

The recognition that atherosclerosis is a systemic process means that the fields of cardiology and vascular surgery frequently overlap. The cardiologist should have an understanding of the recent developments in the treatment of carotid artery disease, aortic aneurysms, and chronic limb ischaemia. Similarly, the vascular surgeon should recognise the incidence of coronary artery disease in their patients presenting with peripheral vascular disease and the need for cardiological assessment. The cooperation between the two specialties is being accelerated by the rapid development of endoluminal and minimally invasive techniques in each field.

PERIOPERATIVE CARE IN VASCULAR SURGERY

Enthusiasm for vascular surgery have always been tempered by the rate of perioperative morbidity and mortality resulting from the nature of the surgery and the co-morbidity of the patient. In many institutions, patients undergoing major vascular surgery are managed in general surgical wards. In this setting, there may be poor recognition among nursing and medical staff that these patients are at greater risk than general surgical patients because of the very high prevalence of significant, yet often occult, coronary artery disease. The development of vascular surgery as a subspecialty and the growth of specialised vascular units address this problem but will place increasing demands on the local cardiology services.

The most common cause of postoperative death after vascular surgery is myocardial infarction. Appropriate preoperative assessment can be problematic as nearly half of all vascular operations are urgent or emergency procedures. There has been controversy about how much preoperative investigation and intervention for coronary artery disease is of proven benefit in patients undergoing major vascular surgery. Most work has concentrated on surgery for abdominal aortic aneurysm since it is one of the most common vascular surgical procedures and stresses the heart, with increased afterload during aortic cross-clamping and blood loss. There is good evidence that if a patient has no previous history of coronary artery disease and a normal preoperative ECG, there is no benefit to preoperative invasive cardiological investigation.¹ A previous history of ischaemic heart disease or significant ECG changes warrants further preoperative investigation with stress echocardiography or scintigraphy, proceeding in some to coronary angiography and intervention.

There is evidence that patients undergoing aortic surgery receiving β blockade have a lower incidence of perioperative myocardial infarction,² and a β blocker should be started preoperatively unless there are contraindications. By contrast, angiotensin converting enzyme (ACE) inhibitors should be used with circumspection since between 30–50% of patients with aortic disease have renal artery stenosis.

Modification of atherosclerotic risk factors is as important in peripheral arterial disease as in coronary artery disease, and all patients with symptomatic atherosclerosis should be on an antiplatelet agent (usually aspirin), appropriate antihypertensive treatment, and a statin if the fasting cholesterol is more than 3.5 mmol/l. Smoking is particularly closely associated with peripheral arterial disease, even more so than coronary artery disease, and up to 78% of cases of intermittent claudication can be attributed to smoking. Patients should be offered access to a smoking cessation clinic and nicotine replacement therapy.

It is important to reduce the perioperative stress of surgery by minimising the cardiovascular stress of the operation and providing good postoperative analgesia. Regional anaesthetic techniques such as spinal or combined spinal epidural anaesthesia now allow many lower limb operations to be performed under sedation without general anaesthesia. Epidural analgesia can provide effective relief from the pain of the abdominal incision after aortic surgery and allows patients to be extubated earlier as well as reducing the postoperative stress induced by pain. Similarly, carotid endarterectomy is frequently performed under local anaesthesia and will be discussed in detail later.

See end of article for authors' affiliations

Correspondence to:
Mr John H N Wolfe,
Department of Vascular
Surgery, St Mary's Hospital,
Praed Street, London
W2 1NY, UK; john.wolfe@
st-marys.nhs.uk

Cardiac investigations before abdominal aortic surgery

- ▶ If a patient has no history of ischaemic heart disease and a normal ECG, there is no benefit in further routine cardiological workup before abdominal aortic surgery
- ▶ If a patient gives a history or has ECG changes suspicious of coronary artery disease, then early investigation with a view to intervention is warranted.

