Atherosclerosis is a systemic disease affecting quality and length of life. Endovascular revascularization can be used to improve quality of life. The benefit is greatest in patients with subclavian, renal, or iliac artery symptomatic disease. The advent of stents improves the initial technical success rates of angioplasty to more than 90% in most locations. The development of stent: grafts has altered the treatment of abdominal aortic aneurysms and should be strongly considered as an alternative to open surgery.

(Key words: peripheral arterial disease, percutaneous transluminal angioplasty, stents, aneurysm, stent: graft)

Endovascular therapy for peripheral arterial disease is rapidly evolving. Balloon technology (percutaneous balloon angioplasty, percutaneous transluminal angioplasty [PTA]) has improved along with guidewires, sheaths, and guide catheters to enable application in the carotid, innominate, subclavian, aortic, mesenteric, renal, iliac, femoral, and tibial arteries. Research activities are exploring the ancillary use of stents, stent: grafts, excimer-laser light, and new thrombectomy/thrombolysis systems. Endovascular therapy is complementary to traditional surgery and can be useful to many patients. This article outlines current endovascular care organized according to anatomic problem and focusing on the most common endovascular approach (PTA and stents).

Atherosclerotic occlusive disease iliac, femoral, and tibial artery disease
The utility of revascularization is to improve on the clinical symptoms of intermittent claudication, resolve ischemic rest pain, or to heal ischemic ulceration. Generalizations about the clinical efficacy of PTA can be made. Patients with isolated iliac disease benefit the most with intervention by improving their maximal treadmill walking distance 230%. Patients with isolated superficial disease improve 165%. Patients with multilevel (iliac and superficial femoral artery [SFA]) disease are more limited in their walking distance both before and after intervention. With treatment of the iliac lesion and not the SFA lesion, maximal walking distance improves by only 64%. Resolution of ischemic rest pain or ulceration with PTA is dependent on the ability to correct the inflow lesion into an intact outflow bed. The goal of treatment should be to resolve these ischemic symptoms without creating new morbidity.

Isolated lesions of the aortoiliac segment cause intermittent claudication of the calf, thigh, and buttock regions, and they can cause impotence in men. The lesions occur typically at the aortic bifurcation, with disease extending into the origin of each common iliac artery. Stenoses are more common than occlusions by a 4:1 ratio. The most complex lesions are considered to be occlusions greater than 5 cm in length or lesions adjacent to an aneurysm. Lesions of the iliac arteries are usually amenable to endovascular treatment because they are large (7 mm to 12 mm) with good shear forces due to high flow.

Percutaneous balloon angioplasty has been used for years with reasonable results (Table 1). Most operators use stents with all iliac artery interventions. The data supporting primary stenting is nonrandomized and comparative, suggesting at least an 85% patency rate at 24 months (Figure 1). The relative risk of long-term failure was reduced 39% after stent placement compared with that after PTA. Stenting of significant residual stenoses after PTA, dissection flaps, chronic occlusions, and restenotic or complex lesions are well-accepted indications. Patients at greatest risk of early failure are those with isolated external iliac artery disease that extends to the common femoral artery. These patients, particularly female, tend to be young (<50 years old), with a significant smoking history.

The complications with this procedure are generally associated with blood loss at the access site, hematoma, or pseudoaneurysm formation with a 14% occurrence rate. Vessel rupture, embolization, or dissection occurs infrequently with primary stenting. The use of arteriotomy closure devices has lowered the incidence of access site complications while facilitating outpatient care. If in-stent restenosis occurs, then subsequent PTA with or without stenting can reestablish anatomical patency. The infrequency of this problem is attributable to the large poststenotic lumen that is achieved. Traditional bypass surgery carries higher procedural risks. Therefore, endovascular therapy should be the initial offering to most patients with aortoiliac occlusive disease because of its low risk-to-benefit ratio.

