The past year has been one of significant activity in vascular surgery, on the organizational, clinical, and research levels. Perhaps the most significant development of the year was the decision by the two major national vascular societies, the Society for Vascular Surgery and the American Association for Vascular Surgery (AAVS), to combine to form one organization with a coordinated strategic plan to enhance development of the specialty of vascular surgery in the future. This effort, which was led by the executive leadership of the two societies, was ratified by the membership at the conjoined annual meeting in June 2003. The resulting merged society, which will retain the name of the Society for Vascular Surgery, has moved its executive offices to Chicago in the building owned by the American College of Surgeons. This was done to provide a greater focus for the new Society (SVS) and to enhance the relationship between vascular surgery and the American College of Surgeons.

The newly reorganized SVS will focus on advancing excellence and innovation in vascular health and reinforcing the position of vascular surgeons as leaders in vascular health care. The SVS has established six critical strategic initiatives for implementation over the next 2 years: modification and improvement of the current training paradigm in vascular surgery, enhancement of educational programs in vascular disease, strengthening communication between vascular surgery and government at all levels, increasing public awareness of vascular disease and the role of vascular surgeons in improving vascular health, improving communications between the vascular surgical community and industry, and merging the foundations of the two organizations. This proactive approach is designed to position the community of vascular surgeons for success and growth over the next decade.

In the past year a political action committee has been established by the SVS to enhance communication with legislators at local, regional, and national levels. Activities of the current Government Relations Committee helped to reverse the proposed cut in reimbursement by CMS for the year 2003 and supported the recent Medicare bill that reversed proposed cuts in reimbursement for 2004. There will be a modest gain, as a result, in reimbursement for vascular codes in 2004. Efforts are also underway to increase public awareness of vascular disease and to promote screening of high-risk groups of the Medicare population for both carotid stenosis and abdominal aortic aneurysm.

In addition to these sociopolitical developments, there have been a number of specific advances in vascular research and clinical care. These will be summarized briefly in this article.

Developments in vascular disease: high-risk groups, risk-factor reduction, and general medical therapy
Vascular surgeons have traditionally managed both medical and surgical vascular disease. The field of vascular medicine includes identification of patients at high risk, and risk-factor reduction has become increasingly important over the last decade. The dawn of the genomic era has prompted a search for genetic polymorphisms that could be used to predict the risk of future cardiovascular events. Over the past year, publications have focused on genomic analysis of patients with myocardial infarction, stroke, and hypertension. In a study from the University of Pittsburgh, Kibbe and colleagues demonstrated that screening for the methylene tetrahydro-folate reductase (MTHFR) gene may be useful in identifying patients at increased risk of postoperative graft thrombosis and Brown and associates correlated changes in the interleukin (IL)-10 gene with
development of aortic aneurysm. Clearly, there will be considerable work in vascular genomics in the future. An excellent review article on this subject is presented in the New England Journal of Medicine. Other efforts to identify groups at high risk for subsequent cardiac events have focused on identification serum measurement of factors associated with an increased incidence of subsequent cardiovascular events. C-reactive protein (CRP), an acute phase reactant, is one of the more frequently measured levels in 27,939 healthy women and found that although elevations in both were associated with cardiovascular events during followup, CRP was, in fact, a stronger predictor than LDL level. Ariyo and colleagues found that lipoprotein a (Lpa) levels were predictive of subsequent stroke and cardiovascular death in men over 65 years, but not in women. Hill and coauthors measured both CRP and low-density lipoprotein (LDL) levels in 27,939 healthy women and found that although elevations in both were associated with cardiovascular events during followup, CRP was, in fact, a stronger predictor than LDL level. Ariyo and colleagues found that lipoprotein a (Lpa) levels were predictive of subsequent stroke and cardiovascular death in men over 65 years, but not in women. Hill and coauthors measured both CRP and low-density lipoprotein (LDL) levels in 27,939 healthy women and found that although elevations in both were associated with cardiovascular events during followup, CRP was, in fact, a stronger predictor than LDL level. Ariyo and colleagues found that lipoprotein a (Lpa) levels were predictive of subsequent stroke and cardiovascular death in men over 65 years, but not in women. Hill and coauthors measured both CRP and low-density lipoprotein (LDL) levels in 27,939 healthy women and found that although elevations in both were associated with cardiovascular events during followup, CRP was, in fact, a stronger predictor than LDL level. Ariyo and colleagues found that lipoprotein a (Lpa) levels were predictive of subsequent stroke and cardiovascular death in men over 65 years, but not in women. Hill and coauthors measured both CRP and low-density lipoprotein (LDL) levels in 27,939 healthy women and found that although elevations in both were associated with cardiovascular events during followup, CRP was, in fact, a stronger predictor than LDL level. Ariyo and colleagues found that lipoprotein a (Lpa) levels were predictive of subsequent stroke and cardiovascular death in men over 65 years, but not in women.
vascular problems. They found that the majority (78%) were on antiplatelet agents, but only 15% were counseled about smoking cessation, 38% were on lipid-lowering agents and 51% on antihypertensives, and more than 50% had no screening determinations for lipids or blood glucose. These observations from Europe were verified in a single-center experience reported by Henke and coworkers at the annual meeting of the American Association for Vascular Surgery. These authors found that in almost 300 patients who underwent infrapopliteal bypass (75% for limb salvage), statin agents and angiotensin inhibitors were taken in slightly more than 50%. Statin use was associated with increased graft patency and angiotensin-converting enzyme inhibitors with prolonged survival in this same study. The importance of identifying the presence of diabetes and tight control of blood glucose levels was emphasized by Gaede and coauthors, who reported on the effect of an intensive multifactorial intervention in patients with Type 2 diabetes. Patients subject to this intensive regimen experienced more than 50% reduction in cardiovascular disease, and significant reductions in nephropathy, retinopathy, and neuropathy. It is apparent that if vascular surgeons are to act as primary care providers for patients with vascular disease, attention to identification of high-risk states and implementation of risk-factor reduction strategies will need to become part of their practice.

Data continue to be published correlating outcomes with surgical volume. In the past, such data have appeared on aortic aneurysm and carotid endarterectomy, prompting initiatives such as that of the Leapfrog group to develop threshold volumes as a surrogate measurement for quality. This year, two published articles from the University of Michigan looked at a large subset of the Medicare database on aortofemoral bypass and thoracic endograft. 

These articles again demonstrated a correlation between operative volume and results in these two areas, as reported by this same group with other vascular procedures. Despite these reports, regionalization of vascular services has not occurred. A report by Matsen and colleagues looking at carotid endarterectomy in New York State during the calendar year 1999 indicated that most surgeons in the state perform less than 5 cases per year and only 6% perform more than 50 cases annually. How this will be reconciled with the efforts of groups such as Leapfrog remains to be seen.

Aneurysmal disease

This year, guidelines for treatment of AAA were published by a subcommittee of the Joint Council of the SVS/AAVS. These guidelines suggested that the threshold for operative repair in the average patient was 5.5 cm, though this threshold might be lower in women and in younger good-risk men with prolonged life expectancy, who might be at high risk for rupture. They found no evidence to support different thresholds for intervention depending on whether open or endovascular repair was used. In patients with suitable anatomy, endovascular repair appeared to be most advantageous in the older patient; open repair may be preferred for the younger patient with prolonged life expectancy. In the average patient with suitable anatomy, the choice for or against endovascular repair is driven by patient preference. Nonoperative management continues to be an option in high-risk patients with AAA. Tambyraja and associates reported on 128 patients seen over 5 years at the Royal Infirmary in Edinburgh who did not have surgical repair of their aneurysms. Survival was related to aneurysm size, and 30% of patients who presented with AAA of greater than 5.5 cm suffered aneurysm-related death. But mortality from other causes was more frequent than aneurysm-related death in both larger and smaller aneurysms. This report provides support for nonoperative therapy in the patient with a large aneurysm and high medical risk who is not a candidate for an endograft.

Patients with AAA can be followed with either ultrasonography or CT. Wahnainen and coworkers, from Uppsala, reported on measurement variability using these two techniques. In general, ultrasonography was within 8 mm of CT in determining anteroposterior (AP) diameter measurements and 10.6 mm in transverse measurements 95% of the time. This suggests that ultrasonography can be used to follow small aneurysms, but that CT scan will be required when considering operation in patients with aneurysms between 5 and 6 cm. Filinger and coauthors studied 234 patients with AAA using CT scans to define anatomic characteristics of patients that might predict rupture. They found no identifiable variable on conventional CT scan that could predict rupture. Their study indicated that endovascular repair was possible in only 30% of ruptured AAAs because of the size of the proximal neck. This could be increased to 67% of their rupture population if larger diameter devices (30 mm) with suprarenal fixation were
available. This has important implications for some of the newer endovascular devices that are becoming available. This same group studied wall stress using computer modeling of CT scans, and found that peak wall stress was a better predictor of rupture than maximal diameter. Although these measurements are not easily performed at present, they may become important in future surveillance protocols.