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CAROTID ARTERY DISEASE

Carotid artery surgery in symptomatic patients

The indications for carotid surgery for symptomatic carotid stenoses were clarified by the North American symptomatic carotid endarterectomy trial (NASCET) and European carotid surgery trial (ECST) with the publication of the interim results of these trials in 1991 and long term results in 1998.^{3,4} The trials studied patients with carotid artery stenosis who had suffered a recent non-disabling ipsilateral hemispheric stroke, transient ischaemic attack, or amaurosis fugax. Patients were stratified according to the degree of carotid artery stenosis on angiography and randomised to carotid endarterectomy or best medical management. Differences in the measurement techniques used in the two studies means that a stenosis of 80% in ECST is approximately equivalent to a stenosis of 70% in NASCET. Duplex ultrasonography has developed dramatically since the start of these trials and is used in many centres as the single assessment of carotid stenosis; this has the added advantage of avoiding the 1% risk of stroke associated with selective carotid angiography. To apply the findings of the trials accurately, the vascular technologist must be able to correlate the direct diameter reduction and velocity ratio criteria used in Duplex measurements with the angiographic criteria used in NASCET and ECST. It is widely appreciated that magnetic resonance angiography (MRA) tends to overestimate the degree of stenosis.

Severe internal carotid artery stenosis (70–99%)

Both NASCET and ECST showed a clear benefit of carotid endarterectomy in preventing subsequent ipsilateral stroke, including disabling and fatal stroke, in patients with a severe (70–99%) internal carotid artery stenosis.

The incidence of early postoperative stroke or death was 5.8% in NASCET and 7.5% in ECST. Longer term follow up showed a two year incidence of any ipsilateral stroke in NASCET of 9% in the surgical cohort compared with 26% in the control cohort. ECST showed a similar benefit with a three year incidence of any ipsilateral stroke of 10.3% in the surgical cohort compared with 16.8% in the control cohort. The majority of the ipsilateral strokes in both trials were not disabling.

As the majority of the ipsilateral strokes seen after carotid surgery are not disabling, a more clinically relevant end point is the combined incidence of disabling or fatal stroke after endarterectomy. Fatal or disabling stroke had occurred after two years in 2.5% of NASCET patients undergoing endarterectomy compared with 13.1% in the medical control group. Three year results in ECST showed 3.7% of patients suffered a disabling or fatal stroke after surgery compared with 8.4% in the medical control group.

The continued benefit of carotid endarterectomy in patients with a high grade symptomatic stenosis has been

confirmed in the long term follow up of both trials. The incidence of any ipsilateral stroke at eight years follow up in NASCET was 14% in the surgical group compared with 27% in the medical control group. Subgroup analysis in ECST suggests that women may only gain benefit with endarterectomy in the presence of a 90% stenosis using the ECST measurement technique.

Moderate internal carotid artery stenosis (30–69%)
NASCET demonstrated a marginal benefit for carotid endarterectomy in symptomatic patients with a moderate carotid stenosis, although this was limited to those with stenoses measuring 50–69% using the NASCET technique. In these patients, the five year incidence of any ipsilateral stroke was 16% in the surgical group compared with 22% in the medical control group. Because of the differences in measurement criteria, a NASCET stenosis of 50–69% corresponds to an ECST stenosis of 70–80%. Current practice is to consider carotid endarterectomy for symptomatic stenoses over 70% on direct diameter reduction criteria.

Mild internal carotid artery stenosis (0–29%)

The risk of stroke in patients with a mild internal carotid stenosis was studied in ECST. This showed a very low incidence of ipsilateral stroke with medical management and the risks of carotid endarterectomy cannot be justified in these patients.

Carotid artery surgery in asymptomatic patients

The carotid artery is a common site for the development of atheroma, and screening studies in the general population have shown an incidence of significant (> 50%) internal carotid artery stenoses increasing from 0.5% in those in their 50s to 10% aged over 80 years. The vast majority of these stenoses are asymptomatic and the indications for intervention are much less clear than in the symptomatic patients studied in NASCET and ECST. The cardiologist may detect asymptomatic carotid artery disease as a clinical finding of a carotid artery bruit during preoperative cardiac surgical assessment or as an incidental finding during angiography.

A number of trials have tried to define the indications for carotid intervention in asymptomatic carotid artery disease, although until recently the evidence for intervention has been obscured by inadequate statistical power or flawed design of many of the studies. The asymptomatic carotid

Carotid artery disease

- ▶ Carotid endarterectomy is indicated for symptomatic internal carotid artery stenosis of 70% or greater (level 1 evidence)
- ▶ Surgery is indicated in selected cases of asymptomatic internal carotid artery stenosis of 70% or greater (forthcoming publication of asymptomatic carotid surgery trial will further clarify indications)
- ▶ Carotid artery stenting has not yet achieved results equivalent to those of carotid endarterectomy reported in the NASCET/ECST/ACST trials (patients considered for carotid artery stenting should be enrolled in the CAVATAS-2 trial)
- ▶ Prophylactic carotid endarterectomy for asymptomatic disease before coronary artery bypass is only indicated in the presence of bilateral severe internal carotid artery stenosis

atherosclerosis study⁵ was a US trial that randomised asymptomatic patients with severe carotid stenoses (equivalent to an ECST stenosis of 75%) to endarterectomy or best medical management. The trial demonstrated a 5.1% risk of stroke after two years in the endarterectomy group compared with an 11% risk in the medical control group, but was criticised for inconsistencies in the measurement of carotid stenoses and an inverse relation between the degree of stenosis and the risk of stroke.