Femoropopliteal disease is more common than iliac disease. Symptomatic patients have occlusions of the SFA. These occlusions are long, with only 9% being less than 5 cm in length. Stenoses of the SFA are typically short, with 79% being less than 5 cm. Consequently, short stenoses thrombose, producing long occlusions that are thrombus rather than plaque dominant. The length of the lesion predicts the early success of PTA. The integrity of the run-off predicts long-term success. Stand-alone PTA for long-segment (>10 cm) SFA disease has poor durability (Figure 2). Stenting of these long lesions improves initial technical success but fails to improve the long-term durability. Research efforts with laser-light-assisted PTA or thrombolysis/thrombectomy devices focus on removal of the coexisting thrombus by changing the long occlusion into a short stenosis. Excimer-laser (308 nm) light resolves chronic thrombus and plaque without producing thermal injury. Percutaneous transluminal angioplasty after laser therapy can produce an excel-
lent channel without a stent. Within the first year after the initial procedure, restenosis usually occurs in a focal location. A second PTA with or without a stent procedure can then be done on this focal area, thereby maintaining secondary patency rates of 75%. This strategy requires frequent follow-up with noninvasive studies but maximizes the benefit of PTA while limiting the reflex use of stents. The use of stent: grafts seems attractive from early research, but patency is dependent on achieving large lumens (>6 mm). Brachytherapy (post-PTA radiation) is being studied in SFA disease. Conclusions as to its effectiveness in preventing intimal hyperplasia are lacking. It has been shown to improve restenosis rates for coronary in-stent restenosis. Directional or rotational atherectomy has not improved outcome.

Complications are more common with SFA intervention, probably because the lesions are long and occluded. Vessel rupture, embolization, and worsening leg ischemia occur in only about 7%, but nonimprovement in symptoms can occur in 25% to 30%. Endovascular treatment is best rendered early in the disease course with shorter lesions. Surgical bypass works well when good vein is available and the inflow/outflow is well preserved.

Isolated tibial artery disease that is symptomatic is unusual, except in diabetics and immunosuppressed patients. The application of coronary artery techniques (small balloon and wires) improves accessibility and initial technical success rates, particularly in noncalcified arteries. Unfortunately, these vessels are frequently calcified, not allowing PTA to easily stretch the vessel wall. Complex lesions would consist of any lesion longer than 4 cm and carry the worst prognosis with PTA. Debulking techniques with use of rotational atherectomy or laser-light energy can offer an endovascular alternative. The new low-profile balloon-expandable stents are deliverable but may be prone to external compression in this location, thus limiting utility. Amputation-free survival rates at 1 year are 76%, with complication rates around 22%. Treatment should be limited to patients who lack surgical alternatives and have limb-threatening ischemia. Patients with intermittent claudication with disease in this location are best treated conservatively.

Renal and mesenteric arteries
Aortic atherosclerosis can proliferate into the origin of the visceral arteries, produc-
ing stenosis. The stenosis reduces volume flow, inducing a resting pressure gradient. In patients with renal artery disease, the gradient causes the production of renin. A renin-mediated hypertension can result (renovascular hypertension) with unilateral disease. The normal contralateral kidney can compensate by increasing filtration to maintain normal volume and serum creatinine levels. In patients with bilateral renal artery stenosis (RAS), the hypertension is volume mediated and can result in azotemia and possibly congestive heart failure (CHF). The indications to treat RAS include renovascular hypertension, azotemia caused by RAS, or patients with CHF based on ischemic nephropathy. Renal parenchyma preservation is mentioned frequently as an indication to treat RAS but should be reserved for severe stenoses.5