Ruptured AAA has become increasingly associated with abdominal compartment syndrome and its accompanying organ dysfunction. Papavassiliou and associates prospectively measured transcystic abdominal compartment pressures in 75 patients (53 elective and 22 ruptured) after AAA repair. Increases in intraabdominal compartment pressure greater than 15 mmHg were associated with mortality and organ dysfunction. Adopting measurement of intraabdominal pressure and delayed closure in selected patients with ruptured AAA might reduce postoperative mortality. Sala and colleagues addressed the fate of common iliac arteries after aortic tube graft placement by reviewing 74 patients in their experience. Forty-three percent of patients had some dilation (>12 mm) of at least one iliac artery at the time of operation. Iliac aneurysms did not grow significantly within the first 5 years of operation, but, patients with aneurysms greater than 18 mm initially were at risk for developing significant iliac aneurysms 7 to 8 years after their initial operation. This article provides justification for the continued use of tube grafts in open aneurysmectomy with mild to moderate iliac ectasia.

Research into the etiology of aneurysms continues to focus on the role of inflammation and proteases in the pathogenesis of aneurysm. Ailawadi and associates suggested that regional factors, presumably hemodynamic in nature, affect the level of metalloproteinase (MMP)-9 activity in the aorta. Using a rat transplant model, they found that MMP activity was higher in the abdominal than in thoracic aorta and that transplantation of the thoracic aorta into the abdominal position raised MMP levels. These observations add a dimension to the picture of aneurysm formation, which, for several years, has focused on the importance of inflammatory cells. The importance of local hemodynamic forces was emphasized by Sho and coworkers in a presentation at the Lifeline research forum of the SVS. Using a murine aneurysm model, these investigators demonstrated that changing flow conditions in the perfused aorta by iliac artery ligation or creation of an aorto-caval fistula influenced the subsequent development of aortic dilation. They showed that in this model, reduced flow and wall shear stress promoted AAA formation, and high flow retarded the process. The importance of local factors in aneurysm formation continues to be an area of fruitful investigation. Lindholt and coworkers reinforced the correlation of smoking and chronic obstructive pulmonary disease (COPD) with AAA formation, and provided evidence that circulating elastase levels may be the common denominator. In a study of 79 men with small AAAs, they performed serial aneurysm measurements, pulmonary function tests, measurements of serum levels of cotinine and elastase, and institution of a smoking cessation program. Aneurysm expansion over time was correlated with continued smoking and elevations in serum levels of cotinine and elastase. Elevations in elastase were correlated with continued smoking and elevated cotinine levels. These data provide support and a putative mechanism for earlier clinical observations linking COPD and smoking to AAA.

The role of local and systemic inflammatory response in AAA formation continues to be examined. Genomic studies linking alterations in the interleukin (IL)-10 gene with AAA development have already been mentioned. At the Lifeline research forum, Eliason and co-authors reported that neutrophil depletion in a murine model of AAA inhibited aneurysm formation. In these experiments they found no effect of neutropenia on levels of MMP-2 and MMP-9 in harvested aortic segments, suggesting that neutrophils are important in multiple steps of the process of AAA formation.

*Chlamydia pneumoniae* is a common organism found in arterial plaque. Conflicting data on the potential importance of this bacterium in aneurysm formation have appeared during the last year. Tambiah and Powell reported that inactivated chlamydial antigens facilitated aortic dilation in a rabbit model of AAA, and that this could be prevented with azithromycin treatment. But studies of chlamydia in humans did not support these observations. Petersen and colleagues looked for chlamydial DNA in the wall of AAAs in 40 patients subjected to operation. No differences in MMP activity were detected between patients with and without chlamydial DNA in their aneurysm walls. The correlation between inflammatory cells, bacterial antigens, and MMPs continues to be elucidated.
Prevention of AAA or attenuation of AAA growth has been another focus of research. Hoel and associates, from Washington University School of Medicine, presented work on the role of doxycycline in this process at the Lifeline research forum of the SVS. Their observations in a murine model indicated that doxycycline could actually increase aortic tensile strength over that of control animals, suggesting an additional mechanism of action for this drug in attenuating aneurysmal growth. Allaire and colleagues suggested that vascular smooth muscle cells (VSMCs) themselves might have a protective effect in preventing aneurysm formation. They implanted decellularized xenografts into Fisher rats with and without vascular smooth muscle cell seeding. The seeded xenografts showed less aneurysm formation and reduced inflammatory cell recruitment compared with controls. These data may be relevant both for the pathogenesis of aneurysms and the development of biologic grafts.

Research on the prevention of complications of aneurysm surgery continues. Harkin and coworkers studied the role of complement C5a receptor antagonist to prevent multiple organ dysfunction in a model of ruptured AAA. Combining shock with aortic cross-clamping to stimulate ruptured AAA, these investigators demonstrated that changes in both lung and intestinal permeability were attenuated by a C5a receptor antagonist at the end of the period of shock. The potential clinical implications of these observations are obvious. This work won the Lifeline resident research award at the annual meeting of the SVS.

Endoleak continues to be a major problem of endovascular aneurysm repair. Van der Bas and colleagues demonstrated that impregnating Dacron (duPont) vascular prostheses with basic fibroblast growth factor induced increased tissue ingrowth in an organ culture model. They suggested that this may be a mechanism to reduce endoleak after endovascular aneurysm repair (EVAR) by promoting incorporation of the prosthesis. Spinal cord ischemia remains a major source of morbidity after operation of the thoracic and thoracoabdominal aorta. Work by Cakir and colleagues in an experimental rabbit model suggested that N-acetylcysteine works synergistically with hypothermia to prevent spinal cord damage associated with aortic clamping. This drug may join others being evaluated to prevent this devastating complication.

**Thoracic aorta**

The field of thoracic aortic surgery has become increasingly important to vascular surgeons. The major development in this field has been the application of endovascular stent graft technology to acute and chronic pathology of the thoracic aorta, including aneurysm, dissection, penetrating ulcer, and traumatic rupture. Availability of thoracic endografts is limited in the US, and clinical experience is concentrated in only a few centers. In Europe significant clinical experience with this technology has accumulated. Reports from multiple European centers document the feasibility of this approach in both acute and chronic aortic pathology. The cumulative experience of the EUROSTAR and UK registries on thoracic endografts was presented at the VEITH meeting in November 2003. In 432 patients (217 thoracic aortic aneurysms, 115 thoracic dissections, 100 other), technical success was achieved in 81% to 83%, with a 7% to 8% mortality rate. Perioperative complication rates continue to be in the 20% to 30% range in this difficult group of patients. Neurologic complications (central and spinal cord) were seen in 6.3% of patients with thoracic aortic aneurysms and 0.9% of dissections. These complications were related both to spinal cord ischemia and device manipulation in the aortic arch. Iliac or aortic exposure for conduit delivery was required in less than 10% of patients. Mortality rates continue to be in the 10% to 20% range for acute aortic syndromes and paraplegia was not eliminated. But these complication rates are a significant improvement over those associated with open repair. Late problems with thoracic aortic endografts are similar to those with abdominal prostheses, ie, early endoleak and late graft migration. Recurrent dissection, both proximal and distal to the implanted graft, has been reported by several investigators when endografts are used in dissections of the thoracic aorta. The use of uncovered stents at the proximal seal zone may play a role in this phenomenon. Although secondary conversion remains a necessity in a subgroup of patients, current clinical experience in Europe and the US suggests that endovascular techniques may provide a major benefit for patients with degenerative disease of the thoracic aorta. Traumatic disruptions of the aorta may also be amenable to endovascular treatment. This has several obvious advantages in the multiple injured patient. Endografting often requires a delay in treatment, especially when custom-made devices are required. In this regard,
the report by Kwon and colleagues\textsuperscript{52} from the Cleveland Clinic on improved outcomes with delayed repair of traumatic dissections gives reassurance to those who wish to avoid emergent surgery in a multiple injured patient with a stable mediastinum.

Successful endovascular repair of the thoracic and suprarenal aorta must account for visceral and supraortic trunk vessels. The subclavian artery can generally be covered with impunity, though subclavian to carotid transposition may sometimes be required. This is particularly true if there is disease in the right vertebral artery distribution. Endovascular fenestration by puncturing the endograft and using a cutting balloon has been reported to maintain perfusion of the left subclavian artery.\textsuperscript{53} This technique is not easily applicable to the visceral vessels or more proximal arch vessels. When coverage of these vessels is anticipated, extranatomic bypass or branched endografts will be required.\textsuperscript{50,54,55}

Although the field of endovascular repair of the thoracic aorta is exciting, grafts are not currently available in the US outside of investigational protocols, and the level of endovascular skill required for complex reconstructions exceeds that of endovascular infrarenal AAA repair. For now, open repair of these lesions is the only option available to most surgeons in the US. Reports from two large centers of excellence, one in Europe,\textsuperscript{56} and the other in the US,\textsuperscript{37} documented excellent results with open repair of the diseased thoracic aorta. Kieffer and colleagues\textsuperscript{46} noted the significant incidence of both myocardial and carotid disease in these patients, and recommended screening for coronary and carotid lesions before repair. Even in these centers of excellence, significant postoperative morbidity was reported in 20\% to 30\% of patients after open repair. Given the report cited earlier on the relationship of volume to outcomes in thoracic surgery,\textsuperscript{20} management of these patients will continue to be problematic.

Increased use of transesophageal echocardiography and CT angiography has identified the thoracic aorta with increasing frequency as a source for peripheral athroemboli. Management of patients with this condition remains a matter of controversy. Goueffic and associates\textsuperscript{58} reported on treatment of 38 patients over a 20-year period using a surgical approach including circulatory support. Surgery was designed to address the source of embolization by thrombectomy, endarterectomy, patch aortoplasty, or resection, and was associated with a 2.6\% perioperative mortality. The average age of their patients was 49 \pm 12 years. A different population, with different results, was reported by Klocker and colleagues from the Mayo Clinic.\textsuperscript{59} Their 23 patients were older (mean age 73 years), with significantly more comorbidities, and none underwent operation. Only one-third of these patients were alive at a median followup of 13 months. Treatment of this difficult condition must be individualized.

