Editor's Choice — Management of Atherosclerotic Carotid and Vertebral Artery Disease: 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS)


Keywords: Carotid, Vertebral, Stroke, Transient ischaemic attack, Endarterectomy, Stenting, Medical therapy, Screening, Dementia, Asymptomatic, Symptomatic, Thrombolysis, Imaging, Bypass, Surgical techniques, Complications, Patch infection, Restenosis

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ABBREVIATIONS AND ACRONYMS

AAA abdominal aortic aneurysm
ACAS Asymptomatic Carotid Atherosclerosis Study
ACE angiotensin converting enzyme
ACES Asymptomatic Carotid Emboli Study
ACS asymptomatic carotid stenosis
ACSRS Asymptomatic Carotid Stenosis and Risk of Stroke
ACST-1 Asymptomatic Carotid Surgery Trial (first trial)
ACST-2 Asymptomatic Carotid Surgery Trial (second trial)
ACT-1 Asymptomatic Carotid Trial (first trial)
ACTRIS Asymptomatic Severe Atherosclerotic Carotid Artery Stenosis at Higher than average Risk of Ipsilateral Stroke
AF atrial fibrillation
AHA American Heart Association
AMBDAP AMBulatory Dual Anti-Platelet
ARR absolute risk reduction
ARWMC age-related white-matter change
bd bis (twice daily)
BMS bare metal stent
BMT best medical therapy
BP blood pressure
CABG coronary artery bypass graft
CAD coronary artery disease
CAPRIE Clopidogrel versus Aspirin in Patients at Risk of Ischaemic Events
CAPTURE Carotid Acculink/Accunet Post-Approval Trial to Uncover Unanticipated or Rare Events
CARE Carotid Artery Revascularization and Endarterectomy
CAS carotid artery stenting
CAVATAS Carotid and Vertebral Artery Transluminal Angioplasty Study
CCA common carotid artery
CCB calcium channel blocker
CCF congestive cardiac failure
CEA carotid endarterectomy
CEMRA contrast enhanced magnetic resonance angiography
CETC Carotid Endarterectomy Trialists Collaboration
CFA common femoral artery
CHANCE Clopidogrel in High-risk patients with Acute Nondisabling Cerebrovascular Events
CHARISMA Clopidogrel for High Atherothrombotic Risk and Ischemic Stabilization, Management, and Avoidance
CI confidence interval
CMS Centre for Medicare and Medicaid Services
CNI cranial nerve injury
COPD chronic obstructive pulmonary disease
CPD cerebral protection device
CREST Carotid Revascularization versus Stenting Trial
CSN carotid sinus nerve
CSTS Carotid Stent Trialists Collaboration
CT computed tomography
CTA computed tomography angiography
CVR cerebral vascular reserve
DAPT dual antiplatelet therapy
DES drug eluting stent
DSA digital subtraction angiography
DUS Duplex ultrasound
DWI diffusion weighted imaging
ECA external carotid artery
WHAT HAVE THE 2017 GUIDELINES ADDED TO THE 2009 GUIDELINES?

❖ Updated analysis of evidence supporting the prevention of stroke in patients with asymptomatic and symptomatic carotid disease.
❖ New section incorporating evidence supporting the prevention of stroke in patients with atherosclerotic vertebral artery disease.
❖ New sections on screening for asymptomatic carotid disease and the potential role of carotid interventions in preventing dementia.
❖ New section on the evidence supporting rapid interventions in recently symptomatic patients and the timing of interventions after thrombolysis.
❖ New section on the evidence supporting patching, shunting, endarterectomy method, protamine reversal, treatment of coils and kinks, antegrade versus retrojugular exposure, sinus nerve blockade, and the role of monitoring.
❖ New section on the evidence supporting various carotid artery stenting techniques including adjuvant medical therapy, wires, catheters, and stents, and cerebral protection devices.
❖ New section on the evidence for managing complications following carotid interventions including...
stroke, hypotension, hypertension, haematoma, patch infection, and restenosis.
- New section on the management of concurrent carotid and cardiac disease.
- New section on the management of patients with asymptomatic carotid stenoses undergoing major non-cardiac surgical procedures.
- New section on managing patients with occlusive disease of the proximal common carotid artery and innominate artery.

1. METHODOLOGY AND GRADING OF RECOMMENDATIONS

1.1. Purpose of the guidelines
The European Society for Vascular Surgery (ESVS) has prepared guidelines for treating patients with atherosclerotic carotid and vertebral artery (VA) disease. This does not include non-atherosclerotic conditions such as fibromuscular dysplasia, dissection, arteritis, or trauma. Potential users include vascular surgeons, neurologists, stroke physicians, angiologists, primary care physicians, cardiologists, and interventional radiologists. Guidelines promote standards of care, based on evidence; however, they should not be viewed as the legal standard of care. This document is a “guiding principle” and care given depends on the individual patient (presentation, comorbidities, age) and treatment setting (techniques available, local expertise).