A European study, the asymptomatic carotid surgery trial (ACST), announced its interim results in late 2003 and has recently been published.⁶ It has confirmed the benefit of carotid endarterectomy in asymptomatic patients with severe carotid artery stenosis. In common with other trials, there is an incidence of early stroke and death after carotid surgery (3.1%) followed by a reduction in subsequent overall risk of disabling or fatal stroke. To achieve this overall benefit, patients undergoing endarterectomy must survive for at least four years after surgery. The authors of the study conclude that carotid endarterectomy for asymptomatic severe internal carotid artery stenosis conveys significant benefit only to patients under the age of 75 years with a reasonable expectation of five year survival. It has been estimated that 16 carotid endarterectomy operations for asymptomatic disease are required to prevent one disabling or fatal stroke. At present, there are no plans to routinely screen the population for asymptomatic carotid artery disease, but in the light of the ACST results, suitable patients with severe stenoses should be referred for consideration of carotid artery surgery.

Cardiac surgery and carotid artery disease

Ten per cent of patients undergoing coronary artery bypass grafting (CABG) have a co-existent carotid artery stenosis causing a greater than 50% reduction in diameter.⁷ There is an increased risk of perioperative stroke in patients with severe carotid stenoses undergoing CABG, thought to be related to the haemodynamic effect of these lesions critically reducing cerebral blood flow during the period of intra-operative systemic hypotension. An estimated 3.8% of patients with a unilateral severe stenosis, and 8.3% of those with bilateral severe stenoses, will suffer a perioperative stroke following CABG.⁸ Nevertheless, approximately 50% of these strokes following CABG are not attributable to carotid disease.

Despite these increased risks, the indications and timing of carotid interventions in the context of cardiac surgery remain controversial. If the carotid artery disease is symptomatic, then endarterectomy is indicated on the basis of the NASCET and ECST results. It also seems appropriate to consider

endarterectomy in the presence of asymptomatic bilateral severe carotid stenoses (> 80%) before cardiac surgery in order to reduce the haemodynamic effect of the stenoses and potentially reduce the higher risk of stroke in these patients. The situation with asymptomatic unilateral severe carotid artery stenosis is less clear, as the potential reduction in perioperative stroke rate may be less than, or at least comparable to, the risk of stroke and death associated with carotid endarterectomy itself. The benefits of surgery on asymptomatic carotid artery disease seen in the ACST and ACAS trials are not directly applicable to patients undergoing cardiac surgery as a prolonged period of survival is required to gain any overall benefit from a reduction in embolic risk. In our unit, the decision to offer prophylactic carotid endarterectomy before coronary grafting is based on the risk of stroke attributable to carotid artery disease and audit of the stroke and death rate after carotid surgery as outlined in table 1.

The optimal timing of carotid endarterectomy and CABG remains controversial and, although some investigators have found a benefit with synchronous surgery, a meta-analysis of published series has not demonstrated superiority for either staged operations or synchronous surgery.⁹

Carotid artery stenting

The development of endoluminal angioplasty and stent technologies has revolutionised coronary artery interventions, but the application in peripheral arteries remains the subject of considerable debate. Percutaneous endoluminal techniques have obvious attractions, but the introduction of this technology in carotid artery disease has been tempered by significant morbidity with the early experience.

Unlike coronary artery intervention, the most common indication for carotid artery intervention is not for haemodynamic benefit or to preserve vessel patency, but rather to reduce the thromboembolic risk associated with an unstable atherosclerotic plaque. The lessons and techniques of coronary intervention are not, therefore, necessarily directly transferable to the carotid artery. The slow uptake of carotid angioplasty by vascular surgeons and interventionists can be understood by the paucity of evidence from robust randomised controlled studies. This is in contrast with the sound evidence base established for surgical carotid endarterectomy by the NASCET, ECST, and ACST trials. We therefore need to embrace the important International carotid stenting study (ICSS) that is currently recruiting.

