

Atherosclerotic Vascular Disease Conference Writing Group VI: Revascularization

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Revascularization has changed dramatically over the last 2 decades, with the use of percutaneous interventional techniques both replacing much of what was done with open surgery and increasing the number of patients with noncoronary atherosclerotic disease who are treated. Despite major advances, many questions remain, partly because of the continuing evolution of tools and techniques and partly because of the paucity of large prospective randomized trials. This section reviews recent advances, addresses areas of concern, and focuses primarily on the current status of catheter-based vascular interventions for atherosclerotic vascular diseases.

Aortic Diseases

Thoracic disease and abdominal aortic disease are distinct yet related disorders. In the context of this discussion, vascular intervention is relevant to thoracic aortic aneurysms (TAAs), dissection and trauma, and abdominal aortic aneurysms (AAAs). Revascularization of aortic occlusive disease is discussed later in conjunction with peripheral artery revascularization.

AAAs are far more common than TAAs. The reported incidence depends on the method of surveillance and the specific population, but it is estimated that 5% of men >65 years of age have small, asymptomatic AAAs. The incidence is greater in men than women, and >90% of persons with AAA have a long history of tobacco abuse.¹ A more detailed discussion of the etiology and natural history of AAAs is provided elsewhere in this document. The risk of rupture is minimal for aneurysms with a diameter <4 cm. Conversely, for aneurysms >6 cm in diameter, the annual rupture risk is >25%.² A rapid increase in size is the best predictor of

rupture risk. The conundrum of whom to treat centers on patients with aneurysms in the range of 5 to 5.5 cm.

The current status of aortic endografts must be considered in the context of open surgical repair of AAA. Open surgical graft placement has been the standard therapy for AAAs that are 5 to 5.5 cm or larger. Endovascular graft placement for AAA was first reported in 1991. Since then, there has been rapid evolution and use of endovascular grafts for AAA. The focus of development has been making the devices smaller, easier to place, and more durable, effective, and safe. AAA endovascular repair devices are stents connected by graft material, which are implanted superior to an infrarenal AAA and below the distal extension of the aneurysm. This means placing the cephalic-most stent just below or sometimes across the renal arteries and the caudal end in the distal aorta, common iliac arteries, or external iliac arteries, depending on the extent of the aneurysm. If the main renal arteries are covered, the graft material must start just below them, rather than covering the entire cephalic portion of the stent. Newer, low-profile devices can be implanted percutaneously under local anesthesia by use of predelivery sheath placement of percutaneously delivered arterial closure sutures.

Once operators have advanced beyond a significant learning curve, early results have shown 95% to 100% success rate in implantation, 1% to 2% 30-day mortality rate, and 0% to 1.5% conversion rate to open repair at the time of placement or by 30 days.^{3,4} Large studies with 4 to 5 years of follow-up after placement have reported survival of ≈75% to 85%, need for a second procedure of ≈10% to 20%, and rupture rate of 0.4% to 1.0%.⁵⁻⁷ The incidence of endovascular leaks at 1 year ranges from 17% to 31% and may vary among the different devices. Thus, it remains imperative to continue at least annual follow-up with abdominal contrast CT studies to

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ensure that late endoleaks are detected (if they occur) and that the aneurysm size is stable or shrinking after endograft placement.

Studies reported to date have made several salient observations. First, compared with open repair, endovascular repair has comparable 30-day and 1-year survival rates, similar rupture-free survival, and lower total, bowel, and renal complication rates that persist for 2 to 3 years.^{2-4,8,9} Second, endovascular repair has early advantages in length of stay and quality of life, but they diminish or are lost by 2 to 3 years because of late device failures and the need for reintervention. Third, there is no clear cost advantage to endovascular repair, despite decreased length of stay, because of procedure-related complications and long-term frequency of reintervention. Fourth, the rupture rate with endovascular grafts is comparable to that of untreated 5-cm AAA. Overall, questions remain regarding technical aspects of the devices, late complications and failures, overall cost-benefit ratio, and identification of appropriate patients.