**Abdominal aortic aneurysm**

Developments in operative management of AAA continue to focus on refinements and complications associated with EVAR. This was a major focus of the joint SVS/AAVS meeting in June 2003 in Chicago. The learning curve associated with adoption of this technique was evaluated by Forbes and associates\textsuperscript{60} in a retrospective study of a single surgeon’s experience over 4 years that included 96 elective EVARs. Success rates were good throughout the experience but improved significantly after 20 device-specific repairs were accomplished. Broad adoption of EVAR technology with good results was documented by Anderson and colleagues\textsuperscript{61} who evaluated outcomes in New York state during 2000 and 2001. Approximately one-third of elective AAA repairs were endovascular in 2001, with decreased hospital mortality compared with that with open repair (1.5\% versus 4.9\%) and shorter length of stay. During the past year, the Ancure device (Guidant) was voluntarily removed from the market. During this same period two additional devices (Zenith [Cook Group] and Excluder [Gore Medica]) received FDA approval, and results of several device-specific trials were reported. Both the Talent (Medtronic Sofamor Danek)\textsuperscript{62} and Lifepath (Edwards Lifesciences)\textsuperscript{63} trials demonstrated that these devices could be placed safely, with low rates of surgical conversion and with endoleak rates comparable with those of other devices currently in use.

Data on outcomes after EVAR are increasingly available as the various devices have been followed for longer periods. Parlani and colleagues\textsuperscript{64} reviewed their results in 402 endografts (94\% men). Although they found statistically significant increased perioperative complication, conversion, and late failure rates in the female cohort, the small absolute number of women in their study requires confirmation of their results. Reports from the EUROSTAR database\textsuperscript{65} of almost 4,400 patients using multiple devices revealed that patients with large (>6.5 cm) AAAs were at higher perioperative risk and were
subject to a higher rate of Type 1 endoleak on followup. Inferior results in larger aneurysms were also reported in the Cleveland Clinic experience. Similar to the report from EUROSTAR, Type 1 endoleak, early conversion, and midterm mortality were all increased in patients with aneurysms $>5.5$ cm. These data raise the question of efficacy of EVAR versus open repair in large aneurysms. This issue is currently being addressed by a trial in the United Kingdom whose design was described at the VEITH meeting in November 2003. In this ongoing trial, EVAR will be compared with open repair in good-risk patients and best medical therapy in patients medically unfit for operation. Noted previously, current SVS/AAVS guidelines for treatment of AAA do not favor EVAR or open repair. A Markov analysis of EUROSTAR data came to similar conclusions. For most candidates for AAA repair, benefit in quality-adjusted life expectancy was similar whether EVAR or open approaches were used; young patients with prolonged life expectancy would benefit from the decreased risk of re-intervention over time with open repair, and older patients with comorbidities could be expected to benefit from EVAR. Currently, wide necked (28 mm) AAAs are not recommended for EVAR. A report from Leicester on 16 such patients with 12-month followup reported that not only did endoleak not occur, but actual decrease in the size of the aneurysm neck was observed. These data will require confirmation and prolonged followup, but are of great interest.

Late neck dilation, migration and endoleak, and the importance of device-specific complications were subjects of multiple reports. Proximal aortic neck dilation has been reported in 2% to 10% of patients after EVAR. Cao and coworkers correlated this with presence of circumferential thrombus, neck size, and preoperative AAA diameter. Results of the Zenith multicenter trial indicated that oversizing of the graft by more than 30% increased the risk for late dilation, device migration, and endoleak. Comparison of data from phase 2 trials of four different devices revealed proximal neck dilation $>3$ mm in 17.6% of patients with no relationship to graft type. Graft migration was more common in the Lifepath and Aneurx (Medtronic Sofamor Danek) grafts than in Ancure or Excluder, though endoleak in all trials was low. Analysis of the Cleveland Clinic experience revealed equivalent survival rates, but differences in longer term device-related complications. Limb occlusion was most common with the Ancure device, absolute endoleak rate, and Type 2 endoleak in particular was seen most often in the Excluder graft. Types 1 and 3 endoleaks were seen with equal frequency across all devices, and Type 4 (transgraft) endoleak was seen more often in Aneurx. Aneurysm shrinkage was inversely related to endoleak rate in all devices. An important longitudinal study from Sydney on patients followed for 5 years or more indicated that there was no significant enlargement in the proximal aortic neck in the absence of graft migration. Taken as a whole, these studies provide reassurance that long-term dilation at the proximal implantation site is a rare occurrence after EVAR for AAA.

Endoleak remains significant and its detection and management are controversial. Intravascular ultrasonography has been suggested as a means to reduce this complication by allowing better approximation of proximal and distal sealing zones. Garret and associates found that routine use of intravascular ultrasonography at the time of EVAR deployment altered the choice of graft size in 28 of 78 patients treated. But this modality is not readily available in most centers, and it is unclear whether the use of 3-dimensional CT angiographic reconstruction would have improved the accuracy of their initial CT measurements, rendering intravascular ultrasonography unnecessary. Several reports of intrasac pressure measurements after EVAR have appeared in the literature. Sonesson and coworkers correlated a drop in median intrasac pressure of 80% with successful EVAR repair and sac shrinkage. Milner and colleagues reported measurements of intrasac pressure with an implantable ultrasound device in an animal model, and the Mount Sinai group reported initial human experience with ultrasonic monitoring of sac pressure at the VEITH meeting in November 2003. These techniques may replace or supplement the current standard of serial imaging studies to detect endoleak.

Endoleak is usually detected by CT angiography. But several investigators have demonstrated that MRI and duplex ultrasonography can be used to identify the presence of endoleak with accuracies that are as good as or better than CT, without the need for contrast enhancement. But the MRI techniques applied are not uniformly available at all medical centers and ultrasonography remains highly operator dependent. For now, most clinicians will continue to rely on CT angiography to detect endoleaks. Although CT is reliable for detection, it may not give sufficient information to allow
classification of endoleak by type. Stavropulos and coauthors\textsuperscript{83} reported discrepancy between CT and catheter angiography in 33% of their patients with endoleak, which resulted in a change of management in 21% of their patients. Most significant was the misclassification of two Type 1 endoleaks as Type 2. At present, identification of any endoleak more than 1 month after implantation should be an indication for evaluation by catheter angiography. Endoleaks may arise from seal zone failure proximally or distally (Type 1), collateral filling of the aneurysm sac (Type 2), component separation (Type 3), transgraft extravasation (Type 4) or endotension (Type 5). Parra and coworkers\textsuperscript{84} identified Type 1 endoleak in 5 of 189 endografts. These late failures were associated with the use of proximal aortic extender cuffs. Changes in length and angulation of the aorta after deployment placed significant stress on the region between the body of the endograft and the proximal extender cuff. These data emphasize the importance of initial accurate placement of the proximal endograft immediately below the renal vessels.

Vallabhaneni and colleagues\textsuperscript{85} measured intraoperative aneurysm pressure in patients at the time of EVAR, and in the occluded aorta of patients undergoing open aneurysm repair. They demonstrated that during open repair, direct occlusion of the arteries proximal and distal to the aneurysm resulted in significantly lower intrasac pressures than were seen after the completion of EVAR. These data suggest that transgraft transmission of aortic pressure in EVAR remains a significant component of postoperative aneurysm pressurization (Type 5 endoleak) in patients after EVAR.

Type 2 endoleak remains a common finding after EVAR. When aneurysmal change involves bifurcation of the common iliac artery, exclusion of the internal iliac artery has been recommended. This can be associated with significant complications, including buttock claudication and even a report of ischemic sciatic neuropathy.\textsuperscript{86} Sugano and associates\textsuperscript{87} reported on the use of hypogastric artery stump pressure in a series of open aneurysm repairs to predict the likelihood of buttock claudication after hypogastric ligation. In their series, claudication was not seen if the hypogastric artery stump pressure was more than 65% of systemic pressure. It is hard to know how this will convert to the endovascular situation. Direct bypass to or reimplantation of the hypogastric artery using the distal eternal iliac or common femoral artery\textsuperscript{88} seems a more practical approach. Finally, Wyers and coworkers\textsuperscript{89} from Dartmouth reported that exclusion of the hypogastric artery without earlier coil embolization can be successful if there is a good seal at the orifice of this vessel, and that complications with this approach are less than when coil embolization is used.