1.2. The Writing Group
Writing Group (WG) members were selected by the ESVS to represent clinicians involved in the treatment of carotid and VA disease. WG members provided disclosure statements regarding relationships that might be perceived as real or potential conflicts of interest, which are available at ESVS headquarters. WG members received no financial support from any pharmaceutical device, or surgical industry.

1.3. Evidence collection
The WG held an introductory meeting in Copenhagen in November 2014, at which the list of topics and author tasks were allocated. The WG agreed a literature search strategy using Medline, Embase, Cardiosource Clinical Trials Database, and the Cochrane Library databases up to December 31, 2016. Reference checking and journal hand searching added other literature. Only peer-reviewed, published literature and studies presenting predefined outcomes were considered. The selection process followed the “pyramid of evidence,” with systematic reviews and meta-analyses at the top, then randomised controlled trials (RCTs), then observational studies. Case reports and abstracts were excluded, leaving expert opinion at the bottom.

1.4. Recommendations
The European Society of Cardiology (ESC) system was used for grading levels of evidence and class of recommendation. The letter A, B, or C reflects the level of evidence (Fig. 1) and each recommendation was graded class I, IIA, IIB, or III (Fig. 2). WG members reviewed each chapter of the evolving guideline on several occasions. Following preparation of the first draft, WG members participated in a teleconference at which the wording/grading of each recommendation was reviewed. If there was no unanimous agreement, discussions were held to decide how a consensus might be achieved. If this failed, then the wording, grade, and level of evidence was secured via a majority vote of the WG members.

1.5. The review process and update of guidelines
The guidelines underwent external review by Guideline Committee (GC) members and other independent experts in the field of cerebrovascular disease. Each draft was revised according to reviewer suggestions and the final document submitted to the European Journal of Vascular and Endovascular Surgery (EJVES) on June 12, 2017. The GC proposes that these guidelines should be updated in 2021.

1.6. Definition of primary, secondary, and tertiary prevention
The WG adopted the prevention classification proposed by the Institute of Work and Health.1 Primary prevention aims to prevent carotid and VA disease from ever developing (outside the scope of these guidelines). Secondary prevention aims at reducing the clinical impact of asymptomatic carotid and VA stenoses (i.e. stenoses are present and the aim is to prevent...
them from causing a transient ischaemic attack (TIA) or stroke. The goal of tertiary prevention is to reduce the risk of recurrent TIA or stroke in patients who present with a TIA or stroke secondary to carotid or VA stenoses.

2. MANAGEMENT OF CAROTID ARTERY DISEASE

2.1. Introduction

2.1.1. Burden of stroke. In a European population of 715 million, about 1.4 million strokes occur each year. Stroke causes 1.1 million deaths annually in Europe, making it the second commonest cause of death. Over half of stroke survivors remain dependent on others for some aspect of everyday activities. Stroke imposes an enormous financial burden on health systems and caregivers. In Europe, annual stroke costs exceed 38 billion Euros.

2.1.2. Definition of stroke and transient ischaemic attack. For three decades, a stroke diagnosis has been based on the World Health Organization (WHO) definition of a focal, occasionally global, loss of neurological function lasting >24 hours (or leading to death) and which has a vascular aetiology. A TIA was defined in a similar manner, but the duration was <24 hours.

Brain imaging with magnetic resonance imaging (MRI) has shown that many TIA patients have evidence of acute infarction (particularly when symptoms lasted several hours) and this led to proposals that the classical definitions of stroke/TIA should be revised. One revised definition of TIA proposed by the American Heart Association (AHA) is “a brief episode of neurologic dysfunction resulting from focal temporary cerebral ischaemia, which is not associated with acute cerebral infarction.” Ischaemic stroke is defined as “an episode of neurologic dysfunction caused by focal cerebral or retinal infarction, where infarction is defined as brain or retinal cell death, attributable to ischaemia, based on neuropathologic, neuroimaging, and/or clinical evidence of permanent injury.” Silent infarction is defined as “imaging or neuropathological evidence of cerebral/retinal infarction without a history of acute neurological dysfunction attributable to the lesion.”

This “tissue-based” definition of TIA is not applied in all healthcare settings, especially outside the USA, because the definition is dependent on the type of neuroimaging performed (computed tomography [CT], MRI) and the availability and timing of such imaging. Accordingly, the clinical (WHO) definition has been used throughout these guidelines.

2.1.3. Aetiology of carotid territory ischaemic stroke. The principal causes of ischaemic, carotid territory stroke are thromboembolism from the internal carotid artery (ICA) or middle cerebral artery (MCA) (25%), small vessel intracranial disease (25%), cardiac embolism (20%), other specified rarer causes (5%), and unknown causes despite investigation (25%). Overall, about 10–15% of all strokes follow thromboembolism from a previously asymptomatic ICA stenosis >50%.