The incidence of TAAs is estimated to be 8 to 12 per 100 000 person-years but increasing. Currently, only patients with TAA distal to the great vessels are candidates for endovascular repair, although this is expected to change as device technology evolves. The first endovascular repair was reported in 1991, and the first series was described in 1994.^{8,10} Numerous devices are under clinical investigation, but none have been approved by the US Food and Drug Administration. Current devices are similar to AAA devices, consisting of graft material that is tubular, tapered, and supported by metallic stents, generally over its entire length. There is now extensive clinical experience at a number of centers. A review of series of ≥ 40 patients who underwent TAA endografting noted procedural mortality of 0% to 4%, $>98\%$ technical success, and 30-day aneurysm thrombosis of 90% to 100%.¹¹ Paraplegia occurred in 0% to 1.8%, stroke in 0% to 2.8%, late migration in 1% to 2%, and breakage in 10% to 30%.

Other device- and procedure-related problems have emerged. The initially calculated forces exerted on stent-supported grafts, because of the span of aorta covered, pulsatile expansion, aortic curvature and tapering geometry, were grossly underestimated. Consequently, late device-related structural failures have occurred with greater frequency than with infrarenal AAA endovascular repair.^{10,11} Devices must be adapted to cover 20 to 40 cm of an aorta that is often tortuous. Also, both ends must seal effectively, which requires a variably tapered design. Long-term integrity of the graft material and, more problematically, the metal supports is imperative yet difficult to achieve. Long-term success of TAA endografts also may be hampered by problems related to progressive atherosclerotic and degenerative changes throughout the aorta. Ectasia, dilatation, and aneurysm formation may occur at different rates and in various segments of the thoracic and abdominal aortas. This may lead to undermining of a device, loss of attachment, leak, rapid aneurysm expansion, rupture, or stent-graft migration. These specific problems are less important for open repair. Clearly, both technical and procedural concerns are major, but lower mortality and complication rates (particularly paraplegia)

offer considerable theoretical benefits compared with open repair or medical management.

Type A dissections, involving the ascending aorta, represent $\approx 60\%$ of all thoracic aortic dissections, and type B dissections, confined to the aorta distal to the great vessels, represent 40%. Dealing with either type is made both more difficult and often more emergent when branch vessel involvement occurs (because of compromised distal perfusion). As discussed earlier, surgical repair of type A dissection is associated with lower mortality rates than medical management. With type B dissection, mortality rate with medical management is lower than with surgical repair, but there is a 30% to 50% likelihood of developing an aneurysm by 4 years.¹² Thus, there is a potential role for stent-graft placement for both types of dissection. The primary goals of endograft intervention are obliteration of the entry tear, thrombosis of the false lumen (to prevent aneurysm formation and rupture), and relief of visceral, renal, or extremity ischemia if present as a result of true lumen obliteration. Devices used for endovascular repair of aortic dissection are the same as those used for TAA. To date, results are limited, and mortality rates range from 0% to 16%.^{13,14} Obliteration of the entry tear occurs in 90% to 95%, acute branch vessel improvement in 82%, increase in lumen size in 98% to 100%, and thrombosis with progressive shrinkage of the false lumen in 80% to 100% of cases.^{15,16}

The experience with stent-graft repair of aortic dissections is, then, limited and largely confined to type B dissections. Uncertainty remains regarding long-term outcomes, the incidence of complications, the role in chronic versus acute dissections, and even the timing (and advantages) of endovascular repair of acute dissections. Two additional pathological processes in the thoracic aorta are discussed earlier in this report: penetrating ulcers and intramural hematomas. Either can progress to a dissection, although with neither is this inevitable. Whether percutaneous treatment will be indicated for either of these entities remains to be determined.

Atherosclerotic Renal Artery Stenosis

There are 3 important areas of concern to be addressed regarding the treatment of atherosclerotic disease involving the renal arteries. First, the true incidence of hemodynamically or physiologically significant renal artery stenosis (RAS) is not known. Second, it is not yet clear which patients will benefit from revascularization compared with medical therapy. Third, optimal technical approaches remain controversial.