Once endoleaks are detected, their treatment depends on cause. There continues to be controversy about the management of Type 2 endoleaks once they are detected. Many authors suggest that these can be observed with serial followup studies and intervention only when endoleaks persist and the aneurysm sac enlarges. This position is supported by the group at Washington University, who followed 442 patients for a mean of 22 months.\textsuperscript{90} Selective management of Type 2 leaks is well supported in the literature. Faries and colleagues,\textsuperscript{91} from Mount Sinai, found it necessary to treat endoleaks in 11.7% of 597 patients during followup. Most of these problems occurred more than 1 year after implantation, emphasizing again the need for ongoing monitoring. Extension cuffs were used in more than half the patients for Type 1 or 3 endoleaks, with a success rate of 97%. Embolic coils were used in 23% of patients, with an 87% success, and conversion was required in 5% of patients. Becquemin and associates\textsuperscript{92} described the incidence and outcomes of secondary interventions after 271 EVAR repairs by their group. Secondary intervention was required in 26% of patients in their series, 47% of whom required intervention on more than one occasion. Success of extension grafts was 82%, but coil embolization was successful in only 43% of patients, which is similar to other reports. Explantation was required in 2.9% of patients, and longterm survival of patients who underwent intervention was similar to that in those who did not. Recently, there has been a report by the group at New York University on the use of cyanoacrylate to seal Type 1 endoleaks.\textsuperscript{93} This may be an additional option when endoleak occurs in the absence of significant graft migration, or in Type 2 leaks associated with expansion. Kolvenbach and coworkers\textsuperscript{94} reported laparoscopic remodeling of aortic aneurysms after EVAR. Initially used to treat endoleaks, the procedure involves exposure and occlusion of inferior mesenteric and lumbar arteries using laparoscopic technique, and external fixation of the proximal endograft to the aortic neck using laparoscopic suture technique. Kolvenbach and colleagues\textsuperscript{94} applied this approach prophylactically in eight subsequent patients. The ultimate
role of this approach, like that of the New York University group, remains to be defined in the future. A second article, from Mount Sinai, which included both abdominal and thoracic aneurysms, addressed the issue of long-term device fatigue after EVAR. They noted device-related deterioration in 60 of 686 patients. Stent fractures were most common, followed by suture disruptions and holes in the graft fabric. This is one of the few long-term studies focusing on mechanical failure of EVAR devices. Aortic embolization represents a rare but devastating complication of EVAR, usually seen in patients with diffuse atheromatous changes of the aorta. Parodi and colleagues reported a balloon occlusion catheter designed to occlude the iliac arteries during endografting. They described successful deployment of an endograft coupled with an arterio-arterial shunt and an inline filter and filter wires placed in the visceral vessels. Such patients with diffuse atheromatous disease present serious challenges for both open and endovascular techniques.

Endografts with suprarenal fixation using bare stents were developed to improve proximal fixation and prevent late migration and endoleak. The FDA-approved Zenith device has this configuration. Concerns over the effect of suprarenal fixation on long-term renal deterioration have been addressed by several studies. Each of these studies indicates that preoperative renal status, rather than suprarenal fixation, is the major determinant of late deterioration in renal function. No significant late deterioration was seen in patients whose renal function was normal at the time of implantation. These reports from multiple centers are reassuring for surgeons who choose to use such devices. Suprarenal fixation and enlarged devices (30-mm proximal diameter) will be required for routine use of EVAR in cases of AAA rupture. Endovascular approach to ruptured AAA is being applied with increasing frequency. As with thoracic endografts, EVAR in these difficult cases has been associated with decreases in perioperative mortality to the 20% to 25% range. In an intention-to-treat model, Peppelenbosch and colleagues reported that EVAR was feasible anatomically and hemodynamically in 80% of the 40 patients seen at their center. EVAR has also been reported to be successful in the treatment of anastomotic false aneurysms of the abdominal aorta.

Modifications to open surgical techniques have been explored, using incisions 10 to 15 cm in diameter. Laparoscopic aortic aneurysmorrhaphy was described a number of years ago, but is associated with increased operating time and has been replaced for the most part with laparoscopically assisted procedures. Robotics have also been used to facilitate a laparoscopic approach. These techniques will continue to be refined in the near future. Visceral and popliteal aneurysms have been repaired using covered stents. A report at the VEITH meeting in November 2003 demonstrated a 70% patency rate in 40 patients treated with a polytetrafluoroethylene (PTFE)-covered stent. These results will need to be compared with surgical experience and covered stents will likely be complementary and not competitive alternatives in these locations.

Carotid surgery

Stenotic disease of the carotid bifurcation remains the major indication for noncoronary intervention in North America. The majority of such interventions, both open and percutaneous, are for severe asymptomatic stenoses. Indications for intervention, results of carotid endarterectomy, and ultimate role of carotid balloon angioplasty and stent (CBAS) remain controversial. Echolucent plaques are associated with an elevated incidence of neurologic symptoms. Goncalves and associates compared the grey scale median on duplex ultrasound with plaque DNA and soluble protein from removed specimens. They found that echolucency was correlated with increased plaque cellularity and neurologic symptoms, suggesting that these plaques were perhaps more active. Russell and colleagues found that after a neurologic event, plaque echomorphology diminished, suggesting plaque remodeling. Plaque changes were maximal within the first 30 days of the neurologic events, which correlates with the maximal risk of subsequent clinical neurologic events reported from North American Symptomatic Carotid Endarterectomy Trial (NASCET). Duplex ultrasonography is currently the primary means of detecting and following carotid bifurcation disease. It is important to remember that this is an operator-dependent technology. Brown and coworkers compared duplex studies from nonaccredited vascular laboratories with their own results, and found discrepancies in 62% of patients. These results underscore the need for validation of ultrasonographic findings from laboratories with which the surgeon is not familiar.

Disease progression in the contralateral artery re-
mains the major reason for duplex scans after carotid endarterectomy (CEA). Raman and coauthors\textsuperscript{113} followed 279 patients after unilateral CEA and reported an 8.3\% incidence of any progression and a 4.4\% incidence of progression to severe stenosis or occlusion. Their experience confirms the need for longterm followup of these patients. Earlier publications from the US suggested that geographic and socioeconomic factors influenced the frequency of CEA use. Data from Edinburgh\textsuperscript{114} demonstrated a similar correlation in Scotland, with the incidence of CEA decreased in rural and low socioeconomic populations despite an increased prevalence of stroke in these same groups. Such results are disconcerting and suggest discrepancies with access to care.

Identifying high-risk patient groups who are at increased risk after CEA and may be candidates for carotid stenting has been an area of interest and controversy. CEA early after stroke has been associated with increased postoperative morbidity in past reports. Eckstein and coauthors\textsuperscript{114} reported on 164 patients hospitalized for stroke who underwent CEA within 6 weeks of the onset of symptoms. Overall combined perioperative stroke and death rate was 6.7\%, and related to medical risk (American Society of Anesthesiologists class III and IV) and operation performed within 3 weeks of the neurologic event. These data provide good baseline data for comparison with high-risk stenting trials. Three other single-center reports\textsuperscript{116-118} address the issue of high-risk carotid surgery using a variety of criteria including anatomic risk, NASCET/ACAS ineligibility, and other medical comorbidities believed to be potential indications for carotid stenting. In each of these studies, overall stroke and death rate ranged from 1.8\% to 3.1\%, with no statistical difference between normal and high-risk subgroups. Contralateral carotid occlusion was a predictor of moderate increase in perioperative stroke risk in the study by Reed and colleagues\textsuperscript{117}; Illig and associates\textsuperscript{115} found no significant differences in patients who would have been included or excluded from the NASCET, Asymptomatic Carotid Artery Surgery (ACAS), or Acculink for Revascularization of Carotids in High Risk Patients (ARCHER) trials. Gasparis and coworkers\textsuperscript{117} suggested that local factors such as restenosis or radiation might increase technical difficulty of CEA, but they were present in only 5\% of patients. Reconciling these results with those of the Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (SAPPHIRE) trial (see preceding text) is important. Likely differences include the fact that only stroke and death were reported in the previously mentioned series, and that asymptomatic patients with severe medical comorbidities may have been excluded from the CEA groups.

CBAS is widely practiced in Europe; its use in the US has remained investigational up to now. Advances in techniques including lower profile devices, improved balloons and guidewires, and antiembolic protection devices have significantly reduced the complications rates experienced with CBAS in the past. Multiple reports\textsuperscript{119,120} of CBAS with neuroprotection document overall stroke and death rates of 3\% to 5\% and less. These data indicate that short-term results of CBAS in the hands of experienced operators with neuroprotection are similar to those of CEA. But these protection devices, which differ significantly from each other, are not readily available or approved for use in the US. The most important report on CBAS this year was the result of the SAPPHIRE trial that was presented in a variety of venues.\textsuperscript{123,124} This was a prospective randomized trial of CBAS and CEA in patients believed to be at high risk for CEA. Almost one-third of these patients had stenosis after CEA and a large number of patients were asymptomatic. These data indicated that major adverse cardiovascular events (MACEs) were increased in the CEA group (12.6\% versus 5.8\%, \( p = 0.05 \)). Most of this difference was in the incidence of myocardial infarction, diagnosed using both EKG and troponin levels (7.3\% versus 2.6\%, respectively). Although there was no difference between CBAS and CEA in overall stroke or death rates, patients with medical comorbidities, which included severe cardiac, pulmonary, or renal insufficiency, had significantly increased risk of stroke and myocardial infarction with CEA (\( p = 0.02 \)). These data with CEA (stroke 7.0\% and myocardial infarction 8.5\%) are difficult to reconcile with single-center publications on consecutive CEAs, suggesting that there may be a difference in patient selection. The data also suggest that treatment of asymptomatic lesions, whether by CBAS or CEA, may give less favorable results than the natural history of disease and should be carefully considered in the high-risk subgroup. This study has had significant impact on the thinking of many physicians with reference to CBAS, and its data will likely form the basis for potential FDA approval of this technology in the US in 2004.