Renal arteries are usually 5 mm to 7 mm in diameter and the kidney normally has low-residence flow. Atherosclerosis is the predominant underlying disease, but fibromuscular dysplasia should be considered in younger (<30 years old) hypertensive patients. Endovascular treatment with PTA works well for the small number of patients with fibromuscular dysplasia, but not atherosclerotic RAS. Restenosis is seen angiographically in at least 50% at 1 year, probably as a result of aortic plaque recoil.5 Primary stenting seems the most logical endovascular approach to prevent recoil (Figure 2). Initial technical success rates of 98% can be achieved, with 3-year patency rates of 74%.5 When restenosis occurs it is usually within the stent. Repeated PTA/stenting has been the Cleveland Clinic Foundation Department of Vascular Medicine’s approach to this problem with assisted patency rates of 95%. Balloon-expandable stents should be used in this location because self-expanding stents do not redilate well if restenosis should occur. Acute closure or dissection of a stented renal artery is rare.

Hypertension can be expected to improve in 50% to 60% of patients. Those with a recent onset or change in their hypertension (<5 years) or who have severe unilateral RAS to a greater than 8-cm kidney have the best prognosis. Azotemia improves or remains stable after PTA/stenting in most, with worsening in 25%. The main causes for worsening function includes contrast-induced nephropathy (CIN), atheroembolism, and progressive glomerular disease. Contrast-induced nephropathy occurs more frequently in those with elevated preprocedural serum creatinine levels. Using carbon dioxide or gadolinium can lower CIN by minimizing the volume of contrast. Prophylactic measures also include the use of preprocedural hydration, fenoldopam mesylate, dopamine, atrial natriuretic factor, calcium channel blocker, mannitol, or furosemide, either singly or in combination.7 Atheroembolic protection devices may have utility in high-risk patients but are unstudied to date.

Chronic mesenteric ischemia occurs when at least two of the mesenteric vessels (celiac artery, superior mesenteric artery, inferior mesenteric artery) are involved with disease. Symptoms include postprandial abdominal pain (92%) and weight loss (87%).4 The abdominal pain or angina begins about 20 minutes after eating. Patients avoid eating or eat small frequent meals to maintain some nutrition.

Noninvasive testing with duplex ultrasonography, contrast computed tomographic angiography, or magnetic resonance angiography can be done to screen for this infrequent clinical problem. Diagnostic angiography of the aorta in the anteroposterior and lateral projections is necessary before planned repair. Selective artery catheterization for pressure gradient assessment augmented with vasodilators may be necessary to fully exclude significant disease.

The surgical procedure to correct this problem is difficult on these malnourished patients and carries an operative mortality rate of 8%.8 Surgical bypass has a distinct advantage for occluded arteries, allowing for more complete revascularization. Primary stenting is the most appropriate endovascular approach because the disease mirrors that seen in the renal arteries (Figure 3). Revascularization of as many involved arteries is important, because recurrent symptoms are seen in 34% of patients treated by endovascularly compared with 13% of surgically treated patients.9 Endovascular revascularization can also be used as a bridge procedure, allowing the patient to recover nutritional integrity before undergoing a more definitive bypass procedure. Technically, these lesions may need to be approached from the axillary or brachial artery rather than the femoral artery because of the caudal or ptotic angle of the celiac artery or the SMA. Complications and recurrence rates are similar to those with RAS, with a higher risk of death associated with technical failures.9

Subclavian, innominate, common carotid artery disease

The aortic arch and its branches are an excellent example of the typical pattern of atherosclerotic disease. It occurs at vessel’s origin and branch points with a rough, irregular lumen. In contrast, vasculitis will appear as long areas of smooth narrowing in the mid-portion of the arteries.

Asymptomatic innominate/subclavian disease can be detected as a blood pressure discrepancy between each arm or as a carotid/subclavian bruit. When symp-
paring favorably with surgery.11 With 3-year patency rates of 84%, com-
traversing these lesions. Stents improve
be taken not to dissect into the aorta when
visualization of the vertebral artery
through the long sheath, thereby avoiding
the brachial approach allows excellent
symptoms associated with
arteries.