2.1.4. Methods for measuring carotid artery stenosis severity. The European Carotid Surgery Trial (ECST) and the North American Symptomatic Carotid Endarterectomy Trial (NASCET) used different methods for measuring stenosis severity (Fig. 3). Both used minimum residual luminal diameter as the numerator. In ECST, the denominator was the estimated vessel diameter where the residual luminal diameter was measured (usually the carotid bulb). In NASCET, the denominator was the diameter of a disease-free ICA segment above the stenosis, where the vessel walls were approximately parallel. Each method provides different measures of stenosis severity and this has been a source of confusion as to whether interventions should be based on “50%” or “70%” thresholds.

A 50% NASCET stenosis is equivalent to a 75% ECST stenosis. A 70% NASCET stenosis equates to an 85% ECST stenosis. Some units remain uncertain about which measurement method is being used, and this could lead to inappropriate patient selection (or exclusion) from interventions. The NASCET measurement method has been adopted by the WG throughout these guidelines, unless stipulated otherwise.

There is one situation in which the ECST measurement method has important advantages over NASCET. The NASCET method does not permit reliable measurement of stenosis severity in patients with large volume plaques within dilated carotid bulbs. Here, the residual luminal diameter may be only slightly less than that of the distal ICA. In this situation, the NASCET measurement method will record a <50% stenosis, whereas the ECST method will measure this as being >70%. In this rare situation, recently symptomatic
patients with large volume plaques consistent with an ECST >70% stenosis should be considered for revascularisation.

### 2.1.5. Imaging strategies in carotid artery disease

When ECST/NASCET were randomising patients, everyone underwent intra-arterial angiography. This has now been abandoned because of angiography-related stroke. In the Asymptomatic Carotid Atherosclerosis Study (ACAS), the 30-day death/stroke rate was 2.3% after CEA, but about half of these strokes (1.2%) were angiographic related.13

Duplex ultrasound (DUS) is usually the first-line imaging modality because of its low cost and accessibility. B-mode imaging is combined with colour flow, as well as the ability to undertake Doppler flow velocity measurements. Table 1 details DUS criteria for defining stenosis thresholds using peak systolic velocity (PSV), end-diastolic velocity (EDV) and their ratios in the ICA and common carotid artery (CCA), based on the NASCET measurement method.14

The advantage of computed tomographic angiography (CTA) and MR angiography (MRA) is the ability to simultaneously image the aortic arch, supra-aortic trunks, carotid bifurcation, distal ICA, and the intracranial circulation, which is mandatory if a patient is being considered for carotid artery stenting (CAS). Contrast-enhanced MRA (CEMRA) has a higher accuracy than non-contrast MRA techniques (time of flight), but requires administration of a paramagnetic contrast agent such as gadolinium. In a Health Technology Assessment (HTA) meta-analysis, DUS, MRA, and CTA were equivalent for detecting significant ICA stenoses.18 Catheter angiography is now rarely required, unless there are discrepancies on non-invasive imaging. The HTA advise that where centres rely on

### Table 1. Diagnostic velocity criteria for NASCET-based carotid stenosis measurement.

<table>
<thead>
<tr>
<th>% stenosis</th>
<th>PSV ICA cm/s</th>
<th>PSVICA/PSVCCA ratio</th>
<th>St Mary’s ratio</th>
<th>PSVICA/EDVCCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50%</td>
<td>&lt;125&lt;sup&gt;16&lt;/sup&gt;</td>
<td>&lt;2&lt;sup&gt;16&lt;/sup&gt;</td>
<td>&lt;8</td>
<td></td>
</tr>
<tr>
<td>50—69%</td>
<td>≥125&lt;sup&gt;16&lt;/sup&gt;</td>
<td>2.0—4&lt;sup&gt;16&lt;/sup&gt;</td>
<td>8—10</td>
<td></td>
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<tr>
<td>60—69%</td>
<td></td>
<td></td>
<td>11—13</td>
<td></td>
</tr>
<tr>
<td>70—79%</td>
<td>≥230&lt;sup&gt;16&lt;/sup&gt;</td>
<td>≥4&lt;sup&gt;16&lt;/sup&gt;</td>
<td>14—21</td>
<td></td>
</tr>
<tr>
<td>80—89%</td>
<td></td>
<td></td>
<td>22—29</td>
<td></td>
</tr>
<tr>
<td>&gt;90% but not near occlusion</td>
<td>≥400&lt;sup&gt;16&lt;/sup&gt;</td>
<td>≥5&lt;sup&gt;17&lt;/sup&gt;</td>
<td>≥30</td>
<td></td>
</tr>
<tr>
<td>Near Occlusion</td>
<td>High, low string flow</td>
<td>Variable</td>
<td>Variable</td>
<td></td>
</tr>
<tr>
<td>Occlusion</td>
<td>No flow</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td></td>
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DUS alone prior to CEA, the patient should undergo a second corroborative DUS scan, preferably by a second operator.