CBAS does have its own procedure-specific compli-
cations, which include access site difficulty, carotid sinus hyperactivity, and distal embolization associated with manipulation of the lesion. Leisch and colleagues reported carotid sinus reactivity, defined as hypotension or asystole of more than 3 seconds in 40% of 105 consecutive CBAS procedures. Most of these were asymptomatic, but were most common when lesions in the carotid bifurcation rather than the internal carotid artery were treated. Group IIb/IIIa inhibitors have been given during CBAS in an effort to reduce thromboembolic events. A large retrospective review by Wholey and associates reported an increased incidence of neurologic events in the IIb/IIIa-plus heparin group compared with that in patients treated with heparin alone (6.0% versus 2.3%, respectively, p = 0.04), primarily the result of intracranial hemorrhage. These data are strong evidence that routine use of IIb/IIIa inhibitors is contraindicated in CBAS. Increased rates of ipsilateral external carotid artery disease progression have been reported after CBAS. The clinical significance of this, other than possibly reducing the effect of the external carotid artery (ECA) as a collateral, seem to be minimal. Although clinical evidence of cerebral ischemia is reduced by neuroprotection, a report from Schluter and coauthors demonstrated abnormalities in 22% of diffusion-weighted magnetic resonance imaging scans after CBAS. Although only 2.2% of these were clinically manifest, such studies again force one to reexamine the roles of CBAS and CEA in asymptomatic patients. Bicknell and coworkers, using an ex vivo flow model, found that embolic potential of carotid plaques subject to angioplasty was highest in patients with the most severe stenoses and that statin therapy for more than 4 weeks before the procedure reduced the number of emboli after angioplasty. This may be a potential intervention in patients undergoing CBAS in the future.

Timing of complications after CEA has been well documented, with the vast majority of problems seen in the first 6 to 8 hours. Tan and colleagues reviewed 208 consecutive CBAS procedures to determine the frequency and timing of postoperative complications. Neurologic symptoms were present in 84.8% of their patients, and complications developed in 18.6%. More than 50% occurred in the first 6 hours after procedure, but one-third occurred between 24 hours and 30 days. Although this was a high-risk group of patients for intervention, more study is needed before same-day discharge after CBAS can be recommended. The potential for late restenosis after CBAS is currently unknown. Two reports of restenosis after CBAS suggest that factors that may predispose to this complication include female gender, number of stents deployed, postprocedural percent stenosis, and loss of proximal stent apposition. Absolute rates of restenosis are hard to determine because various authors use differing criteria of diameter reduction in their definitions. Lal and colleagues suggest that increases in peak systolic velocity can be expected after CBAS presumably because of wall stiffness, and suggest that ultrasound criteria for detection of restenosis after CBAS need to be redefined.

When significant restenosis occurs after CBAS, a variety of options are available. Balloon angioplasty of the recurrent lesion has been reported with success, and Bendok and associates report that use of a cutting balloon, currently used in coronary stenoses, can be effective in refractory lesions. Endarterectomy, to include the stent and stenotic artery, was successful in four patients reported by deBorst and colleagues. Bowser and associates reported excellent results treating recurrent stenoses with both CBAS and CEA. They believed that CBAS allowed them to treat a larger number of lesions that might have been difficult to treat by CEA. Successful CEA and synchronous retrograde CBAS of proximal carotid lesions were reported in 14 of 16 patients treated by Grego and coworkers with combined carotid bifurcation and proximal common carotid disease. The long-term superiority of CBAS or CEA cannot be determined at present. Given the current data, it seems that they may be complementary therapies, with CBAS reserved for patients at high risk for standard operation. The choice of therapies will depend to a great extent on equivalence of neurologic outcomes, which remains heavily operator dependent. Warren and coauthors found that when patients were presented the data on CBAS and CEA, they would choose CBAS only if the stroke risk was no more than 46% higher than that of CEA.

**Arterial occlusive disease**

Peripheral vascular occlusive disease (PVOD) remains the most pervasive of all arterial pathologies found in 5% to 10% of patients older than 60 years in routine screening efforts. In most of these patients, symptoms are relatively mild and efforts at risk reduction and nonoperative therapy are indicated. Smoking cessation is perhaps the single most important intervention in this popula-
tion. Hobbs and Bradbury\textsuperscript{140} reviewed the evidence for an aggressive smoking cessation strategy as the cornerstone of managing patients with PVOD. This article is an excellent reference that documents the efficacy of nicotine replacement therapy and bupropion as effective smoking cessation therapies. Vascular surgeons are in the optimal position to initiate these therapies, and given their effect in reducing complications of PVOD, should take an active role in their implementation. The issue of general risk factor reduction was discussed earlier. Claudicants continue to be less likely to receive lipid-lowering therapies than patients with coronary disease.\textsuperscript{141} Guidelines for pharmacotherapy of claudicants are nicely summarized in a review article by Hiatt\textsuperscript{142} and should be familiar to every vascular surgeon.

Claudication is a disabling but, not itself, life or limb threatening. There is a current trend toward more aggressive treatment of this symptom complex that affects many older patients. Attempts to increase angiogenesis by adenoviral delivery of vascular endothelial growth factor was initially studied in critical limb ischemia, but has also been evaluated for treatment of claudication. The results of this trial (RAVE) were recently published.\textsuperscript{143} Vascular endothelial growth factor was administered in 20 intramuscular injections at a single setting to patients with unilateral limiting claudication. No benefit to this therapy was found when compared with placebo. In contrast, both oral medication and structured exercise programs offer significant benefits to claudicants.\textsuperscript{144} The effectiveness of a structured exercise program in improving walking distance was documented in two recently published trials. Degischer and colleagues\textsuperscript{145} demonstrated the benefit of 3 hours per week of exercise training plus clopidogrel over home-based training, increasing walking distance by almost 500 meters. Fowler and associates\textsuperscript{146} compared “usual care” to an intensive program of smoking cessation and increased physical activity in a controlled randomized trial. A greater percentage of the treatment group reported increased walking, regular exercise, and smoking cessation than in the “usual care” group. The fact that there is now a cardiothoracic code for supervised exercise programs for PVOD may further encourage physicians to become involved in this activity. Unfortunately, many patients seek help at a time when either the severity of PVOD or their deconditioned state preclude effective physical therapy. In those cases, consideration for either percutaneous intervention or open surgical correction may be entertained, but these should be combined with the other nonoperative therapies previously mentioned.\textsuperscript{144}

Critical limb ischemia (CLI) is most often treated with arterial revascularization, but in some patients, whether because of unfavorable anatomy or medical comorbidity, this may not be safe or feasible. Potential alternatives in CLI include spinal cord stimulation (SCS), counterpulsation, and perhaps applications of growth factors to promote wound healing. Amann and coauthors\textsuperscript{147} reported on the use of SCS in nonreconstructible CLI in a multicenter experience from Europe. The investigators looked at three groups of patients: those who showed an initial response to SCS manifested by pain relief and poststimulation transcutaneous oxygen tension (TcPO$_2$) of $>20$ mmHg, and two groups of nonresponders, one treated with SCS and the other a nontreated control. The study included 122 patients divided into three groups with similar baseline TcPO$_2$ (11 to 15 mmHg). Responders to SCS showed a significant improvement in pain relief, TcPO$_2$, and limb survival at 12 months, compared with nonresponders who received SCS and to controls. Limb survival in all patients with SCS was improved compared with those without SCS. This regimen, used much more in Europe than in the US, merits attention. Arterial counterpulsation therapy is another option in patients with CLI.\textsuperscript{148} This works on the basis of reducing venous pressure and improving the arteriovenous gradient in the ischemic limb. Pain relief and improved ulcer healing have been demonstrated in patients not otherwise suitable for vascular reconstruction. The technique cannot be used as sole therapy in patients with large ulcers and is contraindicated in active infection. A variety of growth factors have been evaluated in the past to accelerate wound healing in patients with CLI. At the VEITH meeting in November 2003, Comerota and colleagues\textsuperscript{149} reported on the progress of a trial of fibroblast growth factor 1 in patients with CLI. Early results indicate increased healing of wounds as compared with controls, but final results are not available. Although revascularization remains the most effective therapy in these patients, alternatives such as those mentioned may be useful in selected patients.

In the area of peripheral vascular research, control of intimal hyperplasia remains a major goal. Both photodynamic therapy and brachytherapy have been used in an attempt to reduce the hyperplastic response after revascularization. Gabeler and associates\textsuperscript{150} reported en-
couraging results in the use of photodynamic therapy in a rat model of balloon injury. A critical review of available data on brachytherapy and restenosis was performed by Hansrani and coworkers. At present, clinical trials of brachytherapy have confirmed its safety and feasibility, but no clear data indicating long-term benefit are available. The only trial combining brachytherapy with stent insertion reported a high incidence of early thrombosis. The majority of trials are in the coronary circulation. Drug eluting stents (DESs) have seized center stage in the coronary circulation, though their ultimate role remains unclear at present. Early benefit of drug eluting stents in the superficial femoral position was suggested by Duda and coauthors. The SCIR-OCCO trial (using sirolimus coated stents in the superficial femoral artery) is designed to test this hypothesis. In a single-center analysis, there was a benefit found in patency at 6 months, but only 36 patients were involved in the analysis. Larger populations and longer followup will be needed before conclusions can be drawn. The cost benefit of drug eluting stents compared with other percutaneous and open surgical interventions, particularly for treatment of claudication, will need to be evaluated before the role of this therapy is defined.