Although there have been numerous reports of small series of selected patients undergoing successful carotid artery stenting, there are few randomised controlled clinical trials. The carotid and vertebral artery transluminal angioplasty

Table 1 Estimated stroke risk in patients with carotid artery disease undergoing coronary artery bypass grafting (after Naylor *et al*⁷) and operative death and stroke rate in our unit

	No significant carotid artery disease	Unilateral 50–99% stenosis	Bilateral 50–90% stenosis	Carotid occlusion and contralateral >70% stenosis
CABG stroke risk	~2%	~3%	~5%	~7–11%
Stroke risk attributable to carotid disease	0%	~1.5%	~2.5%	~3.5–5.5%
Operative risk of carotid endarterectomy at St Mary's Hospital	n/a	<2%	<2%	<4%

CABG, coronary artery bypass grafting.

study¹⁰ is the largest study to date in which 560 patients, from 24 international centres, randomised selected patients considered suitable for angioplasty to either carotid endarterectomy or endovascular therapy. The study reported a similar 30 day incidence of disabling stroke and death in the surgical (5.9%) and endovascular groups (6.4%). The incidence of all strokes, including non-disabling stroke, was also similar (9.9% *v* 10%). The trial has been criticised because the incidence of all strokes, disabling and fatal strokes is much higher in the surgical arm than was seen in the much larger NASCET, ECST, and ACST trials (disabling/fatal stroke 2.5–3.7% at three years), undermining the authors' conclusions that endovascular therapy is comparable to surgery. The immaturity of the current carotid angioplasty techniques was further highlighted by a second randomised trial that was stopped early because of a significant excess of strokes in the carotid angioplasty arm.

Endovascular therapy will undoubtedly find its role in carotid artery disease as the technology and understanding of the indications improves. One such example is the use of filters to capture distal emboli released during stent deployment. Surgical protagonists argue that the results of carotid endarterectomy have continued to improve with the use of local anaesthetic techniques, selective shunting, and patching. The widespread use of endovascular treatment for carotid artery disease can only be adopted in the context of robust clinical trials establishing equivalence or benefit over the well proven and extensively audited carotid endarterectomy operation. The morbidity of this operation is currently almost exclusively associated with the incidence of stroke.¹¹

LOWER LIMB ATHEROSCLEROSIS

Atherosclerotic disease affecting the lower limbs is often asymptomatic but presents with intermittent claudication or critical ischaemia.

Intermittent claudication

While intermittent claudication can cause significant disability, the disease process is stable and only 15% deteriorate and progress to critical limb ischaemia. The priority for the clinician is to assess and treat the holistic aspects of atherosclerotic disease by assessing and modifying risk factors and instigating antiplatelet, antihypertensive, and statin treatment as indicated. The major risk to the patient with intermittent claudication is co-existent, often occult, coronary artery disease. This is primarily responsible for a threefold increase in the relative risk of cardiovascular death seen in claudicants compared with age matched controls.

The natural history of intermittent claudication is variable and approximately half of all patients improve significantly without intervention as collateral arteries dilate and improve blood supply to the affected muscle groups. A study of nearly 2000 patients with untreated intermittent claudication showed that over a period of a year, only 5.5% had symptomatic deterioration to an extent that required intervention and only 1.6% progressed to amputation.¹² This variable natural history has often made clinical studies of intervention difficult to interpret.

Exercise benefits claudicants, although compliance with simple advice alone is often poor. Many studies have shown significant benefit with supervised exercise programmes resulting in a mean improvement of 105% in the maximum walking distance. Drug treatment of intermittent claudication is a contentious issue, as the natural history of the

condition and poor study design has resulted in many clinical trials demonstrating marginal or equivocal benefit for a number of drugs. Cilastazol may improve the exercise tolerance in moderate claudicants.