### 2.1.6. Role of the multidisciplinary team

Where possible, decisions regarding carotid interventions should involve a multidisciplinary team (MDT) including neurologists/stroke physicians, vascular surgeons, and interventional radiologists. Evidence suggests that MDTs increase the proportion of patients undergoing urgent CEA (4% vs. 22%, p < .0001),19 but it is important that urgent decisions can be made by at least two MDT members if meetings only occur weekly. Outcomes after CEA/CAS vary according to who performs the assessment. Rothwell observed that perioperative stroke rates after CEA were 7.7% when patients were assessed by a
neurologist, vs. 2.3% where the operating surgeon adjudicated outcomes. A German Carotid Stenting Registry also observed that neurologist assessment resulted in higher rates of transient (8.2% vs. 5.1%) and permanent (3.3% vs. 0.9%) neurological deficits following CAS, compared with when assessments were undertaken by the interventionist.

<table>
<thead>
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<th>Recommendation 6</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
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<tr>
<td>Multidisciplinary assessment is recommended to achieve consensus regarding the indication and optimal treatment of patients by carotid endarterectomy or carotid stenting</td>
<td>I</td>
<td>C</td>
<td>19</td>
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<tr>
<td>Independent assessment after carotid interventions is recommended to audit procedural risks</td>
<td>I</td>
<td>C</td>
<td>20, 21</td>
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2.2. Secondary prevention in asymptomatic patients

2.2.1. Optimal medical therapy

2.2.1.1. Risk factor control. In a pooled analysis of four population-based screening cohorts, smoking was associated with a significant increase in the prevalence of a >50% ICA stenosis (OR 2.3, 95% CI 1.8–2.8) and of a >70% stenosis (OR 3.0, 95% CI 2.1–4.4). About 5% of males aged >65 years who are current smokers have a >50% ICA stenosis on DUS screening and smoking has been shown to increase plaque progression. In a meta-analysis of 32 studies, smoking was associated with a significant increase in late ischaemic stroke (relative risk increase [RRI] 1.9, 95% CI 1.7–2.2). In a meta-analysis, moderate or high levels of physical activity were associated with a 25% relative risk reduction (RRR) in ischaemic stroke, possibly via reductions in blood pressure (BP), body weight, and effects on other risk factors. Finally, in a meta-analysis of 25 studies involving 2 million people, obesity was associated with a significant increase in stroke prevalence (RRI 1.64, 95% CI 1.36–1.99).

2.2.1.2. Antiplatelet therapy. There is conflicting opinion regarding antiplatelet therapy in asymptomatic patients because of concerns that inappropriate therapy might increase the risk of major bleeding events without reducing stroke risk. In the Asymptomatic Cervical Bruit study, patients with >50% asymptomatic ICA stenoses were randomised to 325 mg aspirin versus placebo (Table 2). After a median 2.3 years’ follow-up, there was no difference in “any ischaemic events” or “any death.” By contrast, the Asymptomatic Carotid Emboli Study (ACES) reported that antiplatelet therapy was an independent predictor of lower rates of “ipsilateral stroke/TIA” and “any stroke/cardiovascular death” in patients with asymptomatic 70–99% stenoses.

However, up to two-thirds of asymptomatic patients have subclinical coronary artery disease (CAD). In a systematic review of 17 natural history studies reporting 5-year all-cause mortality in 11,391 patients with >50% asymptomatic ICA stenoses, 63% of late deaths were cardiac, representing an average cardiac-related mortality of 2.9% per year. In addition, a multicentre review of stroke severity and outcomes, stratified for whether patients were taking aspirin prior to stroke onset or not, observed that pre-existing aspirin users had reduced stroke severity at presentation and improved functional outcomes at discharge, even though aspirin had failed to prevent their stroke. This beneficial effect was only seen in patients with large artery atherosclerotic strokes, as opposed to cardioembolic or lacunar strokes. Park’s data were not included in Table 2 because a small proportion had experienced a remote TIA/stroke in the past and were not, therefore, truly asymptomatic.

In the Clopidogrel for High Atherothrombotic Risk and Ischemic Stabilization, Management and Avoidance (CHARISMA) study, where 7% had an asymptomatic 50–99% ICA stenosis, there was no evidence that dual antiplatelet therapy (DAPT) conferred any benefit over single antiplatelet therapy. In a meta-analysis of the primary prevention trials, aspirin allocation yielded a 12% RRR in serious vascular events, mainly because of a reduction of about a fifth in non-fatal myocardial infarction (MI) (0.18% vs. 0.23% per year, p < .0001). The net effect on stroke was not significant (0.20% vs. 0.21% per year, p = .4: haemorrhagic stroke 0.04% vs. 0.03%, p = .05; other stroke 0.16% vs. 0.18% per year, p = .08). According to the data, monotherapy with aspirin remains the first-line antiplatelet agent in asymptomatic patients, with clopidogrel reserved for patients who are aspirin intolerant.

