Profiles in Aortic and Peripheral Vascular Disease

Stephen R. Ramee, Jose A. Silva, and Christopher J. White

Ochsner Foundation Hospital, New Orleans, Louisiana 70121

The anatomy and interventional approaches to aortic and peripheral vascular disease have been reviewed in Chapters 14 and 27, respectively. In this chapter, we again take a regional approach to reviewing these diseases, using a series of actual case examples to integrate clinical, noninvasive, angiographic, and therapeutic issues.

AORTIC ARCH AND CAROTID ARTERY ANGIOPLASTY

Vertebral Artery Angioplasty

The indications for revascularization of the vertebral arteries are symptoms of vertebrobasilar insufficiency, namely, dizziness, visual disturbances, and confusion or coma. There is a great deal of variation from patient to patient in the severity of lesions causing symptoms (1). In some patients the degree of stenosis may be severe yet the patient may experience minimal or no symptoms; in others there appears to be adequate flow but profound symptoms are present. The lack of correlation between the degree of stenosis and the clinical manifestations is due to variations in collateral blood supply. The posterior fossa receives blood supply from the contralateral vertebral artery and from the carotid artery system through the posterior communicating arteries. Consequently, when assessing a patient with significant stenosis of a vertebral artery, the interventionist should determine the patency of the contralateral vertebral artery, whether the diseased vertebral artery is dominant, and the amount of blood supplied to the vertebrobasilar system by the carotid arteries.

Depending on the location of the stenosis, treatment options to revascularize the vertebral arteries may include balloon angioplasty with or without stenting (2–6), and surgery with transplantation of the vertebral arteries onto the carotid artery, or bypass grafting from the subclavian artery to the vertebral artery (7).

Lesions located in the ostium or the proximal portion of the vertebral artery can be approached percutaneously (2–6). As is the case for other aortoostial lesions (saphenous vein grafts, right coronary arteries, or renal arteries), a strategy of endovascular stenting should be strongly considered for ostial vertebral stenoses to minimize the otherwise substantial degree of elastic recoil. Lesions located more distally may be treated with balloon angioplasty with provisional stenting, depending on the angiographic results and the tortuosity of the vessel. Distal vertebral artery lesions are much more difficult to access and more prone to dissection. Lesions proximal to the basilar artery are readily treatable, but those at the vertebrobasilar junction and in the basilar artery have a higher complication rate and are the most prone to dissection, occlusion, and perforation and stroke (8–10).

In a prospective study from our institution (6), 16 patients and 20 lesions (18 ostial, one in the proximal, and one in the middle portion of the vertebral artery) were treated with 22 stents (8 Palmaz, 5 Crown, 2 NIR, 5 Multi-link, 1 GFX, and 1 Wallstent). The indications for the procedure were as follows: diplopia (n = 1), dizziness (n = 10), transient ischemic attack of the vertebrobasilar system (n = 3), and angiographic stenosis (n = 2). Angiographic success (<20% residual diameter stenosis and freedom from in-hospital death, stroke, or emergent surgery) was achieved in 100%. One patient had a transient ischemic attack 1 hour after the procedure that lasted for 5 minutes. Repeated angiography in this patient revealed a widely patent stent without evidence of embolization. At a mean follow-up of 491 ± 387 days, all patients were alive, and 15 of 16 patients (94%) were free of recurrent symptoms. One patient developed symptomatic in-stent restenosis 6 months after the procedure that was successfully treated with balloon angioplasty.

FIG. 35.1.
A: Digital subtraction angiography of the subclavian artery through a guiding catheter demonstrating that the left vertebral artery origin (large arrow) has a high-grade stenosis with very faint filling of the distal vertebral artery. Notice the location of the left IMA (small arrow) just distal and inferior to the origin of the left vertebral artery. B: After stenting there is very good filling of the vertebral artery and no residual stenosis.

Case 1

A 49-year-old woman presented with six transient episodes of left superior homonymous hemianopsia over a 2-month period. She also complained of episodic dizziness that was orthostatic in nature, without lightheadedness or syncope. Her history was pertinent for hyperlipidemia, systemic atherosclerosis, prior myocardial infarction, coronary artery bypass surgery, and aortobifemoral bypass surgery. Her physical examination revealed a right carotid bruit and a left supraclavicular bruit. Her neurologic examination was normal. A color-flow Doppler examination of the carotid and vertebral vessels revealed no significant carotid stenosis and high velocities at the origin of both vertebral arteries consistent with antegrade flow through a stenosis. She was referred for aortic arch, cerebral, and vertebral angiography and possible intervention.

After pretreatment with clopidogrel and aspirin, diagnostic digital subtraction angiography was performed using a 6F pigtail catheter for arch angiography and a JR4 diagnostic catheter for selective subclavian and carotid angiography. This revealed 80% stenosis of the right vertebral artery, 90% stenosis of the left vertebral artery (Fig. 35.1A), and noncritical carotid artery stenosis. There were no significant intracranial stenoses. Left vertebral artery angioplasty was performed using a 6F multipurpose guiding catheter introduced over a 0.035-inch Wholey wire. A 4.0-× 16-mm NIR stent was deployed at 16 atmospheres (atm) over a 300-cm 0.014-inch Extra Support wire. Poststent angiography (Fig. 35.1B) revealed no residual stenosis or dissection. The patient had complete resolution of her symptoms at 1-year follow-up.

Illustrative points

The vertebral arteries arise from the right and left subclavian artery just proximal and contralateral to the internal mammary arteries. They converge to the basilar artery, which supplies the brainstem (pons, medulla, and midbrain), cerebellum, and posterior cerebral arteries (supplying the visual cortex). Via the posterior communicating arteries, they may also supply collaterals to the middle and anterior cerebral arteries in patients with critical carotid artery stenosis. For a patient to have intracranial symptomatic ischemia from vertebral or subclavian stenosis, both vertebral arteries or the basilar artery itself must be involved. Because the posterior circulation is a dual system, only one artery needs to be treated to relieve the vertebral ischemia. The surgical treatment of symptomatic vertebral artery stenosis has a high complication and failure rate, requires excision and reimplantation of the vertebral artery, and is feasible only for ostial lesions. Angioplasty and more recently, stenting of the vertebral artery can be accomplished using low-profile coronary artery systems that minimize the risk of complications. The acute success approaches 100% and the restenosis rate in our series is less than 10% (6).

Carotid Angioplasty

Most patients with internal carotid atherosclerotic are asymptomatic (11),(12). However, even asymptomatic patients with 75% or greater stenoses have a 2% to 5% risk of stroke during the first year. If there is concomitant plaque ulceration, the risk of stroke increases to 7.5% per year (13).

Several large cooperative randomized trials have shown that surgical intervention with carotid endarterectomy (CEA) changes the natural history of this disease when compared with aspirin alone. The North American Carotid Endarterectomy Trial (NASCET) suggested that patients with symptomatic internal carotid artery (ICA) of 50% or greater will benefit from CEA (14). In this trial, the risk of stroke was 26.0% at 2 years (13% per year) for patients with symptomatic stenoses from 70% to 99% treated medically, compared with a 9% risk of stroke in the surgical group during this 2-year period (4.5% per year). This translates into a relative risk reduction of 65% for the surgically treated patients. The Asymptomatic Carotid Atherosclerosis Study (ACAS) found that endarterectomy in patients with an asymptomatic stenosis of 60% or greater resulted in a 5.8% absolute risk reduction of fatal or nonfatal ipsilateral stroke (15) in asymptomatic patients.
A lateral digital subtraction angiogram of the common carotid artery and its branches demonstrates minor plaquing in the common carotid just before the bifurcation and critical stenosis of the right internal carotid artery 1.0 cm beyond the bifurcation. After stenting there is still 10% to 20% residual stenosis in the internal carotid artery. Overdilating and trying to achieve a perfect result is not recommended because of the risk of distal embolization and stroke. Notice the external carotid artery has minor plaquing and remains patent after stenting across the bifurcation. Note also that it is important to label the films because lateral views of the right and left carotid artery are identical.

Although the widespread use of balloon angioplasty and stenting is not indicated or recommended for the entire spectrum of carotid occlusive disease, certain subgroups may benefit from this technique. Several studies have been published in which stenting was carried out with a very acceptable degree of safety and with excellent acute and 6-month outcomes (17–25). This group of patients represents a cohort at high risk for complications with endarterectomy and for whom the efficacy of surgery has not been unequivocally demonstrated (Table 35.1) (22–25).

Case 2

A 79-year-old man presented with episodic orthostatic lightheadedness without focal neurologic symptoms. He had a history of hyperlipidemia, ischemic cardiomyopathy, coronary artery bypass surgery, chronic atrial fibrillation, a permanent pacemaker, coronary angioplasty, renal artery stenting, and bilateral superficial femoral artery angioplasty. At the time of evaluation he had stable New York Heart Association (NYHA) class II heart failure but no angina. His physical examination was unremarkable, with a normal neurologic examination. Carotid duplex examination revealed 80% to 99% stenosis of the right ICA and 40% to 59% stenosis of the left ICA. Carotid angiography revealed 90% right internal carotid stenosis, 70% right external carotid stenosis, and 50% left internal carotid stenosis. He was referred for carotid angioplasty and stenting.