Balloon angioplasty for intermittent claudication can provide good early results in patients with suitable lesions. Intraluminal angioplasty of femoropopliteal lesions less than 10 cm in length is technically successful in 80–90% of cases but with a small risk of complications requiring surgery (< 2%) or resulting in amputation (< 0.3%). The long term results with angioplasty are less encouraging, with high rates of restenosis or adjacent disease progression leading to a return to original symptoms within 1–3 years. Two randomised trials of balloon angioplasty versus exercise for intermittent claudication both showed an early benefit for angioplasty. In the Edinburgh trial,¹³ the improvement in exercise tolerance in the angioplasty group was not sustained and by two years there was no difference in the exercise tolerance compared with the group simply advised to exercise. The Oxford trial¹⁴ compared angioplasty with a supervised exercise programme and found a similar early benefit with angioplasty. This benefit was not maintained at six months, however, and after this time the walking distance in the supervised exercise group was better than in the angioplasty group.

Stents have been used to try to improve the poor long term patency with balloon angioplasty in intermittent claudication. Stent placement during femoropopliteal angioplasty has not been shown to improve haemodynamic or clinical outcome. The use of stents in the iliac arteries has become more common and a number of studies have suggested a benefit in long term patency. This benefit was not confirmed in a Dutch randomised study comparing balloon angioplasty with primary stenting, with a two year cumulative patency of 70% in both groups.¹⁵ Percutaneous transluminal angioplasty (with or without stent placement) has therefore become the first line treatment for iliac disease causing intermittent claudication.

Bypass surgery for intermittent claudication is reserved for the small proportion of patients who are left with severely disabling claudication after a failure of conservative management and with disease not amenable to angioplasty. In these patients there must be careful counselling about the risks of surgery and specifically about the rare (approximately 1%) but catastrophic risk of serial failures resulting in amputation.

Critical limb ischaemia

Critical limb ischaemia occurs when the severity of chronic limb ischaemia has deteriorated to the extent that the viability of the limb is threatened. Critical ischaemia presents as ischaemic rest pain in the foot or tissue loss with

Lower limb atherosclerosis

- ▶ Intermittent claudication should be initially managed with active modification of risk factors and exercise
- ▶ Angioplasty of significant iliac artery stenoses can provide durable symptomatic improvement (level 2 evidence)
- ▶ Aggressive management of critical limb ischaemia can give limb salvage rates of approximately 70% (TASC international consensus—level 3 evidence)

Table 2 Average results for surgical treatment from pooled data in published series. Distal bypass with prosthetic conduit is still associated with poor long term patency. From TransAtlantic Inter-Society Consensus¹⁶

Site of bypass	Primary patency rate (%)		
	1 year	2 years	5 years
Aortobifemoral	96	92	92
Femoro-femoral	86	76	70
Femoro-distal (vein)	84	78	70
Femoro-distal (prosthetic)	72	36	28

ulceration or gangrene. Patients with critical limb ischaemia should be referred for urgent vascular surgical opinion.

In contrast with intermittent claudication, conservative management of critical limb ischaemia usually results in deterioration and potentially the loss of a previously salvageable limb. Despite the risks associated with endovascular and surgical intervention, these are justified in the face of threatened limb loss. Options for intervention include intraluminal and subintimal angioplasty; bypass surgery using autologous vein or prosthetic graft; and medical treatment with prostacyclin analogues. The TransAtlantic Inter-Society Consensus document has demonstrated that long term patency and limb salvage can be achieved in most patients with critical limb ischaemia using a combination of endovascular, medical, and surgical approaches.¹⁶ The extent and distribution of the atherosclerotic disease is a major factor in determining bypass graft patency. Aortobifemoral grafts for aortoiliac occlusive disease have in excess of 90% patency rate at five years, compared to 70% in femorodistal bypass using vein (table 2).

It has been argued that primary amputation is advisable in critical limb ischaemia to prevent the high secondary intervention rate associated with revascularisation procedures. Although there are some patients in whom this is an appropriate approach, amputation is rarely followed by a return to a significant degree of mobility in patients with severe vascular disease. The poor mobility, disfigurement, and loss of dignity associated with amputation means that revascularisation should be attempted in the majority of patients with critical limb ischaemia. This is a policy that is economically justified.¹⁷

AORTIC ANEURYSMS

Ruptured aortic aneurysm still accounts for 1% of deaths in the UK each year. Over 5.5% of men aged 65–74 years in the UK have an abdominal aortic aneurysm over 30 mm and this prevalence is at least 50% higher in patients with atherosclerosis. Although there are screening programmes in some areas of the UK, the majority of aortic aneurysms are still detected as incidental findings on clinical examination or ultrasound scanning.