Surgical treatment of aortic arch dis-
se using a transthoracic endartectomy or
bypass carried a high mortality (up to
22%) rate. Carotid-subclavian bypass
became popular, reducing the mortality to
5.6%. These bypasses were quite durable, with patency rates to 92% at 5 years.10
Angioplasty success rates of 43% to
100% were reported, with at least a 20% restenosis rate. Occlusions carry the highest technical failure rate, and care should be taken not to dissect into the aorta when traversing these lesions. Stents improve the initial technical success rate to 94% with 3-year patency rates of 84%, comparing favorably with surgery.11
Approaching the subclavian lesion from the brachial approach allows excellent visualization of the vertebral artery through the long sheath, thereby avoiding inadvertent coverage (Figure 5).
The direction of flow in the vertebral artery is important. With significant innominate/subclavian disease, it is retrograde or toward the arm rather than the brain. The reestablishment of antegrade flow in the vertebral artery is delayed for seconds after correction of the inflow lesion.12 Emboli before the reversal would therefore go down the arm. Primary stenting allows for the entire procedure to be completed before the reversal of flow in the vertebral artery, thereby avoiding the feared risk of stroke. In our series of 84 patients treated with primary stenting for atherosclerotic disease, no strokes were encountered unless combined with carotid endarterectomy.11

Abdominal aortic aneurysm
The abdominal aorta is the most frequent site for the development of an aneurysm. The suprarenal aorta is also involved in the aneurysm process in 5% of these patients. The term juxtarenal aneurysm is used for infrarenal aneurysms that require a suprarenal clamp to repair. Iliac, thoracic aorta, or popliteal involvement occurs in 25%, 10% to 12%, and 3% to 20%, respectively. The aneurysm configuration can be fusiform, saccular, or tici-like. Abdominal aortic aneurysm (AAA) can produce symptoms of distal embolization, compression on adjacent structures, thrombosis, or rupture. The most feared symptom of rupture leads to a prehospital death rate of 30% to 50%; 30% to 40% also die who make it to the hospital but do not go to the operating room. Operative death rates range from 25% to 50%, producing an overall AAA rupture mortality of 80% to 90%. Therefore, elective repair before rupture is the advised approach to the care of these patients.

Table 2
Comparison of Open Surgery and Endovascular Repair of Abdominal Aortic Aneurysm17

<table>
<thead>
<tr>
<th>Factor</th>
<th>Endovascular repair</th>
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<th>P value</th>
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<tr>
<td>Procedure time, h</td>
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<td>3.6</td>
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<tr>
<td>Blood loss, mL</td>
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<tr>
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<td>4.0</td>
<td>.001</td>
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<tr>
<td>Length of stay, d</td>
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<td>3.4</td>
<td>.001</td>
</tr>
<tr>
<td>Mortality, %</td>
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<tr>
<td>Secondary procedure success rate, %</td>
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<tr>
<td>Abdominal aortic aneurysm exclusion rate at 30 days, %</td>
<td>91</td>
<td>100</td>
<td>.05</td>
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</table>

*NS = not statistically significant.

Figure 4. Symptoms associated with atherosclerotic disease of subclavian, innominate, common, and internal carotid arteries.