After pretreatment with aspirin and clopidogrel, and 5,000 units (U) of intraarterial heparin, carotid stenting was performed under a protocol for patients at high risk for carotid endarterectomy. A 9F multipurpose guiding catheter was advanced to the right common carotid over a 300-cm Wholey wire and 125-cm Vitek catheter. Angiography was performed using digital subtraction, in anteroposterior (AP) and lateral views to image the common carotid bifurcation and the cerebral circulation. The right ICA had a 90% stenosis just after the common carotid bifurcation (Fig. 35.2A). Some plaque was present in the common carotid and external carotid artery as well. The lesion was crossed with a 0.018 Road Runner (Cook, Indianapolis, IN) wire and dilated with a 4.0-mm × 4.0-cm Cobra balloon. An 8-mm × 2-cm Wallstent was then deployed across the carotid bifurcation. The stent was postdilated to 8 atm using a 5.0-mm × 2-cm Opta-5 balloon (Cordis). Final angiography was performed, including AP and lateral views of the cerebral circulation. There was 10% to 20% residual stenosis at the angioplasty site (Fig. 35.2B). The patient's lightheaded spells were no longer present at 6-month follow-up and the stent had no evidence of restenosis by carotid duplex examination.

**FIG. 35.2.**

A: A lateral digital subtraction angiogram of the common carotid artery and its branches demonstrates minor plaquing in the common carotid just before the bifurcation and critical stenosis of the right internal carotid artery 1.0 cm beyond the bifurcation. B: After stenting there is still 10% to 20% residual stenosis in the internal carotid artery. Overdilating and trying to achieve a perfect result is not recommended because of the risk of distal embolization and stroke. Notice the external carotid artery has minor plaquing and remains patent after stenting across the bifurcation. Note also that it is important to label the films because lateral views of the right and left carotid artery are identical.

**Illustrative points**

Treatment of both symptomatic and asymptomatic carotid artery stenosis remains an experimental technique. It is already clear, however, from more than 2,000 cases that have been performed in a worldwide registry, that this therapy has an acceptable morbidity and mortality in high-risk surgical patients, with less than 5% major stroke and mortality (25). Unlike coronary artery stenting, the goal is not a perfect angiographic result after carotid stenting. The main risk of this carotid intervention is distal embolization (not abrupt closure or restenosis), so great care is taken to avoid unnecessary manipulation of the carotid artery. Using this technique of underdilation of self-expanding...
stents, a restenosis rate of less than 10% can be expected (20). There are no reports of complications from covering the ostium of the external carotid artery using the technique shown. This procedure has also been found to relieve nonfocal neurologic symptoms, such as the dizziness and decreased mentation (i.e., “brain angina”) in a large number of patients at our institution. This suggests that chronic cerebral ischemia can have manifestations other than the classic focal embolic symptoms of transient ischemic attacks and stroke.

Case 3

A 77-year-old man suffered a stroke 4 months previously, with residual left hemiparesis. He has stable angina, prior myocardial infarction, and hyperlipidemia. He previously had radiation therapy to his neck for inoperable laryngeal carcinoma with resultant radiation fibrosis. On physical examination, he continues to have weakness of his left hand, but his leg strength has returned to normal. Carotid duplex examination revealed subtotal occlusion of the right ICA. Angiography revealed 95% stenosis of the right ICA above the bifurcation (Fig. 35.3A).

FIG. 35.3.

A: Critical stenosis (arrow) of the right internal carotid artery demonstrated by digital subtraction technique. The spherical structure in the lower left is a reference ball used for quantitative angiography. B: After placement of a self-expanding nitinol stent there is no significant residual stenosis. A slightly irregular appearance is noted at the site of stenting, characteristic of the first-generation nitinol stents. Notice also that because this stent does not shorten appreciably, the lesion can be treated without stenting the carotid bifurcation.

Carotid stenting was performed after pretreatment with aspirin, clopidogrel, and heparin using a 90-cm 7F Cook sheath inserted over a 125-cm 6F JR4 and a 300-cm extra-stiff Glidewire. After advancing the sheath into the common carotid artery, the lesion was crossed with a Road Runner wire and dilated with a 4.0-mm × 4.0-cm Cobra balloon. An 8- × 20-mm self-expanding Smart stent was then deployed at the site of stenosis and dilated with a 5- × 20-mm Opta-5 balloon. Final angiography of the common carotid bifurcation and cerebral vessels was then performed (Fig. 35.3B). After the procedure, the patient developed transient hypotension that responded to volume expansion and transient administration of an alpha agonist.

Illustrative points

Patients considered to be at high risk for carotid endarterectomy include those with inaccessible carotid lesions (high internal carotid or aortoostial common carotid), contralateral carotid occlusion, prior ipsilateral endarterectomy, permanent tracheostomy, radiation fibrosis, or high medical comorbidity. These patients are candidates for endovascular therapy using stents. Self-expanding stents are preferred for the carotid bifurcation because of the risk of crushing balloon-expandable stents. The Smart stent is one of a new generation of self-expanding nitinol stents that show great promise in experimental trials. These stents can be delivered through either a 7F sheath or a 9F guiding catheter. The choice of delivery depends on the operator's preference. The nonkinking 7F sheaths have an outer diameter that is approximately the same as a 9F guiding catheter, so the size of the access site is similar. Hypotension after carotid endarterectomy may signify bleeding from the access site but may also result from stretching of the carotid sinus by the stent. This generally responds to volume expansion, although atropine and alpha agonists are employed when volume expansion alone is not sufficient.

Intracranial Angioplasty

Several studies have shown that intracranial disease can be viewed as a marker of extensive cerebrovascular and systemic atherosclerotic disease, particularly coronary artery disease (26). Although the traditional risk factors for development of atherosclerotic disease, particularly tobacco abuse and hypertension, also affect the intracranial circulation (27), some authors have suggested that intracranial atherosclerosis is especially prevalent in African Americans and Asians (28),(29).

The incidence of stenotic lesions located in the intracranial ICA, the intracranial vertebrobasilar system, and the proximal middle cerebral artery is less than that of extracranial carotid and vertebral atherosclerosis. In one study...
from the Mayo Clinic, of 1,000 consecutive patients undergoing angiography, 19% had moderate to severe intracranial ICA stenosis and 29% had mild intracranial ICA stenosis (26). The most common location is the intracranial portion of the ICA (49%) (particularly the intracavernous portion), followed by the middle cerebral artery (20%), posterior cerebral artery (11%), distal vertebral and basilar arteries (11%), and anterior cerebral artery (9%) (30). These lesions are responsible for 5% to 10% of all ischemic strokes (31).

The prognosis of symptomatic patients with intracranial stenosis is well characterized, particularly for lesions involving the ICA and middle cerebral artery. In one study (32), 58 patients with intracranial ICA stenosis were followed for 30 months. Forty-three percent of the patients suffered a cerebrovascular incident or had died at follow-up. Most deaths were due to a cardiac event or stroke. In another study (33), 72 patients with stenosis or occlusion involving the anterior circulation were randomized to medical treatment or extracranial/intracranial bypass surgery. The stroke rate was 36% in the patients randomized to medical treatment and 38% in the patients randomized to surgery. A comparable fate has been observed in patients with symptomatic intracranial lesions of the posterior circulation (34).

Because of the current technical limitations of angioplasty for intracranial stenosis, this form of treatment should be reserved only for patients who have failed medical treatment (10,35–37). The best medical treatment for this kind of atherosclerotic disease has not been assessed in controlled prospective studies. Based on retrospective data, warfarin appears to be superior to aspirin (34).

Compared with angioplasty of the extracranial carotid and vertebral arteries, angioplasty of the intracranial portion of these vessels is technically more difficult and carries a higher complication rate. Clark et al. (10) reported their results of intracranial angioplasty in 17 patients and 22 vessels. Their procedural success was 82%. There were two strokes during angioplasty, for a 30-day morbidity rate of 9.1% per treated vessel and 11.7% per case. The average preangioplasty stenosis was 72±8% and postangioplasty stenosis was 43±24%. Interestingly, at 6-month angiographic follow-up, further angiographic improvement was observed (37±21%), in eight patients and 12 vessels, suggesting a process of “positive” remodeling. In another study of 12 patients, Terada et al. (8) reported successful results without complications in eight patients (67%). Two patients suffered thromboembolism and two had acute dissection resulting in permanent neurologic deficit in two patients and transient neurologic deficit in the other two patients. At 11 months follow-up none of the 11 surviving patients had experienced a new neurologic event. Stenting of the intracranial carotid has also been reported with encouraging results (38–40). Whether the new, more flexible coronary stents (Chapter 24) will improve the outcome of angioplasty in the intracranial circulation and change the natural history of the disease will have to be determined in large controlled studies.

Case 4

An 86-year-old man was referred for angiography because of recurrent episodes of lightheadedness and transient ischemic attacks involving weakness of his right upper and lower extremity. On physical examination, he had inability to dorsiflex his right foot and had a remote traumatic amputation of his right arm. Color flow Doppler examination revealed no significant carotid artery lesions. Angiography with cranial angulation revealed 80% stenosis of the left ICA at the siphon with no significant cervical carotid stenosis (Fig. 35.4A). Angioplasty was performed on this lesion using coronary equipment (see Chapter 23). A 6F multipurpose coronary guiding catheter was advanced to the ICA just below the first 90° bend. The lesion was crossed with a 0.014-inch hydrophilic wire over which a Transit catheter was advanced to the middle cerebral artery. The wire was exchanged for an Extra Support coronary wire and the lesion was dilated with a 3.5- × 15-mm monorail coronary balloon. Final angiography was performed revealing less than 30% residual stenosis (Fig. 35.4B). An abciximab infusion was begun after completion of a successful procedure. The patient had resolution of his transient ischemic attacks (TIAs) and was enrolled in a stroke rehabilitation program.

**FIG. 35.4.**

A: Intracranial angioplasty. Left internal carotid artery siphon stenosis before intervention (arrow). Notice the artifact in the proximal internal carotid artery caused by a dental prosthesis. B: The same vessel after balloon angioplasty with a coronary system showing no significant stenosis.
Illustrative points

Intracranial angioplasty is a field in its infancy where collaboration between neurology, neuroradiology, and the cardiovascular interventionist is important. This case illustrates how patients with recurrent focal symptoms in the same vascular distribution should be referred for angiography even if the duplex examination shows no cervical carotid stenosis. Lesions of the aortoostial common carotid artery and the high internal carotid, including intracranial carotid artery, can be missed by carotid duplex examination. The role of platelet glycoprotein IIb/IIIa receptor inhibitors has some theoretic basis but has not been established in this patient population.