<table>
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<th>Recommendation 8</th>
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<th>Level</th>
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<tr>
<td>A healthy diet, smoking cessation, and physical activity are recommended for all patients with asymptomatic carotid disease</td>
<td>I</td>
<td>B</td>
<td>24–27</td>
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<tr>
<td>Low-dose aspirin (75–325 mg) is recommended in patients with asymptomatic carotid stenoses for prevention of late myocardial infarction and other cardiovascular events</td>
<td>I</td>
<td>A</td>
<td>29, 34</td>
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<th>Class</th>
<th>Level</th>
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<tr>
<td>Clopidogrel 75 mg daily should be considered in asymptomatic carotid stenosis patients if aspirin intolerant</td>
<td>Ila</td>
<td>C</td>
<td></td>
</tr>
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</table>
2.2.1.3. Lipid-lowering therapy. In a post-hoc analysis of patients randomised within the Asymptomatic Carotid Surgery Trial (ACST-1) who were on lipid-lowering therapy, the 10-year risk of stroke/death was 13.4% in best medical therapy (BMT) patients and 7.6% after CEA. However, in patients not taking statins, the 10-year stroke risk was 24.1% in BMT patients, versus 17.9% after CEA, suggesting that statins reduced long-term stroke in patients with asymptomatic stenoses.35 With regard to dosage and/or intensity of statin therapy, there are insufficient data from carotid stenosis studies in asymptomatic patients. However, evidence-based treatment goals from studies involving patients with symptomatic and asymptomatic cardiovascular disease advise high-intensity statin treatment goals, including a low-density lipoprotein (LDL) level of <1.8 mmol/L (70 mg/dL) or a 50% reduction of LDL by either 40–80 mg atorvastatin or 20–40 mg rosuvastatin.36–39 A 2013 Cochrane review of 18 RCTs (56,934 patients) on the role of statins in the primary prevention of cardiovascular disease, observed significant reductions in all-cause mortality, fatal/non-fatal stroke, and revascularisation procedures in patients randomised to statins.39

Because of the increased risk of cardiovascular complications and the generally low rate of serious adverse-effects associated with statins, it seems reasonable to apply the same recommendation to patients with symptomatic carotid disease (Section 2.3.2.3.). The role of statin therapy in reducing the perioperative risk of stroke/death following CEA and CAS is discussed in Sections 2.3.2.3.2 and 2.3.2.3.3.

2.2.1.4. Management of hypertension. Hypertension is associated with an increased risk of carotid disease.40 Treatment in older adults with ICA stenoses (compared with placebo) reduces stenosis progression (14% vs. 31%) and promotes regression (32% vs. 0%).41 Regression of carotid intima-media thickness (IMT) has been attributed to reductions in carotid pulse pressure.42 The European Lacidipine Study on Atherosclerosis, which compared lacidipine (calcium channel blocker [CCB]) with atenolol, observed that lacidipine was associated with greater reductions in carotid IMT progression and fewer atherosclerotic plaques, despite smaller falls in BP, suggesting an independent, anti-atherosclerotic action.43 Similar results have been obtained for angiotensin converting enzyme (ACE) inhibitors; however, CCBs reduce IMT progression more than diuretics, beta-blockers, or ACE inhibitors.44

No RCT has evaluated the effect of antihypertensive therapy on stroke prevention in patients with asymptomatic carotid stenoses (ACS). However, a meta-analysis of 25 BP RCTs in patients with no history of vascular disease reported significant reductions in late stroke (RRR 45%, 95% CI 35–55) with stroke reduction being proportional to reductions in systolic BP.45 In a RCT of Chinese hypertensive patients without a history of stroke/MI, enalapril and folic acid (versus enalapril alone) reduced the risk of first stroke.46 In practice, BP should be maintained <140/90 mmHg in patients with ACS.47 The European Society of Cardiology (ESC)/European Society for Hypertension advise that the target for end-diastolic BP should be 85 mmHg in patients with diabetes.48

Table 2. Effect of antiplatelet therapy on stroke prevention in patients with asymptomatic carotid stenoses.

<table>
<thead>
<tr>
<th>Study</th>
<th>ICA stenosis, n =</th>
<th>Endpoint</th>
<th>Outcomes Antiplatelet vs. no antiplatelet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asymptomatic Carotid Bruit study28</td>
<td>50–99%, n = 372</td>
<td>Annual rate of TIA, stroke, unstable angina, MI, or death from any cause at a mean of 2.3 years</td>
<td>11% vs. 12.3% p = .61</td>
</tr>
<tr>
<td>Asymptomatic Carotid Emboli Study29</td>
<td>70–99%, n = 477</td>
<td>2-year risk of ipsilateral stroke or TIA</td>
<td>HR 0.45 (95% CI 0.31–0.66) p &lt; .001</td>
</tr>
</tbody>
</table>

a 95% of patients took antiplatelet therapy during sequential follow-up.