Although it is generally accepted that RAS is the most common correctable cause of hypertension, its true incidence in the general population is unknown. It is estimated that RAS is the cause or a major component of hypertension in 5% of all patients with hypertension and in 10% to 30% of hypertensive patients with known or suspected atherosclerotic cardiovascular disease in other arterial beds (coronary, cerebral, or peripheral).^{17,18} Furthermore, renovascular disease is the primary cause of renal insufficiency in $\approx 15\%$ of patients >50 years of age who develop end-stage renal disease.¹⁹

As discussed earlier by Writing Group V, revascularization often leads to improvement or cure of patients with poorly

controlled hypertension and renal artery stenosis. Percutaneous revascularization has largely supplanted the surgical approach.^{20–22} The former is associated with a lower incidence of adverse events, equivalent outcome in terms of control of hypertension, and improved cost-effectiveness compared with surgery. For certain subsets of patients, however, controversy remains about the superiority of percutaneous revascularization compared with optimal medical therapy. The classic indication for renal revascularization has been “uncontrolled hypertension.” While it remains an important indication, with the availability of modern medications (including ACE inhibitors and angiotensin receptor blockers), uncontrolled hypertension is decreasing in incidence. The most important question that must be answered, then, is whether mechanical correction of RAS confers advantages over medical control.

Much of the skepticism regarding angioplasty or stenting for RAS was generated by the Dutch Renal Artery Stenosis Intervention Cooperative Study (DRASTIC), a prospective randomized study of medical therapy versus percutaneous transluminal angioplasty (PTA) in 106 hypertensive patients.²³ This study concluded that PTA had no advantage over medical therapy, but it had several major flaws. The first was that state-of-the-art technology was not used. Stenting has been shown in several studies to have a lower incidence of restenosis than balloon angioplasty alone and therefore leads to superior results.^{24,25} Yet in this study, patients were primarily revascularized with balloon angioplasty alone, with stenting reserved for cases of acute angioplasty failure. Even with the caveat that DRASTIC did not use state-of-the-art therapy (stenting), renal artery occlusion occurred in 16% of the medically treated group and 0% of the angioplasty group, suggesting at least anatomical if not physiological superiority of the latter treatment, yet this was not included as a variable in the final analysis. Second, 44% of the patients assigned to the medical therapy group failed medical therapy by 3 months and were allowed to cross over and undergo balloon angioplasty. Analysis on an intention-to-treat basis failed to take this high crossover rate into consideration. Considering the 44% crossover rate and the 16% occlusion rate in the medical group, medical therapy failed in at least 60% of patients assigned to that strategy. Finally, there was a trend toward better blood pressure control in the revascularization group, yet the study was not sufficiently large to detect whether this difference was significant.

When this and other studies are taken into consideration, it is apparent that revascularization with stent-assisted angioplasty should be considered when hypertension and significant RAS exist, particularly when hypertension is not completely controlled with medication (because of an inadequate medication regime, intolerance of medications, or noncompliance). Furthermore, renal angioplasty or stenting diminishes or eliminates the hyper-reninemic state, a theoretical advantage in mortality and morbidity over medication alone. Clinical trials to confirm this hypothetical advantage are required.

Two additional special patient populations are thought to benefit from revascularization: those with episodic left ventricular dysfunction related to hypertension (ie, flash pulmo-

nary edema) and RAS, and those with renal failure. Patients with flash pulmonary edema related to renovascular disease usually have bilateral RAS or significant stenosis (or occlusion) of a solitary renal artery. Although not well documented in clinical trials, such patients generally benefit from angioplasty or stenting. Revascularization for patients with RAS and compromised renal function is undertaken to stabilize and occasionally improve renal function. Unless there has been acute renal failure related to renal artery disease (eg, ruptured plaque leading to severe stenosis in a solitary kidney), renal function generally does not return to normal. Studies suggest, however, that revascularization prevents or slows the rate of worsening of renal function.^{26,27} This is important because RAS is progressive in $\approx 50\%$ of patients over 5 years.²⁸ The prognosis of patients with RAS as the cause of end-stage renal disease is very poor, with 5-year mortality rates of $\approx 80\%$.^{29,30}

Several studies have shown that stent placement for RAS is superior to PTA alone because of a better acute hemodynamic result and a lower restenosis rate.^{24,25,31–34} This is particularly important in regard to ostial stenoses, which are the predominant lesions in the atherosclerotic population. Most such lesions are the result of plaque that involves or originates in the aorta and extends into the renal artery rather than being confined to the renal artery itself.