Subclavian and Brachiocephalic Artery Angioplasty

The prevalence of brachiocephalic or subclavian artery stenosis ranges between 12% to 15% of patients undergoing angiography for cerebrovascular symptoms. It is usually located in the proximal portion of the vessel before the origin of the vertebral and internal mammary artery and tends to be relatively focal. The left subclavian artery is involved three to four times more frequently than the right. Although atherosclerotic disease is by far the most common cause of subclavian artery stenosis, unusual conditions such as Takayasus's arteritis, fibromuscular dysplasia, giant cell arteritis, radiation-induced occlusive disease, and thoracic outlet syndrome may affect this vessel and cause significant stenosis.

The clinical manifestations of subclavian artery stenosis include upper extremity ischemic symptoms with arm claudication related to exercise or resulting from embolization to the digits. Subclavian steal syndrome occurs as a result of flow reversal in the vertebral artery, leading to symptoms of vertebrobasilar insufficiency. In coronary/subclavian steal syndrome, there is reversal of flow in an internal mammary graft as a result of a proximal subclavian stenosis that may cause symptoms of myocardial ischemia.

Before the advent of percutaneous revascularization techniques, surgery was considered the standard treatment for this condition. Several surgical techniques were used, including transthoracic procedures, carotid/subclavian bypass, and axilloaxillary bypass. However, they all carry significant risk of morbidity and mortality. Hadjipetru et al. recently reviewed the outcomes of 52 surgical studies with 2,496 patients. The technical success was 96% (range, 75% to 100%) and the complication rate was 16±11% (range, 0 to 43%), with a mortality rate of 2±2% (range, 0 to 11%) and a stroke rate of 3±4% (range, 0 to 14%). At a mean follow-up of 51 ± 25 months, recurrence of symptoms occurred in 16±14%.

Balloon angioplasty for subclavian artery stenosis can be carried out with considerable technical success and has been described as a feasible alternative to surgery. Yet there has been uncertainty regarding distal embolization and patency rates due to inadequate long-term follow-up. When stenting is used in addition to balloon dilation, it may reduce the risk of embolization and achieve anatomically and physiologically superior results. The previously mentioned study of Hadjipetru et al. also summarized the published series of patients treated with stents. Of 108 patients treated with these devices, technical success was obtained in 97 ± 4%. Adverse events were reported in 6 ± 5%. In a multicenter registry involving eight centers, stenting of the subclavian artery was successful in 98.5% of patients and a TIA occurred in only one (0.5%) patient.

Based on the current available data, percutaneous revascularization with balloon angioplasty followed by stenting appears to yield superior results with fewer complications than surgery. Until a large prospective randomized trial is carried out, stenting should be considered the treatment of choice with these lesions.

Case 5

A 66-year-old woman presented with a chief complaint of left arm claudication. She stated that she had a history of progressive pain and weakness in her left arm that was associated with the symptom of the room “spinning around her” during left arm exertion. Symptoms were especially prominent while washing the dishes, folding laundry, and using the “butterfly” machine at the gym. She had a history of hypertension, hyperlipidemia, and diabetes. Her blood pressure was 180/90 in the right arm and 130/60 in the left arm. Her left radial pulse was weak. Duplex scanning revealed reversal of flow in the left vertebral artery. Coronary angiography by the referring physician revealed nonobstructive coronary disease. Angiography of the left subclavian artery revealed 90% stenosis of the left
Critical stenosis in the left subclavian artery ( ), which supplies both the left vertebral (underfilled) and left internal mammary artery as well as the axillary artery. There is ostial disease in the subclavian artery as well. After placing tandem balloon-expandable Palmaz stents in the left subclavian artery, there is normalization of flow to the left vertebral and left axillary arteries. The left vertebral has a 50% ostial stenosis that was not treated.

The patient underwent percutaneous intervention using a 9F multipurpose guiding catheter inserted over a 0.035 Road Runner PC wire and a 125-cm long 6F diagnostic multipurpose catheter. The peak translesional gradient was measured to be 50 mm Hg. The lesion was predilated using a 6- × 20-mm Opta-5 balloon. A P204 Palmaz stent mounted on a 7- × 20-mm Opta-5 balloon was then advanced across the lesion and deployed. A second P154 stent was deployed proximal to the first stent using 12 atm inflation. Final angiography was performed revealing restoration of antegrade flow into the left vertebral artery (Fig. 35.5B). The pressure gradient across the lesion was abolished.

Illustrative points

Subclavian artery stenosis can present with claudication, critical limb ischemia, or subclavian steal syndrome. This patient's symptoms and examination were classic for the lesion that was found. In patients with prior left internal mammary artery (LIMA) to coronary artery bypass surgery, angina may be the presenting symptom. The surgical treatment of this lesion by carotid to subclavian bypass has a mortality of 5% and a major morbidity (mainly cardiac) of approximately 25%. In a multicenter registry (57) the treatment of these patients with stents has a major morbidity of less than 1% and a restenosis rate of 10%. The same technique is used to perform aortoostial stenting of the carotid and innominate arteries. Balloon-expandable stents are preferred in this location because of the ability to position them precisely at the ostium without compromise of important side branches.

THORACIC AORTIC INTERVENTION

Coarctation of the Aorta

Patients with long-standing coarctation of the aorta have an increased risk for development of coronary artery disease, aortic dissection, and pseudoaneurysm (58). The treatment of native coarctation of the aorta has traditionally been surgical. Although this procedure is effective in obliterating the pressure gradient and relieving symptoms, the incidence of restenosis and aneurysm formation is not negligible, ranging from 5% to as high as 50% (59),(63). Percutaneous catheter-based procedures have emerged as a feasible option to surgical treatment in selected patients (see also Chapter 28). Several studies have shown that balloon angioplasty can be carried out with high technical success and few complications (64–69). Whether balloon angioplasty or surgery is the treatment of choice for native coarctation of the aorta remains controversial, but many investigators agree that balloon angioplasty is a better treatment for postoperative coarctation (70),(71).

Most of the published studies found that angioplasty was highly effective in reducing the pressure gradient (64–71). In one study of 43 patients in native coarctation of the aorta, pressure gradient was reduced from 69 ± 24 mm Hg before angioplasty to 12 ± 8 mm Hg after angioplasty (65). In three patients (7%) the pressure gradient remained more than 20 mm Hg after the procedure. There were no procedural deaths but 7% developed a local aneurysm at follow-up (range, 1 to 10 years). Recurrence coarctation developed in 7% at 12-month angiographic follow-up. In another study of 90 patients with recurrent coarctation, pressure gradient was reduced from 31 ± 21 mm Hg to 8 ± 9 mm Hg (68). There were two neurologic events and one death. In 11 patients (12%), the procedure did not reduce the pressure gradient to less than 20 mm Hg (procedure failure). At 12-month follow-up, 72% remained free from the need for reintervention. Other investigators have not found significant differences in treating native or recurrent coarctation with balloon angioplasty (69).
The use of endoluminal stents to minimize the elastic recoil, improve the immediate hemodynamic results, and possibly decrease the recurrence of coarctation has been investigated, although the experience is still limited (72),(73). In one study (73), nine patients were treated with stenting. (Seven patients had had previous operation or balloon dilation.) Reduction in gradient across the coarctation and increase in diameter of the narrow segment occurred immediately after stent implantation. At a median follow-up of 13 months, residual gradient across the stented segment remained low in 8 patients. One patient required redilation of the stent.

**FIG. 35.6.**

A: A typical coarctation just distal to the left subclavian artery seen by digital subtraction angiography with a pigtail catheter located in the aortic arch. B: After stenting with a balloon-expandable P308 Palmaz stent there is no residual stenosis compared with the isthmus (proximal part) of the coarctation. It is important to size the balloon by measuring the vessel proximal to the coarctation rather than distal to reduce the risk of the serious complications of dissection and rupture.

Indications for the use of endoluminal stents in coarctation of the aorta are yet to be determined, but on the basis of this limited but encouraging experience it has been suggested that potential indications for these devices include hypoplasia of the isthmus or transverse aortic arch; tortuous coarctation with misalignment of the proximal with distal aortic segment, which are difficult to treat surgically; and recurrent aortic coarctation or small aneurysm after previous surgical or balloon therapy (74).

**Case 6**

A 41-year-old woman who had undergone coarctation repair at the age of 2 years now presents with hypertension, congestive heart failure, and decreasing ejection fraction over time. Despite treatment with digitalis, diuretics, and ACE inhibitors she continues to have NYHA class II heart failure. Her examination was remarkable for a systolic bruit between her scapulae, a gradient of 40 mm Hg between her arm and leg blood pressure, and weak but symmetric pulses in her lower extremities. Catheterization revealed a 70% stenosis in the aorta just distal to the left subclavian artery with poststenotic dilatation (Fig. 35.6A) and 35-mm peak systolic gradient across the coarctation. Intravascular ultrasound demonstrated the aorta to measure 17 mm in diameter proximal to the coarctation and 25 mm in diameter distal to the coarctation. The coarctation was dilated with a 16 mm × 4.0 cm XXL balloon with a 0.035-inch Amplatz extra stiff exchange wire advanced through a 90-cm-long 10F sheath. Intravascular ultrasound (IVUS) demonstrated significant recoil with dissection and persistent gradient of 18 mm Hg, so that a P308 stent was deployed at 8 atm using the same balloon. Angiography (Fig. 35.6B), IVUS, and pressure gradients all confirmed correction of the coarctation.