Recommendation 11

Statin therapy is recommended for long-term prevention of stroke, myocardial infarction and other cardiovascular events in patients with asymptomatic carotid disease

<table>
<thead>
<tr>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A</td>
<td>36–39</td>
</tr>
</tbody>
</table>

Recommendation 12

Antihypertensive treatment is recommended for patients with hypertension and asymptomatic extracranial internal carotid artery stenoses to maintain long-term blood pressure <140/90 mmHg

<table>
<thead>
<tr>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A</td>
<td>45,47</td>
</tr>
</tbody>
</table>
2.2.1.5. Treatment in diabetic patients. Diabetes is associated with an increased risk of ACS, as well as hypertension and abnormal lipid profiles. However, neither plaque burden nor plaque instability are increased in diabetic patients. Diabetes doubles the risk of stroke. In meta-analyses, however, there is no evidence that tight glycaemic control reduces stroke risk, but it will reduce other diabetes-related complications, for example microangiopathy. In a study of type II diabetic patients who received risk factor advice and took statin, antiplatelet, and antihypertensive therapy (as appropriate), there was a 60% reduction in cardiovascular events (hazard ratio [HR] 0.41, 95% CI 0.25–0.69, p < .001) and cardiovascular deaths (HR 0.43, 95% CI 0.19–0.94, p = .04). The UK Prospective Diabetes Study observed that tight BP control (mean BP 144/82 mmHg) was associated with a 44% RRR in stroke (95% CI 11–65, p = .013), compared with patients who had less tight BP control (mean BP 154/87 mmHg). Accordingly, the ESC/European Society for Hypertension advise that the target for end-diastolic BP should be 85 mmHg in patients with diabetes.

<table>
<thead>
<tr>
<th>Recommendation 13</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>In diabetic patients with asymptomatic carotid stenoses, strict glycaemic control is recommended</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 14</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>In diabetic patients with asymptomatic carotid stenoses, the target blood pressure should be &lt;140/85 mmHg</td>
<td>I</td>
<td>B</td>
<td>48</td>
</tr>
</tbody>
</table>

2.2.1.6. Adherence to optimal medical therapy. In patients with carotid disease, there is a paucity of data relating to the potentially adverse effect of non-adherence with antiplatelet/antithrombotic therapy and medications for hypertension, diabetes mellitus, and dyslipidaemia. This was never evaluated in the landmark RCTs. In a single-centre study, 114 patients with TIA or ischaemic stroke were recruited via a rapid access stroke prevention (RASP) or inpatient vascular neurology service between 2006 and 2009 and followed-up for a median of 630 days. The proportion continuing medications prescribed at the initial RASP clinic assessment or hospital admission and who were also taking these medications at their last follow-up was 94% for aspirin, 73% for dipyridamole MR, 81% for clopidogrel, 88% for statins, and 90% for antihypertensives. Overall, 99% reported that they were fully adherent to prescribed medications the preceding day, while 11% reported they had missed at least one medication over the preceding 14 days. Half of the patients in this study (54%) reported that they never forgot to take their medications.

Studies in CAD or heart failure patients report better clinical outcomes in those who adhered to their prescribed medications, compared with those who did not. It has been suggested that adherence to antihypertensive medications has important implications for primary stroke prevention in the general population, where “real world” compliance may be worse than in RCTs. Statins have the widest variation in treatment compliance, possibly because of side-effects. This may contribute to many patients not achieving pre-defined LDL-cholesterol reduction targets, thereby predisposing them to recurrent or new cardiovascular events. The same may also be true for aspirin plus dipyridamole (because of dipyridamole-induced headache), but this can be reduced by dose escalation during treatment initiation.

In patients with ACS, adherence to medications may be significantly reduced in the presence of undiagnosed cognitive impairment, which also has implications for monitoring medication usage. Other predictors of poor compliance include psychological problems (particularly depression), asymptomatic disease, inadequate follow-up or discharge planning, medication side-effects, a patient’s lack of belief in the benefits of medical treatment, a patient’s lack of insight into the illness, poor provider—patient relationships, presence of barriers to care or medications, missed appointments, complexity of treatment, and cost of medication, co-payment, or both. In a simulation model in patients with ACS, survival was significantly better for patients who remained adherent to BMT, compared with non-adherent patients.

2.2.2. Screening for asymptomatic carotid stenoses. According to Wilson and Jungner, the rationale for screening requires that: (i) the condition being prevented is important, has a latent phase, and its natural history is fully understood; (ii) there is a reliable screening test that is acceptable to the population in question; (iii) there is an accepted treatment for screen-positive patients and an agreed policy for whom to treat; and (iv) the intervention for screen-positive patients should be cost-effective.

2.2.2.1. Is stroke important to prevent? In Europe, stroke causes 1.1 million deaths annually. It is the commonest cause of acquired disability in adults, with more than half of stroke survivors being dependent on others for everyday activities. Stroke costs health providers in Europe 38 billion Euros per year, and successful prevention strategies could have enormous clinical, social, and financial benefits. It is, therefore, a very important condition to prevent.

2.2.2.2. Unheralded stroke and asymptomatic carotid stenoses. About 10–15% of all first-ever stroke patients will experience an unheralded ischaemic, carotid territory stroke following thromboembolism from a previously untreated, asymptomatic significant carotid stenosis.