Technical issues that need to be addressed include the characteristics of the stent that optimizes long-term outcome, ie, the type of metal (steel alloy versus Nitinol [nickel-titanium alloy] versus platinum), design (pattern, area of metal versus open space, strut thickness), hoop strength, and flexibility. With the demonstration that drug-eluting stents coated with sirolimus or with a taxol derivative are associated with dramatically lower restenosis rates in treatment of coronary artery stenosis, it is likely that such stents will emerge as the standard of care in renal arteries.³⁵ However, the restenosis rate is lower in the renal arteries than coronary arteries; therefore, the potential benefits of drug-eluting renal artery stents must be assessed in a clinical trial. There is relatively little known about the role of ancillary medications to improve stent patency. The incidence of acute reocclusion after renal artery intervention is low, perhaps because the renal artery is a relatively large, high-flow vessel, so the use of adjunctive medications may be of less concern and importance than in the coronary circulation. Aspirin and heparin are routinely administered in association with renal stenting, but use of glycoprotein IIb/IIIa receptor antagonists is not widespread. Although clopidogrel is often used routinely before a procedure, the evidence supporting this practice is currently limited to use during coronary intervention studies.

Embolization into the renal vascular bed and elsewhere remains a major concern. In particular, the visceral circulation, pelvis, and lower extremities may be affected. At this time, it is not clear what effect distal protection devices will have; to date, the reported experience is favorable but limited.³⁶ Another concern with percutaneous renal artery revascularization is contrast nephrotoxicity, as occurs with radiocontrast administration in other situations. This problem has been addressed, albeit not conclusively, in several recent

studies. In 1 study, the use of iodixanol, a nonionic, dimeric, isotonic contrast agent, was shown to lower the incidence of contrast nephropathy.³⁷ *N*-acetyl cysteine has also been shown to decrease contrast nephrotoxicity in some studies, but was not helpful in others.^{38–40} Overall, it does appear to be of value.⁴¹ Further investigations are ongoing.

In summary, percutaneous renal revascularization with stenting is usually effective in improving (but rarely in curing) hypertension, in stabilizing renal failure in a substantial percentage of patients, and in eliminating recurrent cardiac events (ie, flash pulmonary edema) in patients with atherosclerotic RAS.

Carotid Artery Stenosis

Carotid artery stenosis secondary to atherosclerosis, as detailed elsewhere in this report, is relatively common and has a high association with strokes if left untreated. Two major multicenter trials—1 in symptomatic patients with $\geq 70\%$ stenosis, the North American Symptomatic Carotid Endarterectomy Trial (NASCET), and 1 in asymptomatic patients with $>60\%$ stenosis, the Asymptomatic Carotid Atherosclerosis Study (ACAS)—compared surgical carotid endarterectomy (CEA) with medical management. Both demonstrated a statistically significant decrease in the incidence of strokes in the distribution of the affected carotid artery.^{42,43} These studies were completed in the early 1990s. Major advances in the last decade in both medical therapy and percutaneous revascularization mandate reevaluation of the treatment of both symptomatic and asymptomatic carotid stenosis. Advances in the understanding of the pathophysiology of atherosclerotic plaque, diagnostic imaging, and medical therapy for carotid artery atherosclerosis are dealt with elsewhere in this report. The major issues in revascularization are improved identification of patients who are most likely to benefit from such an intervention, the role of carotid stenting versus CEA, and optimal technical approaches to carotid stenting and medical versus percutaneous outcomes.

Because the understanding of atherosclerosis has improved, it is logical to reevaluate the efficacy and role of medical therapy of carotid atherosclerosis versus revascularization. It is worth considering, in randomized, controlled, prospective clinical trials, that better control of blood pressure, use of statin therapy, and modification of other risk factors may allow stabilization and even regression of carotid plaque and may limit the relative benefits of revascularization.

It is also important to consider CEA versus percutaneous treatment. Some studies suggest that, in experienced hands, CEA and percutaneous carotid stenting may have equivalent success and complication rates. Combined perioperative mortality and major morbidity rates should be $<6\%$ for symptomatic patients and $<3\%$ for asymptomatic patients for percutaneous stenting, as for CEA.^{44,45} The first percutaneous treatment of carotid stenosis was angioplasty. In a notable randomized study of symptomatic patients, the outcome with angioplasty was equal to that with CEA.⁴⁶ Two trials with a large number of patients who underwent carotid stenting reported a stroke and death rate at 30 days of $\approx 6\%$ to 7% .^{46,47} Many early reports noted that a large percentage of the

patients included would not have met the strict enrollment criteria for NASCET, because of age >79 years, coexistent cardiac or renal disease, or active cancer. NASCET, however, also had strict criteria for severity of stenosis, and neither severity of stenosis nor specific inclusion/exclusion criteria are given in some of the reports. In these largely observational studies of carotid stenting, it is possible that the included patients had either more or fewer risk factors.