**Illustrative points**

Coarctation of the aorta usually presents with hypertension proximal to the coarctation and symptoms related to hypertension. In this patient with long-standing coarctation, congestive heart failure had resulted from chronic pressure overload. When treating coarctation of the aorta with endovascular techniques, IVUS is recommended to size the vessel and to avoid overdilation of the aorta, which can lead to serious dissection, rupture, or even death. Self-expanding stents tend to migrate into the distal ectatic aorta rather than remain in the narrowed coarctation, so balloon-expandable stents are recommended. The maximum diameter that a P308 stent can be expanded to is 16 mm, and considerable shortening occurs at this diameter, so careful positioning is important. Postsurgical correction coarctations are less likely to develop dissection and rupture with balloon angioplasty than virgin coarctations.

**Endoluminal Thoracic Aneurysm Repair**

The prevalence of thoracic aneurysms in the United States is difficult to determine because of underreporting of these aneurysms in mortality statistics. In Sweden, in a stable urban population with an autopsy rate of 83%, the incidence of thoracic aortic aneurysm between 1958 and 1985 was 489 per 100,000 autopsies in men 65 years of age and 670 per 100,000 autopsies in 80-year-olds (75).
The prognosis of patients with untreated thoracic aneurysms is poor. In three large studies that included 264 patients with thoracic aneurysms who did not undergo surgery at the time of diagnosis, rupture of the aneurysm was the most common cause of death, ranging from 42% to 70% of the patients (76–78). In these series of patients, the 5-year survival rate ranged from 13% to 39%.

In general terms, patients with aneurysms larger than 5.0 to 5.5 cm in the ascending aorta, larger than 5.5 to 6.0 cm in the aortic arch, or larger than 5.0 to 6.0 cm in the descending aorta should undergo surgical intervention (79).

Because of the high prevalence on cardiovascular disease and the age of this patient population, surgical treatment carries a significant mortality, which can be as high as 12% when the procedure is performed electively or as high as 50% when the procedure is performed emergently (76),(80). Similarly, brain infarction and spinal cord injury are not infrequent complications of surgical treatment (79).

Endovascular stent-grafts have been described as an alternative to surgical treatment for descending aortic aneurysms in selected patients (81),(82). Dake et al. (82) reported their experience in 13 patients with descending thoracic aortic aneurysm with a mean diameter of 6.1 cm (range, 5 to 8 cm). Technical success was obtained in all 13 patients. There were no deaths, paraplegia, or stroke at 11.6 months of follow-up. There was complete thrombosis of the thoracic aortic aneurysm surrounding the stent-graft in 12 patients, and one patient with extensive chronic dissection required open surgical graft replacement because of progressive dilation of the arch. The authors added that since the time of the submission of their paper until the time of its publication, 20 additional patients with 23 thoracic aneurysms underwent endovascular stent-grafts. In 21 cases, the procedure was successful. Two patients died of multiorgan failure, and one of the deaths was preceded by paraplegia.

Although the experience is still limited, endovascular stent-grafts appear a promising alternative to surgery for the treatment of thoracic aortic aneurysms in selected patients.

Case 7

A 58-year-old man was referred with an asymptomatic 6-cm saccular descending thoracic aneurysm (Fig. 35.7A). He was treated by endovascular means using a femoral cutdown and a self-expanding nitinol endoluminal graft during a procedure that lasted under 1 hour. Following deployment of the graft, there was still a bulge of graft material into the aneurysm due to a lack of external support on the graft; however, there was no evidence of leaking (Fig 35.7B).

**FIG. 35.7.**

A: Digital subtraction aortography of the descending thoracic aorta demonstrates a saccular aneurysm (arrow). B: After placement of an oversized, self-expanding endoluminal graft, there is no evidence of graft leaking. There is ectasia at the site of the aneurysm caused by expansion of the prosthesis into the aneurysm. This appearance is expected. Oversizing is necessary with self-expanding stents and endoluminal grafts to ensure good apposition of the stent or graft to the vessel wall.

Illustrative points

Although this is a very promising and exciting area for endovascular intervention, the nonsurgical treatment of these aneurysms is still in its infancy. Because standard surgical repair carries with it a high morbidity and mortality, as stated earlier, investigators are anxiously awaiting the development of an endovascular solution to this problem. Of note, the most likely cause of this type of saccular aneurysm of the thoracic aorta is infection, especially salmonellosis, not atherosclerosis.

**CELIAC AND MESENTERIC ARTERY ANGIOPLASTY**

Chronic mesenteric ischemia has been recognized as an uncommon but unequivocal cause of chronic abdominal pain. Although its prevalence is approximately one case in 100,000 (83), its lethal nature requires vigilance and a high
clinical suspicion. The mesenteric circulation includes three arteries: the celiac trunk, the superior mesenteric artery (SMA), and the inferior mesenteric artery (IMA). The stomach and upper half of the duodenum comprise the foregut and are supplied by the celiac trunk. The lower half of the duodenum, jejunum, ileum, cecum appendix, ascending colon, and proximal two-thirds of the transverse colon comprise the midgut and are supplied by the SMA. The distal third of the transverse colon, sigmoid colon, descending colon, sigmoid colon, rectum, and the upper part of the anal canal comprise the hindgut and are supplied by the IMA.

There is significant communication among these three vessels and significant collateral flow to the mesenteric circulation from other aortic branches (such as the lumbar intercostal, middle sacral, mammary, and internal iliac arteries). Because of this, the clinical syndrome of chronic mesenteric ischemia usually develops as a result of critical stenosis or occlusion of more than two of the celiac artery, SMA, or IMA. More than 90% of the cases of chronic mesenteric ischemia are due to atherosclerosis, usually extensions of aortic atheroma rather than intrinsic disease of the mesenteric branches.

Abdominal pain is the most frequent symptom, with some series reporting this manifestation in up to 100% of the patients (84–86). Other symptoms include weight loss, diarrhea, nausea, vomiting, and constipation. The abdominal pain is usually crampy, localized in the epigastrium or middle abdomen. More than 80% of the patients note the relationship of pain with caloric intake (85),(86). A significant percentage of patients may have concomitant coronary or peripheral vascular disease, which may make the clinical presentation confusing (87).

The traditional treatment for chronic mesenteric ischemia has been surgical. Because stenosis of the mesenteric branches is frequently focal, limited to the ostium and/or the very proximal portion of the vessel, percutaneous, catheter-based techniques of revascularization have been explored and appear to be an alternative to surgery in selected patients. An analysis of 11 published studies with 126 patients treated with balloon angioplasty (88) revealed a mean initial technical success of 86% (range, 38% to 100%). After exclusion of technical failures, the clinical success rate (resolution of symptoms) was 90%. At a mean follow-up of up to 101 months the primary and secondary clinical success was 76% and 92%. Major complications occurred in 6% of the patients, and the 30-day mortality was 3%.

Endovascular stenting of the mesenteric branches has rarely been reported but appears to be safe and effective in selective patients. In a study from our institution (89), 11 vessels (five SMA and six celiac arteries) of eight patients with chronic mesenteric ischemia were treated with Palmaz-Schatz stents. Clinical success (<30% diameter stenosis and relief of symptoms without in-hospital need for surgical revascularization or death) was obtained in 100% of the patients. There were no significant procedural complications. Two patients died of cardiovascular causes after discharge. At a mean follow-up of 11.5 ± 7.6 months, all survivors (six patients) were asymptomatic. Although experience is still limited, catheter-based techniques of revascularization such as balloon angioplasty with or without stenting appears a promising alternative to surgical intervention in selective patients with chronic mesenteric ischemia.

FIG. 35.8.

A: Angiography of the celiac artery demonstrating high-grade stenosis at the origin (arrow) before intervention. B: After stenting, there is no residual stenosis. The stent is placed so that several millimeters of stent extend into the aorta, because this is an ostial lesion.

Case 8

A 69-year-old man presented with a 9-month history of postprandial midepigastric pain with a 50-pound weight loss. He denied anorexia but had essentially stopped eating to avoid the recurrence of the pain. On examination, he was cachectic, weighed only 120 pounds, and appeared chronically ill. He had bilateral carotid bruits, an epigastric bruit, and diminished tibial and dorsalis pedis pulses bilaterally. An extensive gastrointestinal workup was negative, including upper and lower endoscopy; small bowel follow-through; computed tomographic scan of the abdomen; ultrasound of the gallbladder, liver, and spleen; complete blood count; and serum chemistries. He denied cardiac symptoms and had quit smoking 10 years earlier. He was referred for abdominal aortography and selective celiac and mesenteric angiography, which was performed via percutaneous brachial artery entry. The superior mesenteric artery
and inferior mesenteric artery were occluded. Figure 35.8A demonstrates high-grade stenosis of the celiac trunk, engaged with a 6F multipurpose catheter. This lesion was crossed with a Wholey wire, and a $6 \times 20$ Opta-5 balloon was advanced through a multipurpose guiding catheter and used to predilate the lesion. A P154 Palmaz stent was then deployed mounted on this same balloon. After deployment, the stent was postdilated with a $7 \times 20$-mm Opta-5 balloon at 12 atm. Final angiography (Fig. 35.8B) demonstrated no residual stenosis. The gradient was reduced from 60 mm Hg to less than 5 mm Hg. The patient's symptoms were immediately relieved, and by 2 months later he had regained 20 pounds.

Illustrative points

This is a classic case of chronic mesenteric ischemia. The diagnosis is usually missed in the early stages because of the myriad causes of abdominal pain. Profound weight loss with postprandial abdominal pain is the hallmark of this condition. Symptoms do not usually occur unless there is stenosis or occlusion of two or more of the three vessels (celiac, SMA, IMA). The traditional management of this condition has been surgical; however, mesenteric ischemia lends itself very nicely to an endovascular approach, because the lesions are usually ostial and ideal for balloon-expandable stents. Furthermore, by the time the diagnosis is made, the patients are usually cachectic and not ideal surgical candidates. Because of the high flow in these vessels, the poststent medical regimen consists of aspirin alone.

