

Endovascular therapy has emerged as a primary modality in the approach to aortoiliac and peripheral vascular disease. Technologic advances have allowed endovascular therapy to become the treatment of choice for most infrarenal aortic, iliofemoral, and femoropopliteal stenoses and occlusions. The role of balloon angioplasty in the infrapopliteal region is still limited, but it is being used more frequently as knowledge of drug therapy and improved catheter, wire and balloon systems increases. Further clinical tests on alternative endovascular modalities need to be performed to assess their efficacy in the treatment of peripheral vascular disease.

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