There have been some attempts to identify the groups most likely to benefit from percutaneous rather than surgical therapy. It is widely accepted that patients with restenosis after CEA and those with radiation-induced stenosis are at increased risk from surgery. It is reasonable to accept these 2 conditions as good indicators for stenting. A lower overall complication rate with stenting compared with CEA in these patients, however, can be conclusively demonstrated only with a well-controlled prospective study. Similarly, patients with contralateral carotid occlusion or coronary artery disease requiring coronary artery bypass surgery are at particularly high risk of CEA-associated adverse events. Observational information suggests that stenting has a lower incidence of adverse events in these groups.^{48,49} The importance of other hypothesized risk factors such as contralateral carotid stenosis, prior stroke, or renal dysfunction also deserves prospective evaluation.

The first randomized and controlled trial of carotid stent placement with embolic protection compared with CEA in patients at increased risk for surgery has been reported.⁵⁰ The Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (SAPPHIRE) trial was reported at the American Heart Association Scientific Sessions in 2002. Patients were evaluated by a team consisting of a neurologist, a surgeon, and an interventionalist. Consensus among the treatment team regarding randomization was achieved in 310 patients (stent in 159, CEA in 151). An additional 406 patients were refused surgery by the surgeon and were treated with a stent in a registry, whereas only 7 patients were refused by the interventionalist and treated with surgery. In the randomized patients, the combined end point (death, stroke, or myocardial infarction) at 30 days was 5.8% for the stent group and 12.6% for the CEA group ($P<0.05$). The 1-year follow-up data demonstrate a significant advantage for the combined end point in the carotid stent group at 11.9% compared with 19.9% for the CEA group ($P<0.05$).⁵¹

Strokes related to carotid artery lesions are generally embolic, in contrast to the acute occlusions that occur in the coronary arteries. Thus, there is concern about embolization caused by the intervention itself. Both symptomatic embolization and asymptomatic embolization have been documented with angioplasty and stent placement with a higher incidence than with CEA, leading to a general consensus that distal protection devices should be used.⁵² Data confirming the advantage of distal protection devices, however, are not yet conclusive. One recent study suggested that such devices protected against distal embolization but caused other complications; overall stroke and major morbidity rates were not significantly improved.⁵³ Although not yet approved specifically for carotid interventions, numerous devices are available, including filters designed to catch embolic material and

occlusion balloons to prevent distal flow of emboli and enable suction removal. All devices add cost and complexity. Therefore, prospective randomized studies to demonstrate their benefits are important.

Stenting of the carotid artery has a number of unique aspects. Risk of stroke related to this procedure is the major concern. This has led to evolution in technique and the use of ancillary medications that are largely the same as those used for stenting of the coronary arteries. A preprocedural and periprocedural antiplatelet regimen typically includes aspirin and clopidogrel on the basis of evidence derived from coronary stent trials. Heparin is administered during the procedure; however, the optimal level of anticoagulation is not known. With the availability of safe and effective arterial closure devices, it has become more practical to maintain a high activated partial thromboplastin time during and after the procedure. The poststenting antithrombotic regimen is not well defined, and it may not be as important as in other vascular beds because the incidence of acute reocclusion in the carotid artery is low. The incidence of (clinically relevant) restenosis also appears to be low.⁵⁴ The true incidence of restenosis, however, is not known. Such information is important because the incidence of clinically relevant restenosis after CEA is also low.⁵⁵

In summary, carotid stenosis is an important cause of stroke and is treatable. The treatment, however, clearly must have a positive risk-to-benefit ratio. A decade ago, studies demonstrated a clear advantage in certain populations of CEA compared with medical therapy. With the development of both improved medical therapy and less invasive percutaneous approaches over the last few years, some of the same questions must be addressed again.

Peripheral Artery Revascularization

Peripheral arterial disease is a significant cause of morbidity because it causes functional limitations that reduce walking ability, impair quality of life, and at times, threaten limb viability.⁵⁶ Percutaneous revascularization strategies are being used to improve symptoms of claudication and to salvage limbs. Considerable information is available regarding the safety and anatomical success of PTA and stents in patients with peripheral arterial disease. There is, however, a relative lack of data from appropriately sized prospective randomized, controlled clinical trials regarding the efficacy of revascularization compared with medical therapies to improve symptoms of claudication and to salvage limbs. Percutaneous revascularization techniques and outcomes vary among the major segments of the limb arteries. The following discussion addresses separately the distal abdominal aorta, iliac arteries, femoropopliteal arteries, and infrapopliteal arteries.