There is considerable variability between patients in the rate of expansion and the size at which any individual aneurysm ruptures. This is used to excuse a policy of intervention. The risk of rupture in an aneurysm less than 5 cm is 1% per year; in an aneurysm up to 6 cm this increases to 3–4% per year, and is 9% per year in an aneurysm up to 7 cm.¹⁸ Few patients would therefore risk intervention if the aneurysm is less than 5 cm, but at greater than 6 cm the argument is persuasive. Individual judgment should be

particularly acute for those between 5–6 cm. The UK small aneurysm trial has helped to clarify the lack of benefit of surgery for relatively small aneurysms, by showing no clear benefit in added life-years for early prophylactic surgery on asymptomatic aneurysms between 45–55 mm in maximum diameter.¹⁹

The standard operation carries a significant mortality, in the region of 5% of patients deemed suitable for operation, as well as significant morbidity. This level of mortality and morbidity, though significant, must be balanced against the risk of rupture when considering prophylactic operative repair.

Endovascular aneurysm exclusion techniques have promised safer surgical repair than conventional open operation since the first reported successful deployment by Parodi in 1991. Endovascular repair avoids much of the morbidity of the open operation by introducing a covered stent graft through small groin incisions, femoral arteriotomies, and deploying the device in the abdominal aorta under radiographic guidance. There is a lower early morbidity and mortality than associated with the large laparotomy and extensive dissection of conventional open surgery, but longer term problems following endovascular repair are now well recognised.

Only a proportion of infrarenal abdominal aortic aneurysms are morphologically suited to current endovascular devices. For successful stent graft deployment, the iliac vessels cannot be too tortuous if the device is to be passed and there must be a length of normal diameter infrarenal aorta free of thrombus and without pronounced angulation for proximal graft attachment. Some devices use hooks for fixation to the suprarenal aorta to reduce the length of normal infrarenal aortic neck required, although this results in uncovered stent struts crossing the ostia of the renal arteries.

Even apparently successful stent graft deployment may not provide long term protection against aneurysm expansion as continued perfusion of the aneurysm sac (endoleak) can occur. Endoleak may lead to further expansion of the aneurysm, dislodgement of the stent graft device, and even rupture.²⁰ Despite considerable improvements in the design of the early stent grafts, further developments are necessary to overcome these limitations. Prospective reporting of endovascular aneurysm repair to international registries such as RETA, and two prospective trials of endovascular aneurysm repair versus conventional or no surgery (EVAR-1 and EVAR-2, respectively) are expected to clarify the indications and long term results with this evolving technology.

CONCLUSIONS

Peripheral vascular surgery is continuing to evolve and modern practice encompasses a broad spectrum of medical management, endovascular interventions, and conventional surgery. The roles of the different treatments are better

Abdominal aortic aneurysms

- ▶ There is no benefit for surgery on aneurysms less than 5.5 cm (level 1 evidence—UK small aneurysm trial)
- ▶ Endovascular aneurysm repair can offer some patients a lower morbidity and mortality intervention, but with a significant rate of secondary procedures and unknown long term results (EVAR trials expected to report in 2005)

defined with the publication of randomised controlled trials and international consensus documents. The continued development of technologies such as endovascular aneurysm repair and carotid artery stents with distal protection are likely to change practice in the future, but their current efficacy is yet to be established in controlled trials against conventional treatment.

Small aortic aneurysms are at low risk of rupture, and although there is support for routine screening, there are no plans at present to implement a national screening programme. Aneurysms over 5.5 cm are at higher risk of rupture and should be considered for either open or endovascular repair.

Symptomatic severe carotid stenoses should be treated with carotid endarterectomy, now commonly performed under local anaesthesia. Carotid artery stenting has not yet been shown to match the low stroke rates seen in the large endarterectomy trials and should only be undertaken in the context of a controlled trial. The recent publication of the asymptomatic carotid surgery trial is set to increase dramatically the number of carotid operations performed each year in the UK.

The first line treatment in intermittent claudication is medical management of risk factors and exercise. However, an active approach should be pursued in critical limb ischaemia. Limb salvage rates in excess of 70% can be achieved using a combination of endovascular techniques (intra-luminal and subintimal angioplasty) and bypass surgery. Primary amputation may sometimes be appropriate, but rarely leads to a return to mobility and causes disfigurement and loss of dignity.

Authors' affiliations

T W G Carrell, J H N Wolfe, Department of Vascular Surgery, St Mary's Hospital, London, UK

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Additional references appear on the *Heart* website—<http://www.heartjnl.com/supplemental>