Revascularization after aortic surgery is known to be associated with a systemic inflammatory response. Edrees and colleagues asked whether this same phenomenon could be observed after isolated lower limb revascularization. They measured the systemic inflammatory response in four groups of patients: group 1, CLI with bypass; group 2, claudication with bypass; group 3, CLI with amputation; and group 4, CEA. Markers of systemic response included intestinal permeability, endotoxemia, and urinary level of tumor necrosis factor. No patients showed evidence of endotoxemia. Patients with CLI and lower extremity revascularization (group 1) showed increased intestinal permeability and elevated tumor necrosis factor, though these two measures were not correlated with each other. The peak of intestinal permeability occurred on the third postoperative day and was correlated with arterial clamp time. This study demonstrates that patients with CLI do show systemic response after revascularization. The role of this response in postoperative morbidity remains to be elucidated. A study by Silvestro and associates shows that acute exercise in claudicants is associated with increased oxidative stress. This was documented by elevated levels of thiobarbituric acid reactive substances, soluble intracellular adhesion molecules, and abnormal brachial artery flow-mediated dilation. These changes were reversed by administration of vitamin C. Implications of these findings for claudicants who are entering an exercise program remain to be defined.

Efforts to improve lower extremity bypass graft patency continue to be the subject of clinical investigation. Tiwari and coworkers provide a nice review of the effect of technical modifications in efforts to reduce compliance mismatch at the site of arterial anastomosis. Continuous suture technique has been shown to increase compliance mismatch, but remains the most popular form of arterial anastomosis. Efforts to move to an interrupted technique by using clips, and adjuncts such as laser welding or biologic glues are nicely summarized in this article. Similarly, data on cuffs and patches and their effect on graft patency are discussed. An animal study by Begoc and colleagues reported on efforts to enhance thrombo-resistance of ePTFE by surface coating its inner lining with a stable heparin. Improvement in thrombus-free surface and graft patency were reported. Use of adenoviral vectors, specifically E2F decoy, to coat the surface of autogenous veins as the time of implantation was the subject of several large clinical trials in both coronary and peripheral circulations. The trial in lower extremity autogenous bypass, which involves immediate treatment of excised saphenous vein at the time of bypass, has accrued more than 1,400 patients, as reported by Conte at the 2003 VEITH symposium. Data from this trial should be forthcoming in the next year.

The etiology of Buerger’s disease remains unknown. Lee and colleagues reported on immunologic analysis of tissue from eight patients with Buerger’s disease. The authors found a preponderance of T-cell infiltration, particularly cells of the CD4 variety. This might suggest an avenue for future therapy in this difficult disease.

Imaging plays a particularly important role in PVOD because it has traditionally been the primary method for selecting inflow and outflow vessels for reconstruction. Angiography, using iodinated contrast agents, has been the most common method used to evaluate PVOD. Although contrast agents have improved over time, nephrotoxicity associated with their use continues to be a problem. This issue of contrast-induced nephrotoxicity was exhaustively discussed in a review by Lindholt. The author discussed etiology, predisposing risk factors, and potential agents to reduce this problem.
point, solid evidence for efficacy exists for administration of 600 mg acetylcysteine twice daily for 48 hours around the time of exposure. Treatment with the calcium blocker nifedipine 20 mg daily for 3 days beginning 1 day before angiography also shows some effect. The data on fenoldopam, a renal vasodilator, are inconclusive at present. This article represents a succinct summation of the current knowledge on this topic. Gadolinium and CO₂ angiography have been offered as alternatives to iodinated contrast use. CO₂ angiography has had uneven success, and it is important to remember that gadolinium, used in significant doses, is also associated with renal dysfunction.¹⁶⁰

Magnetic resonance imaging and duplex ultrasonography have been evaluated by multiple investigators to supplant angiography in patients who require lower extremity reconstruction. Hofman and colleagues¹⁶¹ compared selective digital subtraction angiography, contrast enhanced magnetic resonance angiography, and duplex ultrasonography for pedal artery imaging in patients before revascularization. In their hands, magnetic resonance angiography performed better than either contrast angiography or digital angiography. But this conclusion is not supported by others¹⁶² who have found magnetic resonance angiography to be less reliable than duplex ultrasonographic arterial mapping. Although this technique is highly operator dependent, Eiberg and coworkers¹⁶³ found a high degree of interobserver agreement (kappa 0.79) with duplex, similar to that seen with digital arteriography, through all arterial segments of the lower extremity. In a related article, this same group demonstrated that use of ultrasonographic contrast agents can improve imaging results in PVOD.¹⁶⁴ Vascular surgeons are relying more and more on use of duplex ultrasonography to identify patients for potential intervention, rather than relying on contrast angiography. Back and colleagues¹⁶⁵ documented their ability to differentiate aortoiliac lesions suitable for percutaneous therapy from those longer lesions that are better treated by open techniques. This facilitated patient triage and selection of noninterventional, percutaneous, or open therapies for patients with PVOD. This practice reinforces the position of vascular surgeons as the central providers of vascular care. Queral and coauthors¹⁶⁶ reported on an increasingly common practice, that of avoiding preoperative angiography in favor of lower extremity angiography in the operating room at the time of reconstruction. Over a period of 5 years, the authors evaluated 455 patients by physical examination and duplex ultrasonography. All but six patients, who were reconstructable, were successfully managed by angiography in the operating room before intervention. Of 120 percutaneous cases, only 10 required conversion to an open approach. This experience is becoming increasingly typical for practicing vascular surgeons, but it requires easily accessible high-quality imaging in the operating room.

Thrombolysis continues to be an important part of the armamentarium of the vascular surgeon, though the frequency with which it is used appears to be decreasing. Richards and colleagues¹⁶⁷ reviewed their institutional experience with thrombolysis and the results of a questionnaire sent to 24 centers that provide data for the United Kingdom Thrombolysis Study Group. They noted both a marked decrease in the use of thrombolysis in their home institution and a corresponding decrease in 86% of the centers that responded to the questionnaire. Reasons for reduced use included concerns over efficacy and complication rate. Although responses varied, the most common use for thrombolysis remained acute limb ischemia, most often from vascular graft thrombosis.

One of the major reasons behind the drop in thrombolytic therapy over the last several years was the recall of urokinase, with subsequent reliance on tissue plasminogen activator (t-PA). Although there has been a general impression that t-PA is associated with increased bleeding problems, Sugimoto and associates¹⁶⁸ found that safety and efficacy of low-dose t-PA (<2 mg/hour) combined with subtherapeutic heparin was equivalent to urokinase and therapeutic heparin in a retrospective analysis of nonrandomized patients. In their review, which included both arterial and venous thromboses, t-PA was associated with more rapid clot lysis and less expense. It is not clear if the reemergence of urokinase on the American market has had significant effect. Efforts to improve the efficacy of thrombolysis, reducing treatment times and complications, have involved modification of the lytic protocols in several ways. Mumme and colleagues¹⁶⁹ reported increased efficacy of high-dose fibrinolytic therapy (0.5 mg/kg body weight rt-PA) combined with regional hyperthermic perfusion in patients who had undergone unsuccessful catheter thrombectomy for extensive deep vein thrombosis (DVT). This study, which involved 53 patients, was associated with 60% success, 4% bleeding complications, and 2% pul-
monary embolism. Mechanical thrombolysis has been used with increasing frequency as an alternative to chemical infusions, primarily in venous thromboses and arteriovenous grafts. At the annual meeting of the AAVS, Sarac and colleagues reported results of a technique combining mechanical and chemical thrombectomy in the treatment of acute and chronic arterial occlusions. Their results involved 26 patients at 12 different centers, but they suggest that this technique may be as effective as catheter-directed chemical thrombolysis, while associated with reduced procedure time and bleeding complications. The current cost of the device may limit its widespread adoption.

Management of suprainguinal PVOD has shifted from open to percutaneous techniques in the vast majority of patients. But, young patients with aggressive aortoiliac atherosclerosis remain a particularly difficult group to treat. Reed and associates reported on results of aortofemoral bypass in 45 patients 50 years of age compared with groups 50 to 59 years old and 60 years or older. Younger patients had smaller aortas, were more likely to require subsequent infrainguinal reconstruction, and experienced the lowest 5-year patency rates. Because the indication for operation was more often claudication in the younger patients, these results are even more sobering, and they suggest that endoluminal treatment may be preferred in younger patients with suitable anatomy.

Longterm outcomes of isolated aortic (as opposed to iliac or aortoiliac) stenosis after endovascular intervention was reported by Feugier and coworkers. Treatment in 86 patients involved a single-balloon technique in 60 patients and double-balloon technique in 26 patients. Stents were placed in 88% of patients. Initial technical success was achieved in 92%, with 1.2% mortality and 9.3% morbidity. Primary patency was 77% at 5 years. Because the mean age of these patients was 53 years, this experience provides an interesting counterpoint to Reed’s report.

Endoluminal treatment of more complex aortoiliac disease often requires the use of “kissing stents.” The results of this technique in 25 patients are reported by Greiner and coauthors. Overall, 49 segments were treated (41 stenoses, 8 occlusions), and technical success was achieved in 86% of patients, with primary assisted patency of 65% at 2 years. These results are not as good as those for isolated aortic disease, and patient selection will remain critical.