Occlusive disease of the abdominal aorta is relatively uncommon. Short aortic occlusions can often be traversed with a catheter and guidewire and then treated by thrombolysis, angioplasty, and stenting. When aortic occlusions extend from below the renal arteries into the iliac arteries, as is more frequently the case than short occlusions, surgical revascularization is recommended.⁵⁷ Abdominal aortic stenosis is encountered less frequently than complete occlusion and is more prevalent in women than men. There

are no prospective studies regarding its treatment. Open surgery with endarterectomy is one option; angioplasty with or without stent placement is another.

Overall, results of percutaneous revascularization of aortic occlusive disease appear to rival surgical treatment, with small series reporting patency rates of $\approx 80\%$ at 5 years.^{58,59} To date, there is no evidence that stent placement offers advantages over angioplasty alone. Outcome appears to depend substantially on the quality of the more distal vessels: the worse the distal runoff, the lower the patency. Also, because atherosclerosis is often progressive, patients with symptoms related to a proximal lesion often present subsequently with symptomatic lesions distal to the site of intervention.

The experience with iliac lesions is more extensive and better documented. Iliac occlusions and stenoses commonly present with claudication, which may involve the buttocks, thigh, calf, or all three. Initial presentation with rest pain is unusual. It is axiomatic that most patients with claudication do not progress to frank limb ischemia, although such progression can occur. Treatment is undertaken primarily for patient comfort (ie, "lifestyle-limiting claudication") and to facilitate an exercise program as ancillary treatment. In most patients, claudication will at least stabilize and sometimes improve with a supervised, graduated exercise program, so the potential risks and benefits of revascularization, whether percutaneous or surgical, must be carefully weighed. Any invasive treatment must have a high likelihood of success, low morbidity and mortality, and reasonable cost. Much of the available information regarding outcomes of percutaneous and surgical treatment for iliac artery occlusive disease is summarized in the report of the Trans-Atlantic Intersociety Consensus (TASC) on Peripheral Arterial Disease.⁵⁷ In general, surgical bypass is recommended for long, irregular iliac artery stenoses and long occlusions, whereas endovascular intervention is recommended for shorter stenoses and occlusions.^{57,58} Over the last 5 years, however, the percutaneous approach has been used increasingly, even for chronic occlusions. Adjunctive use of thrombolysis may uncover focal lesions that are treated more successfully than long ones, but it adds cost and morbidity. Dense calcification is a relative contraindication to percutaneous revascularization because of risk of rupture or distal embolization. Covered stents and a contralateral approach with distal protection devices may be applicable in this setting, although data are lacking.

Both PTA and stenting have been shown to have high initial success and good long-term patency in the iliac arteries. Patency after iliac PTA alone is $\approx 60\%$ to 80% at 4 to 5 years.^{59,60} Although patency is higher after surgical bypass (aortoiliac or aortofemoral bypass, depending on the length of the obstruction), cost and morbidity related to open surgical procedures are also greater. In many circumstances, particularly for focal lesions, it is safer and more cost-effective to perform and, if necessary, repeat percutaneous treatment than to perform bypass surgery. There has been an evolution to stent-assisted iliac artery angioplasty in preference to PTA alone, although the available data do not fully support this approach. Overall 1- and 3-year patency appears to be marginally better with iliac artery stenting than with

angioplasty alone.^{57,61} There is still a need, however, for large prospective randomized trials. In the absence of conclusive data, it is generally accepted that stenting is preferred for lesions longer than 2 cm. There is no real evidence to suggest that covered stents offer any particular advantages. At this time, their use is confined mostly to situations such as iliac rupture or leak after angioplasty or other trauma. Drug-eluting stents offer theoretical benefits, but in light of the good long-term patency achieved with angioplasty and bare metal stents, trials of drug-eluting stents in the iliac system are not a high priority.