**RENALE ARTERY ANGIOPLASTY**

Renal artery stenosis is common in patients with known coronary or peripheral atherosclerotic disease (90)(91). In one study of 196 patients undergoing cardiac catheterization for presumptive coronary artery disease, the prevalence of significant (>50%) renal artery disease was 18%, and when coronary artery disease was confirmed in 152 patients, the prevalence was 22% (90). Some investigators have reported a prevalence of renal artery stenosis of more than 60% in patients with concomitant peripheral vascular disease and hypertension (92). For this reason in many cardiac catheterization laboratories, including ours, screening renal angiography is routinely performed in patients undergoing cardiac catheterization for atherosclerotic coronary disease.

Significant hemodynamic obstruction of the renal blood flow causes renovascular hypertension. This activates the renin angiotensin system leading to excessive production of angiotensin II, which in turn causes systemic hypertension and fluid retention. The diagnosis of renovascular hypertension should be suspected in patients with onset of hypertension at the ages of less than 35 years and more than 55 years, malignant or refractory hypertension, renal failure, resistant hypertension, coronary or peripheral atherosclerosis, an abdominal bruist, and a unilateral small kidney, and in patients who develop azotemia with ACE inhibitor therapy (93). These groups should undergo a noninvasive screening test to rule out this entity. The noninvasive test of choice for making the diagnosis of renal artery stenosis is the renal duplex ultrasound examination (94). Although captopril renal artery scintigraphy is a sensitive and specific test to demonstrate unilateral renal artery stenosis (95), the incidence of a false-negative test is substantial in patients with parenchymal disease or bilateral renal artery stenosis, which occurs in approximately one-third of the patients. Renal vein renin assays have been used in the past, and because many antihypertensive medications such as beta blockers may interfere with the release of renin, the need to withhold these medications prior to the test makes it impractical as a routine examination (96).

Surgical revascularization of atherosclerotic renal artery stenosis is an effective treatment for renovascular hypertension (97). Nevertheless, it carries an operative mortality of up to 3% as well as complications such as bypass graft thrombosis and nephrectomy in up to 4% of the cases (98)(99). Percutaneous transluminal renal angioplasty is the treatment of choice for fibromuscular dysplasia (100–102) and is an accepted treatment for selected patients in whom renal artery stenosis is causing renovascular hypertension and/or renal insufficiency (100)(103). However, atherosclerotic aortoostial renal artery lesions are particularly difficult to treat with balloon angioplasty alone because they are prone to significant vascular recoil, leading to a restenosis rate of approximately 50% over 6 months (104). On the other hand, endovascular stents have the capacity to scaffold dilated lesions and minimize the elastic recoil. Several studies have shown a significantly greater acute gain in luminal diameter and better angiographic results with renal artery stenting than with balloon angioplasty alone (105–107). In a study of 76 patients and 92 renal arteries treated with primary stenting, technical success was obtained in 100%, with a restenosis rate at 6 months of 25% (106). Blum et al. (108) treated 74 renal artery stenosis with endovascular stents. Technical success was achieved in 100% of the vessels, and the restenosis rate at 12-month follow-up was 11%. The renal function remained unchanged.
in all patients, but 62% of the patients had significant improvement of blood pressure, including 16% in whom the blood pressure normalized. In another study, balloon-expandable stents were placed in 100 patients and 133 renal arteries (109). Angiographic success was obtained in 132 of 133 (99%) of the lesions. At 6-month follow-up the systolic blood pressure was reduced from $173 \pm 25$ to $147 \pm 12$ mm Hg ($p < 0.001$) and the diastolic blood pressure was reduced from $88 \pm 17$ to $76 \pm 12$ mm Hg ($p < 0.001$). At a mean angiographic follow-up of $8.7 \pm 5.0$ months, the restenosis rate was 19%. Renal function after stent placement showed a small but statistically significant decline in blood urea nitrogen but no significant change in serum creatinine.

FIG. 35.9.

A: Typical appearance of an aortoostial renal artery plaque (arrow) causing renovascular hypertension. An internal mammary artery, Cobra 1, or Simmons 1 catheter will usually engage the renal ostium for angiography and guidewire passage without causing atheroemboli. Use of a guiding catheter to engage the renal artery is discouraged. B: After stenting there is no residual stenosis.

Stenting for renal artery stenosis also appears to have a beneficial effect in patients with refractory unstable angina and congestive heart failure (110). In 48 patients with unstable angina ($n = 23$) or congestive heart failure ($n = 25$) who had hypertension refractory to medical therapy and significant unilateral ($n = 30$) or bilateral ($n = 18$) renal artery stenosis, stenting significantly improved the blood pressure and functional class at 24-hour and 6-month follow-up. The dramatic improvement seen in this very sick group of patients was independent of a coronary angioplasty procedure.

In conclusion, the incidence of renal artery stenosis in patients with poorly controlled hypertension and atherosclerotic cardiovascular disease ranges from 20% to 30%. These patients should be identified at the time of diagnostic cardiac catheterization. The treatment of renal artery stenosis has a dramatic impact in the hypertension control and appears to have a beneficial effect in the treatment of refractory unstable angina and congestive heart failure. Considering the treatment alternatives for atherosclerotic renal artery stenosis causing medically refractory hypertension and/or renal insufficiency, stent placement is the current treatment of choice.

Case 9

A 68-year-old man underwent diagnostic coronary and renal angiography because of hypertension and congestive heart failure. His blood pressure was 185/90 on three antihypertensive medications and his blood urea nitrogen (BUN) and creatinine were normal. Renal color flow duplex examination demonstrated unilateral left renal artery stenosis. Angiography demonstrated moderate three-vessel coronary disease, an ejection fraction of 45% with global hypokinesis, and elevated left ventricular end diastolic pressure. Selective renal angiography performed at the time of coronary angiography with a 6F IMA catheter revealed high-grade unilateral left renal artery ostial stenosis (Fig. 35.9A). Renal angioplasty and stenting were performed using a soft, steerable 0.035-inch wire, an Opta-5 balloon, an 8F hockey stick guiding catheter, and a P154 Palmaz stent. The wire was positioned through the diagnostic catheter; then the balloon and guiding catheter were advanced to the lesion as a unit. The lesion was predilated with the balloon and the guiding catheter was carefully advanced into the renal artery to facilitate stenting. The balloon was withdrawn and the stent was mounted between the balloon markers. The stent was then advanced across the lesion and the guiding catheter was withdrawn into the aorta before stent deployment (Fig 35.9B). The sheath was removed 2 hours later and the patient was discharged the following morning.

FIG. 35.10.

A: This patient has both atherosclerotic ostial stenosis and fibromuscular dysplasia. The typical appearance of fibromuscular dysplasia (arrow) is a corrugation of the vessel. This is diagnostic of fibromuscular dysplasia but not of renovascular hypertension (see text). B: The corrugated appearance of the vessel does not change after balloon angioplasty; however, the ostial lesion has been successfully stented. Stenting of the fibromuscular disease is reserved for persistent hypertension after balloon angioplasty.

Illustrative points
Unilateral renal artery stenosis may cause hypertensive heart disease and heart failure because of diastolic dysfunction. In the elective patient, renal color flow Doppler examination is recommended before angiography in institutions that can perform high-quality diagnostic studies. The management of diastolic dysfunction and congestive heart failure is facilitated by treatment of the renal artery stenosis. Currently, an 8F guiding catheter is required to place balloon-expandable renal stents. The average diameter of a single renal artery is 5 to 6 mm, but vessels as large as 8.0 mm and as small as 3.0 mm can be found. Patients with dual or triple renal arteries on one side often have vessels that are less than 3.0 mm in diameter. Although predilatation is always recommended for these ostial lesions, atherectomy is rarely required.

Case 10

A 77-year-old female with known coronary artery disease and angina has a history of long-standing hypertension and diastolic dysfunction. Despite three antihypertensive medications, her blood pressure was 200/95. Her physical examination and laboratory data were normal. A color flow duplex Doppler examination suggested unilateral right renal artery stenosis. At the time of diagnostic coronary angiography, renal angiography was also performed; this revealed fibromuscular dysplasia of the middle right renal artery and ostial atherosclerosis (Fig. 35.10A). Balloon angioplasty was performed on the area of fibromuscular dysplasia with a 5.0-mm balloon and 0.035-inch Wholey wire. The ostium was treated with a balloon-expandable stent (Fig. 35.10B). She was discharged the next morning on only one antihypertensive medication with a blood pressure of 145/70 mm Hg.

Illustrative points

Fibromuscular dysplasia (FMD) is commonly found in young adults, especially women, but the condition can persist into later life. This interesting case illustrates the combination of two classic lesions: atherosclerotic renal artery ostial stenosis and FMD of the middle renal artery. The angiographic appearance of a corrugated vessel is diagnostic of FMD, and the renal artery is the most common location for this abnormality. The finding of fibromuscular dysplasia is not diagnostic of renovascular hypertension, but the noninvasive screening tests and selective renal vein renin analysis also lack sensitivity and specificity for this condition. In a patient with FMD who is hypertensive despite medical therapy, balloon angioplasty is indicated and the lesion usually responds to balloon angioplasty without the need for stenting. Ostial renal artery stenosis due to atherosclerosis does not respond to balloon angioplasty and does require stenting. In this hypertensive patient, both treatments were utilized to treat the specific lesions that were found with clinical success.