TransAtlantic Inter-Society Consensus (TASC) recommendations indicate that long stenoses or occlusions are best treated by open operation rather than percutaneous angioplasty. Ali and colleagues presented data on the use of angioplasty combined with covered stents in the treatment of complex (TASC C and D) lesions of the iliac arteries. These authors found a 2-year patency of 84%, suggesting that use of covered stents may extend the applicability of percutaneous therapy in patients with more complex aortoiliac lesions. The reasons for this improvement are unclear, but they may be related to a smoother intimal lining or more aggressive dilation because the covered stent would protect against bleeding from arterial rupture.

Infrainguinal therapy has also seen a shift from open to endovascular approaches, though the role of open surgery remains most secure in this area. The issue of the most appropriate conduit for above-knee femoropopliteal bypass was addressed by Klinkert and associates in a prospective randomized trial involving 151 bypass grafts. These results showed superior performance for saphenous vein compared with PTFE (75.6% versus 51.9%). The 5-year survival in this group of patients was 62%. Roddy and coworkers indicated that a policy of primary prosthetic bypass to “save the vein” is not effective. In their series of 672 reconstructions, one-third of patients who needed secondary reconstructions did not have suitable vein available. It appears clear that if vein is available, it should be used at the first operation. The major indication for infrainguinal bypass has been limb salvage. A Finnish report analyzing bypass and amputation rates in hospitals where there was either an active or a passive approach to infrainguinal bypass demonstrated an inverse relationship between the frequency of bypass and the amputation rate. Although this is comforting information, initial infrainguinal bypass is often not suitable as sole therapy for these patients. In a study of 318 patients, Goshima and coauthors documented that nearly 50% of patients required readmission within 6 months and 40% required a second operation for limb salvage. The group at the New England Deaconess Hospital presented three reports of their extensive experience with infrainguinal bypass. They confirmed the finding of Kaoru, reporting that 16.5% of their patients required an additional ipsilateral procedure and 21% a contralateral revascularization. Their operative results (1.16% mortality and 90.6% 5-year limb salvage) were outstanding, but diabetes, end-stage renal disease, and
gangrene were predictors of reduced long-term outcomes. Even moderate renal dysfunction (Cr of >2.0 mg/dL) was a significant risk factor in their series.\textsuperscript{181}

Identification of bypass grafts at risk for occlusion can be facilitated by duplex scanning. Identifying technical errors using completion ultrasonography has been widely reported in the literature. Rzucidlo and colleagues\textsuperscript{182} reported that intraoperative duplex evaluation at completion of arterial bypass could not only be used to detect technical problems as reported by others, but also to predict early graft failure. In particular, the finding of low-end diastolic velocity at the proximal or distal anastomosis (<8 cm/second) predicted early graft failure in an otherwise technically adequate conduit. The authors suggested that these findings prompt measures to improve graft flow. Intraoperative duplex ultrasonography is not easily performed at all institutions. Ferris and colleagues\textsuperscript{183} evaluated the value of early (less than 6 weeks postoperative) duplex ultrasonography to identify grafts at high risk for thrombosis. Abnormalities on early duplex ultrasound were found in 26% of grafts despite normal completion angiography. Although one-third of these abnormalities resolved, more than half of the abnormal scans led to operative revision of the conduit. Although further data on the natural history of grafts with abnormal velocities are needed, it is apparent that if completion duplex ultrasonography is not performed in the operating room, it should be done in the early postoperative period. Completion angiography cannot exclude lesions of potential significance.

When patients with prosthetic inflow to the groin require infrainguinal reconstruction, a decision must be made whether the outflow conduit should originate from the proximal prosthetic bypass or the native circulation. Lam and associates\textsuperscript{184} reported on 229 patients in whom this situation occurred. Five-year patency was improved in the group in which inflow was taken from the native artery rather than the prosthetic bypass (72% versus 50%, respectively) because the occlusion of the proximal prostheses was almost uniformly associated with distal graft occlusion in the latter groups, at the same time distal graft perfusion was maintained in 80% of grafts originating from an autogenous artery. It is important to note that distal reconstructions in this series were all autogenous so were able to tolerate low (but not absent) inflow when proximal graft occlusion occurred. Limb-threatening acute arterial occlusion from atheroemboli (“trash foot”) is a difficult clinical problem. Mahmood and colleagues\textsuperscript{185} report results with open embolectomy of tibial vessels at or below the ankle, often under local anesthesia. Patency rates of 69% with limb salvage rates of 62% recommend this technique as an alternative in these difficult situations.

Alternatives to arterial bypass are becoming more popular. These techniques all aim to revascularize the lower extremity with minimal incisions, or percutaneously. Smeets and his colleagues\textsuperscript{186} continue to accumulate experience with remote endarterectomy of the superficial femoral artery. They reported\textsuperscript{184} procedures (70% for claudication) with 5-year assisted primary patency of 48%, which approximates the results of above-knee bypass with prosthetic. The average length of occlusion in their series was 31 cm.

Endovascular alternatives are becoming increasingly common, particularly in Europe. Jamsen and associates\textsuperscript{186} reported on 233 patients (308 limbs) with claudication followed for a mean of 81 months. Although a mean of two operations per limb were performed during followup, 50% of limbs required no additional intervention. Overall patency rates were 61% at 5 years and 41% at 10 years. Surgical treatment was required in 21% of patients during followup, but was avoided in the remainder. Results such as this have prompted many European centers to pursue endoluminal approaches as first-line therapy in all patients with infrainguinal occlusive disease.

Nasr and coworkers\textsuperscript{188} reported that in their institution the numbers of femorotibial bypasses and tibial angioplasties performed as primary procedures were equivalent over a 5-year period—a strong argument for the acquisition of endovascular skills by the vascular surgeon. Encouraging results of endovascular therapy have also been reported from centers in the US. Costanza and colleagues\textsuperscript{189} treated 112 limbs in 93 patients. All patients had TASC B lesions (stenosis of <5 cm) and 82% were claudicators. One-year patency rate was 54%, and was not improved by stent placement. Vogel and colleagues\textsuperscript{190} reported on 41 patients who had placement of nitinol stents in the superficial femoral (35) or above-knee popliteal (6) artery. In contrast to Costanza’s results, 68% of these patients were treated for limb salvage, 54% were diabetic, and 38% had end-stage renal disease. Despite these comorbidities, the authors reported a 2-year primary assisted patency of 90% with a limb salvage rate of 89%.
The question of routine or selective stent placement after infrainguinal angioplasty was addressed by Becque-min and colleagues, who described on 227 patients prospectively randomized between routine and selective stent placement after angioplasty of the superficial femoral artery. No advantage to routine stent placement was found. Pozzi Mucelli and associates reported similar results in 86 limbs treated by superficial femoral percutaneous transluminal angioplasty (PTA) with or without stent for claudication. Saxon and coworkers reported on their single-center experience that was part of a larger multicenter trial evaluating the role of covered stents combined with angioplasty. They showed increased primary patency at 2 years in the covered stent group (87% versus 25%), but there were only 28 patients in their single-center experience. Covered stents may be detrimental in the treatment of stenotic in contrast to occluded lesions because they sacrifice collateral in the stenotic area.

Although PTA is useful in short stenosis or occlusion, longer infrainguinal occlusions do not fare as well. Subintimal angioplasty is increasingly being investigated in treating these lesions. Early success rates are in the 80% range, with low periprocedural morbidity. But patency rates at 18 to 24 months are less than 40%. This technique has the advantage that collateral may often be salvageable if occlusion occurs. The technique may be best suited for treating patients with critical limb ischemia. Its current role in claudication is unclear, in view of the other alternatives of nonoperative and interventional therapy described above.

**Thromboembolism and venous disease**

In sheer volume, thromboembolic disease and venous insufficiency are more common than peripheral arterial insufficiency and affect a broader range of the population. A systematic review of strictly selected articles on the incidence of DVT by Fowkes and colleagues estimated a mean incidence of first DVT of 5.04 per 10,000 person years. Incidence was similar between genders, but increased dramatically with age to 20 per 10,000 patient years in patients between the ages of 70 and 79 years. In 40% of cases, the cause of DVT was unknown. Low molecular weight (LMW) heparin has emerged as the treatment of choice for DVT of the lower extremities. A report by the “Matisse” investigators compared low molecular weight heparin given once daily without monitoring to continuous intravenous heparin for the initial treatment of pulmonary embolism. Longterm therapy in both groups was initiated with vitamin K antagonists. Once-daily low molecular weight heparin was as safe and effective as continuous intravenous therapy. One-third of the patients in the low molecular weight heparin group were treated as outpatients. Cellular adhesion molecules, such as P-selectin, are critical in the thrombotic process. P-selectin inhibitors have been shown to inhibit thrombus formation. Myers and associates demonstrated that P-selectin inhibition can also accelerate thrombus resolution in a rat model of vena caval ligation. Modifications of the inflammatory process by manipulation of adhesion molecules and inflammatory cytokines might be a novel approach to DVT.