2.2.2.3. Is Duplex ultrasound reliable for diagnosing stenosis severity? The US Preventive Services Taskforce (USPSTF) concluded that DUS was accessible and non-invasive, with a sensitivity of 94% and a specificity of 92% for diagnosing 60–99% carotid stenoses. However, USPSTF observed that the accuracy of DUS varied considerably (especially in inexperienced hands) and that its indiscriminate use in low prevalence populations could result in a low positive predictive value because of a large number of false
to 4% in those with a score of 21, and 6% for those whose score was 25. Screening those with the lowest “useful score” of 11 identified 100% of subjects with an ACS >50% at a cost of 41 screenings per >50% ACS detected. This study provided no data on their ability to identify a cohort with an increased likelihood of having a >70% stenosis, which is the more clinically important stenosis threshold.65

2.2.2.6. Potential benefits of selective screening. Screening for ACS could enable risk factor modification and BMT for all screened patients (irrespective of stenosis severity or whether they undergo CEA/CAS) and this could contribute towards preventing MI and cardiac deaths, which are more common than late stroke.66 In ACST-1, 40% of patients aged <75 years at trial entry died within 10 years, with 55% of deaths being cardiac.35 In a recent systematic review and meta-analysis, 17 studies reported late mortality in 11,391 patients with an ACS >50%.31 Overall, 5-year mortality was 24% (95% CI 20.5—26.8). Two-thirds of late deaths were the result of heart disease. Accordingly, risk factor modification and implementation of BMT in patients with screen-detected ACS could significantly reduce cardiac morbidity and mortality.

2.2.2.7. Harm associated with screening. Patients might undergo an unnecessary intervention following a false positive screen and suffer a stroke after CEA or CAS. This was the main concern of USPSTF.64

2.2.2.8. Harm associated with carotid interventions. All RCTs involving CEA or CAS in asymptomatic patients reported 30-day death/stroke rates <3% (Section 2.2.3.1.2). However, most surgeons/interventionists were credentialed before randomising patients and 40% of surgeon applicants in ACAS were rejected following review of their track record.67 Several audits and registries of “real world” practice suggest that many surgeons/interventionists do not achieve death/stroke rates ≤3% in asymptomatic patients.68—70

2.2.2.9. Does screening prevent fatal or nonfatal ipsilateral stroke? There is no evidence that population screening reduces stroke and there have been no RCTs of the benefits of screening versus no screening for ACS.

2.2.2.10. Who advocates population or selective screening? The AHA recommends against screening low-risk populations, but did not define who they meant.71 The Society for Vascular Surgery (SVS) advise that screening for ACS should be considered in selected patients with multiple risk factors, provided that “patients are fit for and willing to consider a carotid intervention if a significant stenosis is discovered.” Such patients might include those with PAD (regardless of age), and patients aged >65 years with a history of one or more of CAD, smoking, or hypercholesterolemia.72 The “14 Society” guidelines advise against routine screening of low-risk patients, but advise that screening might be considered in people without clinical evidence of atherosclerosis who had at least two risk factors, including hypertension, hyperlipidaemia, tobacco smoking, a family history of stroke and “early onset” atherosclerosis.73 Using the SVS screening criteria described above, Thapar determined that

<table>
<thead>
<tr>
<th>Age</th>
<th>Stenosis</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50 years</td>
<td>&gt;50%</td>
<td>0.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>&gt;70%</td>
<td>0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>50—59 years</td>
<td>&gt;50%</td>
<td>0.7%</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td>&gt;70%</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
<tr>
<td>60—69 years</td>
<td>&gt;50%</td>
<td>2.3%</td>
<td>2.0%</td>
</tr>
<tr>
<td></td>
<td>&gt;70%</td>
<td>0.8%</td>
<td>0.2%</td>
</tr>
<tr>
<td>70—79 years</td>
<td>&gt;50%</td>
<td>6.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td></td>
<td>&gt;70%</td>
<td>2.1%</td>
<td>1.0%</td>
</tr>
<tr>
<td>≥80 years</td>
<td>&gt;50%</td>
<td>7.5%</td>
<td>5.0%</td>
</tr>
<tr>
<td></td>
<td>&gt;70%</td>
<td>3.1%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

Table 3. Prevalence of asymptomatic >50% and >70% stenoses in the general population, stratified for gender and age.”

screening all 60-year-old UK claudicants with a “one off” DUS would cost £17 million (£20 million). If all patients with a 70–99% stenosis then underwent CEA, this would prevent about 230 strokes annually in the UK, which represents only 0.2% of the annual UK stroke burden.\textsuperscript{74} In practice, 143 claudicants would need to be screened to identify 20 with a 70–99% stenosis for CEA, to prevent one stroke at 10 years. This would cost £76,000 (£88,300) per stroke prevented.\textsuperscript{74}

USPSTF recommends against screening for ACS\textsuperscript{64} on the basis that RCTs may have overestimated benefits and used highly selected surgeons, while DUS screening (even with MRA corroboration) might lead to a large number of false positive patients being diagnosed as having a significant ACS. They also noted that medical therapy in the RCTs was outdated (Section 2.2.3.1.4), stroke rates have probably declined over recent decades and ‘real world’ stroke risks may have been under-reported.\textsuperscript{64}