Case 11

A 77-year-old man who had had coronary bypass surgery was referred for coronary angiography because of unstable angina. He was noted to have hypertension with recent onset, so renal angiography was also performed at the time of coronary angiography. His renal function was normal. He was found to have critical stenosis in the LIMA to left anterior descending (LAD) coronary artery and critical right renal artery stenosis (Fig. 35.11A). Combined coronary and renal angioplasty was performed. The LIMA to LAD was dilated and stented using coronary equipment. The left renal artery was predilated with a 6×20-cm Opta-5 balloon, advanced through an 8F hockey stick guiding catheter over a Wholey wire. The guiding catheter was positioned across the lesion, and a P154 Palmaz balloon-expandable stent was introduced. After pulling the guiding catheter back into the aorta and careful positioning of the stent at the renal artery ostium, it was deployed at 12 atm (Fig. 35.11B). The patient was discharged the following morning without angina and with control of his hypertension on no medications.

**FIG. 35.11.**

A: Atherosclerotic left renal artery stenosis (arrow) before intervention. B: After stenting there is no residual stenosis. Note that the preangioplasty angiogram is performed through the diagnostic catheter before passing the Wholey wire. The poststent angiogram is performed through the 8F guiding catheter.

Illustrative points
Renal stenting can facilitate the management of angina pectoris by controlling hypertension. In patients with combined coronary and renal atherosclerosis and normal renal function, both coronary and renal lesions can be treated at one time. In patients with renal dysfunction, selective renal angiography and stenting are performed first. The patient then returns for staged coronary intervention in 24 to 48 hours after the renal function has improved or normalized. Unilateral renal artery stenosis does not cause renal dysfunction, because the contralateral kidney can still function normally. In patients with hypertension and renal insufficiency, either bilateral renal artery stenosis or parenchymal disease (i.e., nephrosclerosis) is usually present.

Case 12

A 73-year-old man was referred for evaluation and treatment of uncontrolled hypertension and ischemic cardiomyopathy with congestive heart failure. His blood pressure was 179/96 on four antihypertensive medications: diltiazem, 300 mg qd; metoprolol, 200 mg qd; Cardura, 2 mg qd; and Dyazide. He had undergone coronary artery bypass surgery 12 years previously. There were no audible abdominal bruits. His BUN was 23 mg/dL and creatinine 1.4 mg/dL. Because he was unstable, noninvasive studies were deferred and he underwent cardiac catheterization and renal angiography. Nonselective renal angiography was obtained with an AP abdominal aortogram (Fig. 35.12A).

![Fig. 35.12](file://EPJ OBS/Lippincott/BAIM/pdf%20development/htmlbaim%204%2Fpdf/3501.TXT.HTM)

A: Bilateral aortoostial renal artery stenosis (arrows) as demonstrated by cineangiography at the time of cardiac catheterization. Notice the diffuse atherosclerotic involvement of the infrarenal aorta. B: Aortogram of the same patient immediately after bilateral stent implantation.

This demonstrated bilateral severe, aortoostial renal artery stenosis and no significant coronary artery stenoses. The left renal artery was engaged with a 5F IMA catheter and selective angiography was performed. Renal artery stenting was performed using peripheral balloons and biliary stents. The right renal stent was dilated with a 7.0-mm balloon, and the left renal stent with an 8.0-mm balloon. Final angiography revealed no significant stenosis (Fig. 35.12B). The patient remains asymptomatic without recurrent hospitalizations on dyazide and metoprolol 50 mg qd 5 years after renal stenting.

Illustrative points

As this case illustrates, not all patients with bilateral, severe renal artery stenosis have renal insufficiency. It also illustrates how the lesions of renal artery stenosis are often aortic plaque that encroaches on the renal ostia rather than plaque originating in the renal arteries themselves. Notice how diseased the abdominal aorta is in this patient. For this reason these authors strongly recommend selective cannulation of the renal arteries using a diagnostic 5F or 6F catheter rather than an 8F guiding catheter to avoid the risk of distal atheroembolism. Furthermore, as this case also illustrates, bilateral renal artery stenosis can be easily treated at one session using the same catheters and balloons. The enduring effects of renal stenting on control of hypertension and congestive heart failure is very gratifying. With the controversy that exists in many medical communities over providing credentials for peripheral procedures, the patient may get lost in the shuffle. Given the fact that we have an excellent, low-risk treatment for atherosclerotic renovascular hypertension, study of the renal arteries in patients with atherosclerosis and hypertension during otherwise-indicated cardiac catheterization would appear to be good medical practice.

AORTOILIAC ANGIOPLASTY

Angioplasty has proved to be an effective technique for the treatment of aortoiliac occlusive atherosclerotic disease. Nevertheless, angioplasty should be performed only in symptomatic patients, despite the fact that the procedural complication rate is low (111) or in patients who have severe aortoiliac arterial occlusive disease and who require insertion of an intravascular balloon pump for high-risk coronary revascularization procedures or cardiogenic shock (112). The ideal candidates for aortoiliac angioplasty are patients with discrete stenosis. The technical success and 5-year patency rate of iliac angioplasty are related to many factors, including lesion length, adequacy of distal runoff, presence of occlusion or stenosis, and presence of diabetes (113–115). Based on this, the American Heart Association,
in the Guidelines for Peripheral Percutaneous Transluminal Angioplasty of the Abdominal Aorta and Lower Extremity Vessels (111), stratified lesions according to the degree of complexity. Category 1 iliac lesions are concentric uncalcified stenoses less than 3 cm in length. Category 2 lesions are calcified stenoses 3 to 5 cm in length or eccentric stenoses less than 3 cm in length. Category 3 lesions are stenoses 5 to 10 cm in length or occlusions less than 5 cm in length after thrombolytic therapy. Category 4 lesions are stenoses more than 10 cm in length, occlusions longer than 5 cm, extensive bilateral disease, iliac stenoses in patients with abdominal aortic aneurysms, or other lesions requiring aortoiliac surgery.

Category 4 lesions should be treated surgically, whereas categories 1 to 3 can be treated with angioplasty. The overall technical success for categories 1 and 2 lesions is 95%. The 5-year patency rate is 80% to 85% for categories 1 to 2 lesions compared with a patency of 65% to 75% for category 3 lesions. A very similar classification applies for aortic lesions with a technical success of aortic angioplasty of 90% for category 1 (less than 2 cm [111]).

Endovascular stents have been introduced in the treatment of aortoiliac atherosclerotic disease in an attempt to overcome the acute procedural complications such as abrupt occlusion and long-term restenosis rate. Several studies have suggested that the procedural success with these devices is as high (or higher) and the restenosis rate lower than balloon angioplasty alone (106–119). However, comparative studies between these two catheter-based approaches are scarce in the literature. Bosh et al. (120) performed a metaanalysis of 6 percutaneous transluminal angioplasty (PTA) studies (1,300 patients) with eight stent placement studies (816 patients). The technical success was higher for the stent patients (96% vs. 91%, p < .05). The complication and mortality rates were similar for the two groups. The 4-year primary patency rate for stenosis (77% vs. 65%) and occlusions (61% vs. 54%) in patients with claudication was statistically higher in the stent-treated group. The 4-year primary patency rate for stenosis (67% vs. 53%) and occlusions (53% vs. 44%) in patients with critical ischemia was also statistically higher in patients treated with endovascular stents.

Until large prospective randomized trials comparing PTA with stenting are available, stenting when possible should be the treatment of choice for aortoiliac arterial occlusive disease.

Case 13

A 73-year-old woman was referred for global revascularization. She complained of severe dizziness and intermittent left arm weakness, left arm claudication and exaggerated dizziness with use of her left arm, poorly controlled hypertension, and long-standing bilateral buttock, thigh, and lower extremity claudication at less than 100 yards (Fontaine IIB). She had no cardiac symptoms. On examination, she had diminished blood pressure in her left arm, bilateral carotid and subclavian bruits, and femoral and tibial pulses that could only be detected on Doppler examination. Her ankle–brachial index (ABI) was 0.5 bilaterally; BUN and creatinine were normal. Color flow Doppler examination revealed reversal of flow in the left vertebral artery, antegrade flow in the right vertebral with a high-velocity jet at the ostium consistent with ostial stenosis, and critical left carotid stenosis. A dobutamine echo demonstrated inferior ischemia. The left subclavian artery ostium was not visualized; however, there was evidence of left subclavian stenosis by the presence of reversal of flow in the left vertebral artery. Global angiography was performed using digital subtraction and cineangiographic techniques. This confirmed the presence of left carotid, right vertebral, left subclavian, left renal, and bilateral common iliac artery stenoses. The right coronary artery was occluded with good collaterals.

The abdominal aortogram (Fig. 35.13A) demonstrates the presence of stenosis at the terminal aorta involving the common iliac artery bifurcation. Note the presence of a small abdominal aortic aneurysm and the presence of diffuse atherosclerosis in the aorta and both common iliac arteries. A staged approach to global revascularization was planned in this patient with severe, symptomatic, systemic atherosclerosis. The first step, to secure and preserve access for future procedures and relieve her claudication, was aortoiliac bifurcation stenting.

FIG. 35.13.

A: Severe atherosclerotic involvement of the terminal aorta and common iliac artery origins (arrow) with a small infrarenal aortic aneurysm. Bifurcation Palmaz stents (insert). B: Angiographic appearance after stenting the aortoiliac bifurcation.
Right common femoral access was obtained by fluoroscopic visualization of calcium in the common femoral artery, since there was no palpable pulse. A 30-cm-long 7F sheath was inserted and advanced into the right external iliac artery. Using a steerable 0.035-inch guidewire, a pigtail catheter was advanced into the abdominal aorta. There was a 60-mm gradient across the common iliac bifurcation. Aortography was performed that visualized the left common femoral artery, into which a second long 6F sheath was inserted. A second steerable wire was positioned through this sheath, terminating in the aorta. After documenting the diameter of the infrarenal aorta (16 mm) and both common iliac arteries (9 mm) two 8- × 40-mm balloons were advanced across the aortoiliac bifurcation (one balloon through each femoral sheath) and inflated simultaneously to 8 atm. The sheaths were then advanced across the stenosis over the partially deflated balloons. Two Palmaz balloon-expandable stents (P294) were mounted on the balloons and positioned across the aortic bifurcation using bony landmarks and roadmapping techniques. After withdrawing the sheaths and confirming correct stent position with contrast injections through the sheaths, the stents were deployed simultaneously at 8 atm. The right common iliac stent appeared underdeployed angiographically, so a second simultaneous inflation was performed across the bifurcation using a 9-mm balloon on the right and an 8-mm balloon on the left. The stents were then fully expanded (Fig 35.13, insert), with no residual gradient across the bifurcation and an excellent angiographic result without residual stenosis or dissection (Fig 35.13B). Her ABI was 0.9 bilaterally and her claudication was relieved. The patient was discharged 8 hours later and was scheduled to return for endovascular revascularization of the other vascular beds in a staged manner.