Chronic venous insufficiency is a ubiquitous, multifactorial phenomenon. Several presentations demonstrated an association between chronic venous insufficiency and obesity, even in the absence of demonstrable venous reflux on duplex examination. This might be from chronic venous hypertension from increased caval pressure. Padberg and colleagues demonstrated improvement in calf muscle strength and calf muscle pump function in a prospective randomized trial of structured exercise. All patients had CEAP class 4 to 6 disease. This finding underscores the observation that venous ulceration is often seen in sedentary patients, and suggests muscle conditioning as an additional modality in patients with chronic venous insufficiency. Compression therapy is the other mainstay of conservative treatment of chronic venous insufficiency; such therapy is often poorly tolerated, and ulcers treated by this method alone are characterized by a high degree of recidivism. Zamboni and associates conducted a randomized clinical trial of compression therapy and operation in the management of 47 venous ulcers. Time to healing and rate of ulcer recurrence were both significantly decreased in the surgical group. This gives further impetus to the search for evidence of surgically correctable superficial venous insufficiency in patients with leg ulcers.

The role of perforator ligation in the treatment of venous insufficiency continues to be debated. Subfascial endoscopic perforator surgery (SEPS) has been associated with a significant incidence of persistence of perforating veins. Begisun and coauthors dissected lower extremity veins of 15 cadavers and demonstrated that only two-thirds of perforating veins pass through the superficial posterior compartment of the foreleg. This reinforces the point made by others that a paratibial...
fasciotomy is required if a complete SEPS procedure is to be performed. The Dutch SEPS trial randomly allocated 200 patients with active ulceration (CEAP class 6) to either compression therapy or SEPS combined with superficial venous ligation as indicated. Ulcer healing and recurrence rates were not different between the groups as a whole, though operation did show benefit in larger ulcers and those of longer duration. This experience is confirmed by the single-center experience at the New England Medical Center in which SEPS was performed on 51 limbs in 45 patients with active or healed ulcers (CEAP 5 and 6). More than half of the patients underwent stripping of the saphenous vein. Ulcers healed in 74% of patients, and the 5-year recurrence rate was 13%. Ulcer healing was faster in patients who had SEPS and greater saphenous stripping. Recurrence rates were correlated with reflux in the lesser saphenous vein.

Patients with superficial and perforator incompetence but without ulceration are unlikely to benefit from SEPS, and are best treated by stripping of incompetent superficial veins. Similarly, when superficial and deep venous insufficiency coexist, correction of the superficial incompetence will correct deep venous abnormalities in 50% of cases and is associated with ulcer healing in 77% of limbs. The clinical effectiveness of superficial vein surgery was also demonstrated by MacKenzie and colleagues across all categories of disease severity. Although advanced CEAP classes demonstrated poorer results, significant improvement in symptoms was still noted with saphenous stripping in this group.

Alternatives to saphenous stripping have emerged. Ablation of the long saphenous vein, from the knee to just distal to the saphenofemoral junction, using either radiofrequency or laser energy has become an increasingly popular method for treating saphenous insufficiency associated with mild or moderate reflux. Results of large trials using both methods have been published, showing excellent immediate and intermediate results. Radiofrequency ablation is not recommended for veins larger than 10 to 12 mm in diameter and may not be possible with extremely tortuous veins. The advantages of both techniques are more rapid patient recovery associated with less invasive, often percutaneous approaches. Transilluminated power phlebectomy (TIPP) has enjoyed less success. This method, which is used to remove secondary varicosities, has been developed as an alternative to hook phlebectomy. Early results with transilluminated power phlebectomy in both nonrandomized and randomized trials showed no improvement in pain, cosmetic results, or patient satisfaction when compared with hook phlebectomy. In the randomized trial, it was associated with a shorter operative time that was not statistically significant. It is likely that this technique will find its major use in patients with extensive secondary varices. Sclerotherapy is the mainstay in treatment of patients with small (<3 mm) varicose veins. Posttreatment pigmentation can be a problem. Scultetus performed a randomized controlled trial of microthrombectomy performed within 1 to 3 weeks after sclerotherapy. Microthrombectomy was beneficial in reducing pigmentation in patients with small (<1 mm) varices, and the pain and inflammation associated with post sclerotherapy thrombophlebitis in patients with larger (1 to 3 mm) veins.

The role for surgical correction of deep venous obstruction and insufficiency remains elusive. Several articles described animal and human experiments with implantable tissue valves. Teebken and colleagues reported on a tissue-engineered valve using decellularized donor allogeneic veins repopulated with antigenous myofibroblasts and endothelial cells. When implanted in sheep, these bioengineered valves remained patent and competent. In contrast, Neglen and Raju showed disappointing human results with cryopreserved vein valves. Patency and competency rates at 24 months were not good, and ulcer recurrence was 50%. It does not appear that these valves are clinically useful in their current state. Endovascular placement of prosthetic vein valves is currently in clinical trials. Such endovenous placement would obviate some of the problems associated with early anticoagulation and open operations. Salles-Cunha and associates reported on femoral vein size and size variation in 20 subjects under various conditions. Large variations in vein diameter were seen from patient to patient and within the same patient during changes in position and with exercise. These variations represent a significant challenge in valve design which will need to be addressed.

Raju and colleagues described encouraging results with percutaneous recanalization of long segments of occluded iliac and common femoral vein using self-expanding stents. An average length of 22 cm of vein was recanalized using three stents. Improved results were noted when stents extended into the inferior vena cava. Secondary patency rates of 76% were reported, with
relief of pain and healing of ulcerations in about two-thirds of patients. These provocative results will need to be confirmed by other investigators. Scultetus and associates gave longer results in 57 patients with pelvic venous congestion syndromes. Patients with mild symptoms were adequately treated by sclerotherapy and local excision of varices. Surgical excision was superior to embolization in patients with gonadal vein reflux. In contrast, when tributaries of the hypogastric vein were involved, embolization of incompetent branches was superior to surgical division. These results stand as guidelines for treatment of women with this unusual but potentially debilitating syndrome.

Finally, two large series on the management of venous and aortovenous malformations were published. These established the beneficial role of multiple sessions of sclerotherapy for management of venous malformations and the importance of repeated embolizations including the use of cyanoacrylate glue in the treatment of arteriovenous malformations. Both articles stressed the importance of a multidisciplinary approach and lifetime followup. An individual surgeon will have relatively little experience with cases such as this, and the cumulative experience from these two centers of excellence provide important reference data.

Dialysis access

Construction and maintenance of access for hemodialysis constitute one of the major responsibilities and challenges facing the vascular surgeon. Native arteriovenous fistulas are the preferred conduit for dialysis because of their superior patency rates. In a large series by Fisher and Neale, autogenous fistulas were initially created in 75% of patients. During followup of 273 access procedures, 172 revisions were required and 44% of patients ultimately had a prosthetic bridge graft placed. When cephalic vein is not available, transposed basilic vein may serve as a suitable substitute. Gormus and coworkers achieved equivalent results using basilic transpositions in either the forearm or the upper arm. When a synthetic conduit is required, shorter patency is usually expected. Rosas and colleagues studied 284 patients with PTFE graft placement over a 4½-year time frame. Graft dysfunction or failure was seen in 61%. Adverse events were associated with a history of claudication, earlier access grafts, and use of clamps during access creation. Use of the axillary vein as the venous outflow was associated with improved outcomes. Configuration of prosthetic graft (ie, straight versus tapered) did not affect patency rates in a multicenter prospective randomized trial in the Netherlands. All grafts were placed as forearm loops. This can remain a matter of surgeon’s choice. When upper arm autogenous grafts are selected, use of grafts with a flow diffuser at the venous anastomosis to reduce shear stress is supported by both experimental data and clinical data. Polyurethane grafts have the potential advantage of immediate access after placement because of improved sealing. Longterm data from Kiyama and associates demonstrated performance identical to that of PTFE. New bioengineered grafts are being developed with the hope that their patency rates may exceed those of PTFE. These are not currently in widespread use in the US.

Access complications include thrombosis, aneurysmal degeneration, infection, and central venous stenosis. Green and coworkers performed a metaanalysis comparing surgical thrombectomy, mechanical thrombectomy, and pharmacomechanical thrombolysis for salvage of thrombosed dialysis grafts. Review of the available trials indicated that surgical thrombectomy is superior to current percutaneous techniques in terms of both immediate success and late patency. Nonetheless, percutaneous techniques are still frequently used, often because of convenience. Establishing a “dialysis access center” may make surgical thrombectomy more convenient and increase use of this technique. When pseudoaneurysms develop in access grafts, surgical revision is often undertaken, frequently removing that graft from use until healing occurs. Linet and coauthors reported use of covered stents to repair these lesions in an animal model, and this concept has been successfully extended to humans. The area of the covered stent can be accessed within 1 to 3 weeks after placement. When prosthetic bridge grafts become infected, partial graft excision may provide a mechanism to prolong access site use. Ryan and colleagues reported a 75% success rate in 15 grafts managed by partial graft excision in the face of local infection but without signs of systemic sepsis.

Central vein obstruction is a common occurrence in patients who have been on dialysis for extended periods of time. This can be managed by either surgical intervention or percutaneous dilation. Dammers and associates described 45 interventions in 28 patients with central vein obstruction. Three-quarters of the interventions were percutaneous. Initial success rate was 92% by both methods. One-year primary patency was 75% after
operation and 50% after PTA. They recommend PTA as the initial therapy with surgery reserved for PTA failure. Patients currently survive on dialysis for many years. An increasing number of patients as a consequence, are encountered in whom conventional upper extremity access is no longer possible. An implantable dual port system for hemodialysis has been evaluated for patients in whom conventional access is deemed no longer possible. Results have been mixed, with early success giving way to a late incidence of device infection within the first year. More data are needed. The problems presented by this group of patients remain unresolved.

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