In the femoropopliteal segment, data regarding long-term patency with surgical bypass are relatively good. The data for angioplasty are somewhat controversial but suggest a long-term primary patency of $\approx 70\%$ at 4 to 5 years for PTA of focal stenotic lesions.^{62,63} For occlusions and lesions >4 to 6 cm, angioplasty has generally had very low patency rates.⁶³ Studies examining the efficacy of stents in the femoropopliteal segment suggest that long-term patency is similar to and possibly worse than with PTA alone.⁶⁴ This may be due to extensive disease and poor distal runoff. Yet, a recent report on the use of a covered stent has been encouraging, with 78% 1-year and 74% 2-year patency.⁶⁵

Studies of brachytherapy for femoropopliteal occlusive disease have been encouraging, but the number of patients reported to date is small.^{66,67} Because drug-eluting stents have proved so successful in limiting restenosis in the coronary circulation, there is reason for optimism regarding their use in the femoropopliteal system. Only 1 small trial has been reported to date: 36 patients were treated with a drug-eluting stent in the superficial femoral artery. None had $>50\%$ restenosis at 6 months.⁶⁸ Other percutaneous technologies such as endarterectomy or application of cryotherapy have been proposed for treating femoropopliteal occlusive disease. Multiple stent designs have also been proposed. Given the relatively poor long-term patency in the femoropopliteal system with most percutaneous approaches and the small size of most prospective trials to date, it is imperative, perhaps more than in other arterial beds, that multicenter trials of promising approaches be performed. Also, it is important that clinical trials take selected risk factors such as diabetes into consideration because this disorder in particular is frequently associated with poorer outcome.

The relative efficacy of percutaneous versus surgical revascularization for infrapopliteal disease is even more difficult to determine. Several reports suggest that angioplasty, particularly for focal lesions, leads to good long-term patency and limb salvage.^{69–71} Prospective studies, are required to assess the appropriate role for PTA in the management of peripheral arterial disease affecting the tibial and peroneal arteries.

Recommendations

1. Aortic Diseases

- Define the role of surgery versus endovascular repair versus medical therapy in high-risk patients with >5.5 -cm AAA and in those with TAA.
- Monitor long-term outcomes with all devices compared with open repair. In conjunction, better define risk factor profiles and what constitutes high risk. Standardize data collection for trials and registries of new stent-grafts and other innovative technologies.
- Develop a broad-based registry for aortic dissection to examine predictors of aneurysmal dilatation of the false lumen; define technical success and long-term outcomes with new devices; and define the outcomes of minimally symptomatic dissection, penetrating ulcers, and chronic dissections.

2. RAS

- Fund appropriately sized studies to determine the outcomes (including effect on hypertension, development of end-stage renal disease, and incidence of cardiovascular events) and cost-effectiveness of medical therapy versus stenting in patients with RAS. Such studies should investigate patients with hypertension and patients with/without renal compromise.
- Conduct prospective randomized controlled trials to investigate distal protection devices and drug-eluting stents for endovascular treatment of RAS.
- Conduct studies to determine the importance of incidentally noted RAS. Elucidate the natural history of such lesions in patients who are normotensive and have normal renal function.
- Develop better imaging methods to allow more accurate and cost-effective identification of patients who will benefit from renal revascularization.
- Investigate means of decreasing the nephrotoxicity of contrast agents used in renal angiography and interventions.

3. Carotid Artery Stenosis

- Address the efficacy of optimal medical management versus revascularization for the treatment of both symptomatic and asymptomatic carotid artery disease.
- Complete prospective randomized trials comparing optimal carotid stenting with CEA. Define optimal techniques for carotid artery stenting through a series of controlled prospective trials.
- Establish appropriate training and credentialing guidelines.
- Investigate the long-term benefit of medical versus percutaneous treatment for carotid stenoses.

4. Peripheral Artery Revascularization

- Conduct large studies to define the benefits of medical treatment alone versus percutaneous treatment plus risk factor modification for both symptomatic and asymptomatic disease of the distal aorta and infrapopliteal arteries.
- Define optimal technical approaches in rigorous clinical trials.
- Investigate the role of tools that are now routinely used in the coronary system, including drug-eluting stents, distal protection devices, and ancillary medications such as

clopidogrel and platelet glycoprotein IIb/IIIa receptor antagonists, in the lower extremities.

- Establish and standardize outcome measures, including effect of therapy on functional capacity, quality of life, economic status, overall cardiovascular health and mortality, and other relevant factors.
- Undertake a prospective evaluation of PTA compared with conventional surgery for treatment of infrapopliteal disease.
- Emphasize the role of the multidisciplinary approach to the treatment of limb-threatening ischemia.

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