Illustrative points

This case is an example of the systemic nature of atherosclerosis and how a global approach to the diagnosis and management of these patients is important for providing optimal care. Although this patient had no coronary symptoms, the primary cause of death in patients with claudication is cardiac, so coronary angiography is indicated to rule out life-threatening coronary lesions. The staging of procedures in this patient is necessary because too much contrast is required for each intervention to allow global revascularization as one procedure. The iliac arteries are treated first to preserve vascular access for the other procedures. The carotid, vertebral, and subclavian lesions will be stented next because of their importance in causing the patient symptoms. It has not been established whether treating asymptomatic patients with aortic arch and carotid stenoses by endovascular means has any value in preventing stroke or prolonging life, so treating symptomatic lesions remains the benchmark. The renal artery stenosis will be treated last because this will likely lead to relative hypotension, which could exacerbate symptoms in the presence of symptomatic aortic arch and carotid stenoses.

Case 14

A 74-year-old gentleman with unstable angina was referred for complex coronary intervention. He had an ischemic cardiomyopathy with an ejection fraction of 15% and had severe stenosis of the saphenous vein graft to the left anterior descending, which supplied all the collaterals to the inferior wall. To accomplish the coronary intervention safely, intraaortic balloon counterpulsation was desirable, but the patient had severe peripheral vascular disease with a long history of bilateral lower extremity claudication. His femoral pulses were present only on Doppler examination, and his ABI was 0.4 bilaterally. Common femoral access was obtained on the right, but the right common iliac artery was found to be occluded. Left common femoral access was obtained, followed by retrograde aortoiliac angiography using cineangiographic technique by injection through the sheath (Fig. 35.14A). This demonstrated subtotal occlusion of the left common iliac artery and occlusion of the right common iliac artery. A gradient of 60 mm Hg was documented across the stenosis. This common iliac lesion was crossed with a steerable 0.035-inch guidewire and balloon angioplasty was performed using a 7- × 40-mm balloon. Because of persistent stenosis, a Palmaz P295 (iliac) stent was deployed at 8 atm and dilated again to 10 atm with the same balloon through a 30-cm-long 7F sheath. Angiography was performed again through the sheath, demonstrating a widely patent left common iliac artery and a large lumbar collateral to the right internal iliac artery (Fig. 35.14B). There was no residual gradient across the common iliac artery. An intraaortic balloon pump was passed through the stent and advanced to the descending aorta, where counterpulsation was initiated. Coronary intervention was successfully performed via the brachial artery without hemodynamic embarrassment. The intraaortic balloon was removed at the end of the coronary intervention replaced with a 9F sheath. Both the brachial and femoral sheaths were removed when the anticoagulation was sufficiently attenuated. There were no complications.

FIG. 35.14.
A: Right common iliac occlusion and left common iliac stenosis in a patient with severe bilateral claudication who needs an intraaortic balloon pump. B: After stenting with a balloon-expandable stent. Notice the persistence of a large right lumbar collateral supplying the right lower extremity via the internal iliac artery.

Illustrative points

This case demonstrates how valuable it is for cardiologists to possess the knowledge and skill to perform iliac intervention to prevent iliofemoral complications and to preserve access for coronary intervention. Without treatment of the left common iliac stenosis, potentially life-saving intraaortic balloon counterpulsation would not have been feasible in this patient without jeopardizing his left lower extremity. Iliac stenting can be performed safely in patients undergoing intraaortic balloon counterpulsation during coronary intervention (112). It is important that the stent be well expanded to prevent the balloon pump catheter from catching on the stent. In this case, the balloon pump catheter was removed immediately under direct visualization, although such visualization is not required after proper stent deployment. In patients who need prolonged counterpulsation, the balloon pump catheter can be removed in the critical care setting.

FEMOROPOPLITEAL AND PROFUNDA FEMORIS ANGIOPLASTY

Femoropopliteal Angioplasty

Atherosclerotic occlusive disease is three to five times more common in the femoropopliteal artery than in the iliac artery. Among the femoropopliteal artery, occlusions are three times more frequent than stenosis, a distribution that is the opposite of the aortoiliac system (121), (122). Furthermore, most occlusions are long, which often precludes the use of angioplasty in many of these patients (121).

Only symptomatic patients should be considered for percutaneous revascularization of the femoropopliteal artery (111). As is the case for the aortoiliac system, the technical success and the long-term patency rate vary according to the lesion characteristics. Treatment of short (<5 cm) and/or stenosed lesions yield better results than treatment of long (>10 cm) and/or occluded lesions (111). The presence of patent runoff vessels correlates with long-term benefits, reflected in the improved outcome in patients with milder symptoms (114,123,124). Significant residual stenosis after angioplasty correlates with a poor long-term outcome (124), and low residual stenosis and the absence of diabetes correlates with an improved patency rate (111).

In a study of 236 patients who underwent conventional balloon angioplasty in 254 femoral or popliteal arteries, procedural success was obtained in 96% (123), (125). At 1-month follow-up, 88.8% of the procedures were considered successful (determined by an improved clinical grade and noninvasive vascular laboratory measurements). The success rate was 62.5% at 1-year follow-up and only 38% at 4-year follow-up. In this study, the most important independent predictors of long-term success, using multivariate analysis, were adequate distal runoff and lesion stenosis (rather than occlusion). Adar et al. (126) reviewed several published studies and found an early patency rate of 89% with a 3-year patency rate of 62% for patients with intermittent claudication compared with an early patency rate of 77% and a 3-year patency rate of 43% for limb salvage.

Although the long-term patency rate of femoropopliteal angioplasty is not as favorable as in PTA of the aortoiliac system, particularly when treating long or occluded lesions, percutaneous revascularization is an alternative to surgery in selected patients or may complement surgical treatment in patients with more extensive disease.

In contrast with the favorable impact of endovascular stents in patency rate in the aortoiliac system, these devices have not been shown to improve the late patency rate when implanted in the femoropopliteal system. A European prospective study (127) showed that conventional femoropopliteal PTA has a 1-year primary patency rate (65%) equivalent to that of femoropopliteal Wallstent's secondary patency rate (69%). In this study, early clinically significant restenosis was 38% and early thrombosis was 19% in the stent group. Another large prospective U.S. study showed similar lack of benefits with stents (128).
Because there is no advantage of stenting over conventional balloon angioplasty in the femoropopliteal system, these devices should be used in cases of suboptimal results, flow-limiting dissection, or abrupt occlusions after balloon angioplasty.

Case 15

A 67-year-old man with an orthotopic heart transplant 10 years earlier presented with a 1-month history of progressive claudication that was symptom-limiting (Fontaine 2A). He was no longer able to participate in his cardiac rehabilitation walking program. His femoral pulses were normal; however, he had absent left lower extremity pulses and an ABI of 0.6. He was referred for angiography and possible intervention for symptom-limiting claudication. Diagnostic angiography was performed via the right common femoral artery and demonstrated proximal occlusion of the left superficial femoral artery with mild stenosis in the profunda femoris (Fig. 35.15A). There was three-vessel runoff below the knee, visualized by late collateral filling. The SFA occlusion was recanalized with a contralateral 6F sheath, a guidewire, and a 16-hour coaxial infusion of urokinase that was initiated through a multiple-side-hole catheter at 2,000 U/min (Fig. 35.15B). Following successful lysis (Fig 35.15C), balloon angioplasty was performed on the culprit lesion in the mid-SFA (Fig 35.15D). The patient was discharged the following morning and remains asymptomatic 1 year after angioplasty.

FIG. 35.15.

A: Long occlusion of the left superficial femoral artery (baseline). B: After 4 hours of thrombolysis there is recanalization but persistence of thrombus. C: After 16 hours of urokinase there is no residual thrombus, but a focal mid-SFA stenosis is present. D: Following balloon angioplasty of the mid-SFA stenosis there is no residual stenosis.

Illustrative points

In patients with recent onset of symptoms and occluded vessels, thrombus is likely to be present. Direct angioplasty in this setting carries with it a high risk of distal embolization, which can convert a stable claudicator into a patient with limb-threatening ischemia in a matter of minutes. In the setting of acute thrombus, treatment of the thrombus by thrombolysis (or more recently by mechanical thrombectomy [see Chapter 25]) will help to avoid distal embolization and its consequences. Another advantage of thrombolysis or thrombectomy is the ability to convert a long occlusion that is not ideal for balloon angioplasty into a simple, focal stenosis. Simple, focal stenoses such as the one that was the culprit lesion in this patient (Fig 35.14C) generally respond well to balloon angioplasty with an excellent acute and acceptable long-term result. Stenting of the SFA is only recommended if done in a provisional manner unless it is under protocol. At this time, there are no FDA-approved stents for the SFA, and the reported restenosis rates and reocclusion rates are unacceptably high.

Case 16

This 62-year-old man was referred for SFA angioplasty because of symptom-limiting claudication and serial high-grade stenoses in the left SFA. He was enrolled in a protocol testing the efficacy of a new endoluminal graft. The lesion (Fig. 35.16A) was initially dilated with a 5.0- × 80-mm balloon; then an endoluminal graft was deployed (Fig. 35.16B). The patient’s ABI improved from 0.7 to 1.0 after the procedure and he was rendered asymptomatic. He was discharged on aspirin and clopidogrel.