The medical risk factors for AAA rupture are increasing AAA diameter, hypertension with a widened pulse pressure, chronic obstructive pulmonary disease (COPD), smoking, and rapid expansion, shape, and configuration of the aneurysm. The presence of laminar thrombus within the AAA is not protective against rupture. According to Mitchell and colleagues,13 the rupture risk for AAA less than 4 cm is 0%; 4 cm to 5 cm, 0.5% to 5%; 5 cm to 6 cm, 3% to 15%; 6 cm to 7 cm, 10% to 20%; 7 cm to 8 cm, 20% to 40%; and greater than 8 cm, 30% to 50% at 1 year. Early repairs of small AAA (4.0 cm to 5.5 cm) do not benefit late survival as seen in the United Kingdom AAA surveillance trial,14 in which 1099 patients were randomly assigned to ultrasound surveillance or early operation. Those under surveillance went to surgery if they became symptomatic or if the aneurysm expanded to 5.5 cm. Ultimately, at a mean follow-up of 4.6 years, 61% of the surveillance group underwent surgery. The operative mortality was 5.8%, which offset the 25 patients in the surveillance group whose AAA ruptured. The overall survival rate at 6 years was 64% in each group. The study provides support for watchful waiting in patients with small AAAs. The Mayo Clinic also showed that patients who underwent AAA repair, whether small (62%) or large (60%), had a lower 5-year survival rate as
The ability to treat AAA with a traditional operation or with endovascular exclusion has made patient selection difficult. Endovascular exclusion can be done with a shorter operation with less blood loss, ventilator support, and intensive care unit and hospital stays (Table 2). As education of the general public increases, patient demand for this technology increases. Two questions need to be asked:

- Is surgery indicated?
- Is endovascular exclusion an option?

The indication for surgery must consider the rupture risk and operative risk. The operative risk includes age and cardiac, pulmonary, and renal comorbid factors. A patient younger than 75 years with no comorbidities should have an operative risk of less than 1%. In patients 75 to 80 years old with a left ventricular ejection fraction (LVEF) of 30% to 50%, serum creatinine level of less than 2.0 mg/dL, or mild COPD, singly or in combination, should carry an operative mortality of 1% to 3%. In patients 80 to 90 years old with an LVEF of 20% to 30%, moderate COPD, serum creatinine level of 2.0 to 3.5 mg/dL, operative mortality is 3% to 8%. For patients older than 90 years with an LVEF less than 20%, severe COPD, or serum creatinine level greater than 3.5 mg/dL, singly or in combination, mortality is up to 30%. The relative risk ratio is greatest for patients with serum creatinine elevation, followed by symptoms of CHF or ischemia, then COPD, older age, and female gender. The operative mortality also differs according to the medical center and surgical experience.

To consider endovascular exclusion of an AAA, the aortic neck needs to be at least 10 mm in length with a diameter of less than 30 mm (Figure 6). The neck should not be conical (>3 mm/10 mm) or significantly angulated (>60 degrees). The neck should be free of arteriosclerosis obliterans or thrombus. The iliac arteries need to be at least 6 mm in diameter for smaller devices (AneuRx, Talent, Ancure). As the iliac arteries become more tortuous and calcified, the ability to access the AAA via the common femoral artery becomes more difficult. Patent lumbar or inferior mesenteric arteries have not been a contraindication to stent; grafting.

The most frequent problem with stent; grafting is the incomplete exclusion of the aneurysm. Persistent leaks occur (~15% at 1 year) and have been classified into different types.16 Type 1 leaks occur when blood enters the aneurysm sac at an attachment site (either proximally or distally). Retrograde filling of the sac via a patent lumbar artery or the inferior mesenteric artery causes type 2 leaks. Defective fabric in the graft causes type 3 leaks. Expansion of an AAA without a demonstrable leak is thought to be due to persistent endotension, and such leaks are classified as type 4 leaks. The treatment of leaks remains controversial. Most agree with the prompt treatment of type 1 or 3 leaks or if the AAA enlarges. If the AAA remains pulsatile on physical examination, an exhaustive search for a leak should be made. Rupture of the AAA after AneuRx stent; grafting is uncommon, with an incidence of 0.28% (10 ruptures in 3524 patients receiving implants).17,18 Morphologic changes of the aorta and aneurysm sac can lead to late leaks necessitating regular and consistent follow-up.

Comment
There is increasing evidence as to the effectiveness of endovascular therapy for peripheral arterial disease. The advancement of technology allows application in a wide variety of clinical conditions. These procedures are not exclusive of traditional surgical treatment and need to be applied on a case-specific basis. Physician awareness of the advances in this field is paramount to provide state-of-the-art care.

References