FIG. 35.16.


Illustrative points

A number of investigational therapies, including brachytherapy, self-expanding stents, and endoluminal grafts are
being tested in randomized trials to see if they will offer an advantage over simple balloon angioplasty. Although the early registry data are very promising, there are no randomized trials indicating a restenosis benefit from any of these therapies. This case illustrated how a simple, focal stenosis can become occluded and lead to a long occlusion. It is certainly safer and easier to intervene on the simple stenoses; however, without the presence of symptoms this is not justified.

**Profunda Femoris Artery Angioplasty**

The profunda femoris artery (PFA) becomes an essential vessel for maintaining limb viability when occlusive atherosclerotic disease affects other vascular territories of the same limb. The profunda femoris artery not only provides the primary blood supply to the tissues of the thigh, but also is the most important vessel for collateralizing an obstructed or occluded superficial femoral artery (129–132). Historically, significant occlusive disease of the PFA has been treated surgically. However, atherosclerosis of the PFA is usually focal, preferentially involving the origin and the very proximal portion of the vessel in most limbs (133), which makes a percutaneous catheter-based approach an attractive alternative to surgical profundoplasty.

There are a handful of studies in the literature that have suggested that balloon angioplasty is a feasible alternative to surgery in selected patients (134–137). In a study from our institution (138), PFA balloon angioplasty was performed in 31 patients and 32 limbs with severe ischemia (41% had Fontaine class 2B and 59% had Fontaine class 3 or 4). The superficial femoral artery was occluded in 20 limbs (62%). In 22 limbs (69%) an additional vessel was treated. Procedural success was attained in 91% of the limbs. The ABI increased from 0.5 ± 0.2 at baseline to 0.73 ± 0.2 after intervention (p < .01). In-hospital limb salvage in 30 survivors was 94% and the in-hospital amputation- and revascularization-free survival was 90%. At a mean follow-up of 34 ± 20 months, no patients underwent amputation and five additional patients died. Freedom from revascularization of the 25 survivors was 88%. At follow-up, 88% had Fontaine class 1 or 2A, and only 12% had Fontaine class 2B or 3 (p < .001 compared with baseline).

Based on our results as well as previous studies, we conclude that percutaneous revascularization of the profunda femoris artery is a safe and effective alternative to surgical treatment.

**Case 17**

A 65-year-old woman with coronary artery disease, bilateral carotid endarterectomy, and bilateral renal artery stenting presented with a 1-year history of progressive, Fontaine class 2B claudication in both lower extremities, which was worse on the left. She has known chronic bilateral SFA occlusion. The femoral pulses were normal but the tibial pulses were weak and monophasic on the right and absent on the left. The ABI was 0.3 on the right and not obtainable on the left. Angiography performed at the referring institution revealed occlusion of the proximal SFA and serial high-grade stenoses of the left profunda femoris (Fig 35.17A). Using contralateral retrograde femoral access, a 7F contralateral sheath was advanced to the left external iliac artery. Baseline angiography was performed and the lesion was crossed with a 0.035-inch Wholey wire. When the lesion could not be crossed with a 4- × 20-mm balloon, the wire was exchanged for a floppy Rotawire and rotational atherectomy (see Chapter 25) was performed on all three profunda femoris lesions using a 1.75- followed by a 2.25-mm burr. The lesions were then dilated with the 4- × 20-mm balloon at 6 atm. Postangioplasty angiography demonstrated a widely patent profunda femoris and the ABI increased to 0.4 on the left (Fig. 35.17B). The patient was discharged the following morning with relief of his claudication.

**FIG. 35.17.**

**A:** Severe, diffuse atherosclerotic involvement of the infrainguinal vessels. The SFA is occluded and the profunda femoris is diffusely diseased. Involvement of the profunda femoris is typical in patients with long-standing diabetes.

**B:** After rotational atherectomy and balloon angioplasty, an excellent angiographic result.

**Illustrative points**

The two most important arteries for maintaining a viable leg are the common femoral artery and the profunda
femoris. The SFA is often occluded; however, in the presence of a patent profunda, the limb usually remains viable. In patients with chronic SFA occlusion and lesions of the common femoral or profunda, revascularization of these vessels can restore the patient to his previous mild level of symptoms even without revascularizing the chronically occluded SFA. This case also demonstrates that the use of coronary equipment and techniques can permit peripheral angioplasty success in otherwise undilatable lesions. Another option in this patient would have been to use coronary wires and balloons to cross and dilate the lesions; however, by debulking the lesions with rotablator in patients with lower extremity ischemia, it is easier to achieve an acceptable balloon result with lower pressure and less risk of dissection. The acute clinical success and limb salvage rate using the rotablator for undilatable lesions exceeds 90%.

INFRAPOPLITEAL ANGIOPLASTY

The traditional indications for infrapopliteal angioplasty have been ischemic rest pain, ischemic ulceration, or gangrene (111). However, severe claudication that prevents minimal ambulation, and infrapopliteal angioplasty for use in patients with moderate to severe claudication to increase the durability and effectiveness of femoropopliteal PTA has been advocated by some investigators as acceptable indications (139). It is possible that with the advent of small-profile balloons, improvement in technique, and increased operator experience, the use of tibial angioplasty will not be limited to the previously mentioned indications, as it has been proposed (140).

Some centers have reported tibial angioplasty to be an integral component in the treatment of limb salvage, which has led to a dramatic decrease in the amputation rate (141),(142). Dorros et al. (140) reported their results of below-knee angioplasty in 111 patients and 168 tibioperoneal vessels. The indications were claudication (42%), nonhealing ulcer/gangrene (27%), and rest pain (26%). The procedural success was 90% (99% in stenoses and 65% in occlusions). Significant complications (death, emergent bypass surgery, or distal embolization) occurred in 3%. At discharge 95% of the patients were clinically improved. At a mean follow-up of 9 ± 6 months, 40% needed a second PTA; however, only a third of those that required a second PTA showed lesion recurrence, with the rest showing progression of disease. Hanna et al. (143) reported their results of infrapopliteal PTA for limb salvage in 29 diabetic patients. Technical success (<20% residual stenosis) was achieved in 26 patients (90%), and clinical success (avoidance of amputation and achievement of wound healing) at 12-month follow-up was obtained in 23 patients (79%).

Balloon angioplasty of the infrapopliteal vessels is an effective technique for treating patients with distal atherosclerotic occlusive disease. It has been utilized mainly in patients with limb-threatening ischemia and multisegment disease. Appropriate anatomic selection is a key factor to maximize the benefit of the technique.

Case 18

A 68-year-old man with a 100-pack-per-year smoking history presented with a nonhealing ulcer of the second digit on his right lower extremity. He denied trauma to this extremity. He had a history of severe coronary artery disease and peripheral vascular disease, and had undergone bilateral SFA angioplasty 7 years earlier for symptom-limiting claudication. At that time, he had an 80% stenosis of his right tibioperoneal trunk, but this was not treated because his claudication was relieved by treatment of the SFA lesions alone. His ABI was 0.4 on the right, 0.8 on the left. Left common femoral access was obtained and a pigtail catheter was used to perform bilateral aortography and runoff using digital subtraction and a stepping table. Selective right lower extremity angiography was performed from the contralateral access using an IMA catheter and a glidewire, demonstrating critical stenosis in the tibioperoneal trunk and severe stenosis in the right posterior tibial artery with occlusion of the peroneal and anterior tibial vessels (Fig. 35.18A). The IMA catheter was exchanged over an extra-stiff wire for a 6F multipurpose coronary guiding catheter that was advanced to the midpopliteal artery. The lesions were crossed and dilated using a 0.014-inch extra-support wire and a 3.0-× 40-mm coronary balloon. Provisional stenting was performed on the lesion at the tibioperoneal trunk because of a suboptimal balloon result (Fig. 35.18B). The posterior tibial vessel was treated with angioplasty alone. The patient was discharged on aspirin, clopidogrel, and ciprofloxacin and follow-up at weekly intervals until he had complete healing of his ulcer. His ABI improved to 0.9 on the right.

FIG. 35.18.

A: Critical stenosis in the right tibioperoneal trunk (arrow) and posterior tibial artery in a patient with critical limb
ischemia. The anterior tibial and peroneal vessels are occluded. B: After stenting of the tibioperoneal trunk and balloon angioplasty of the posterior tibial artery there is straight-line flow to the foot with a palpable pulse.

Illustrative points

The primary indication for tibial angioplasty in chronic lower extremity ischemia is critical limb ischemia, defined as rest pain, nonhealing ulcers, or gangrene. As this case demonstrates, critical limb ischemia requires stenosis or occlusion of all three infrapopliteal vessels, unlike coronary artery disease, where single-vessel involvement can cause severe symptoms or even death. In some centers with excellent results, tibial intervention is also offered to patients with severe claudication, but this is not the norm. Typically, claudication improves with treatment of the proximal stenoses (i.e., iliac and femoral) even in the presence of untreated severe tibial disease, as was illustrated by this man's course 7 years earlier. Once critical limb ischemia is present, the interventionist and surgeon both attempt to provide pulsatile flow to the extremity since the chances of healing are very low in the absence of pulsatile flow. The introduction of low-profile coronary systems into the periphery has greatly improved the success rate of infrapopliteal intervention. Stenting is not performed routinely in these lesions, but a prudent strategy of provisional stenting with antiplatelet therapy appears beneficial in cases such as this one. The surgical procedure of choice for critical limb ischemia is a distal vein bypass, which has a limb salvage rate of 70%, but a 5-year patency of less that 50%. The important goal here is to heal the ulcer; restenosis, if it occurs, may in fact be asymptomatic and may not require treatment.