**Table 4.** Perioperative and late outcomes following CEA and BMT in VACS, ACAS, and ACST.

<table>
<thead>
<tr>
<th>RCT</th>
<th>30-day death/stroke after CEA\textsuperscript{a}</th>
<th>Ipsilateral stroke plus perioperative death/stroke CEA + BMT</th>
<th>Ipsilateral stroke plus perioperative death/stroke BMT alone</th>
<th>Any stroke plus perioperative death/stroke CEA + BMT</th>
<th>Any stroke plus perioperative death/stroke BMT alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>VACS\textsuperscript{75}</td>
<td>4.6%\textsuperscript{3}</td>
<td>7.0% at 4 years</td>
<td>9.4% at 4 years</td>
<td>10.4% at 4 years</td>
<td>12.0% at 4 years</td>
</tr>
<tr>
<td>ACAS\textsuperscript{13}</td>
<td>2.3%\textsuperscript{3}</td>
<td>5.1% at 5 years</td>
<td>11% at 5 years</td>
<td>12.4% at 5 years</td>
<td>17.8% at 5 years</td>
</tr>
<tr>
<td>ACST-1\textsuperscript{15}</td>
<td>2.8%</td>
<td>Not available</td>
<td>Not available</td>
<td>6.4% at 5 years</td>
<td>11.8% at 5 years</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Includes strokes occurring after diagnostic angiography as well.

**2.2.3.1. Randomised trials: endarterectomy versus best medical therapy.** The Veteran’s Affairs Co-operative Study (VACS), ACAS and ACST-1 compared CEA plus contemporary BMT, versus BMT alone in 5526 patients who were recruited from Europe and North America. VACS randomised males with 50–99% stenoses (n = 444) between 1983 and 1987, with follow-up to 1991.\textsuperscript{5} All underwent intra-arterial angiography prior to randomisation. ACAS randomised 1662 patients aged <80 years with 60–99% stenoses between 1987 and 1993, with follow-up to 1997.\textsuperscript{13} ACAS patients had to have reported no previous ipsilateral cerebral events at all. All were screened by DUS (with an inclusion cut-off corresponding to a >60% stenosis) and those randomised to CEA then underwent intra-arterial angiography. Patients randomised to BMT did not undergo angiography. Any angiographic related stroke in patients randomised to CEA were included within the “intention to treat” analysis of surgical morbidity and mortality. Patients with bilateral ACS had the side with the tightest stenosis treated in the trial. If there were bilateral equal stenoses, the left ICA was designated the “trial” artery. About 40% of surgeons who applied to join ACAS were excluded following a review of their track record.\textsuperscript{67} ACST-1 randomised 3120 patients with 70–99% stenoses between 1993 and 2003, with follow-up extending to 2008. ACST-1 had no age limit and 20% were aged >75 years at trial entry. Pre-randomisation angiography was not required for either trial arm.\textsuperscript{54}

2.2.3.1.1. Medical therapy in the randomised trials. In VACS, 650 mg of aspirin (daily) was taken by 55% of patients, while 27% took lower doses. Antihypertensive therapy was less commonly used in VACS and no patient received statins. During ACAS/ACST-1, the use of BP and antithrombotic treatments increased. ACST-1 and ACAS included patients who took fibrates and statins, although ACST-1 had longer follow-up and more robust evidence about statin use (13% ACAS patients were on lipid-lowering therapy at entry vs. 32% in ACST-1).

2.2.3.1.2. Outcomes of randomised trials. Table 4 summarises the 30-day risks of death/stroke after CEA in the RCTs.
CA patients aged >75 years had a 5.5% risk of “any” stroke at 5 years vs. 8.8% after BMT (ARR 3.3%, 95% CI 1.9—8.4). Half of all patients aged >75 who were randomised to CEA were dead within 5 years and once the perioperative risks (3.7% in patients aged >75 years) were included, there was no evidence that CEA conferred any benefit in patients aged >75. However, if it were possible to develop imaging algorithms for identifying patients at higher risk of experiencing a stroke on BMT (Section 2.2.3.1.5), it is possible that a higher risk subgroup of patients aged >75 years with a predicted life expectancy >5 years might benefit from intervention.

2.2.3.1.3.2 Gender. An early meta-analysis of pooled data from ACAS and ACST-1 reported that males randomised to BMT were twice as likely to suffer a stroke at 5 years (OR 2.04, 95% CI 1.5—2.8). However, at 5 years, CEA conferred no benefit in females (OR 0.96, 95% CI 0.63—1.45). After 10 years of follow-up, ACST-1 reported that females now gained a similar benefit to men (ARR 5.8%, 95% CI 1.1—11.4, p = .05). Reasons for the lack of benefit in women at 5 years were that while their hazard from CEA was similar to men, the “background” stroke risk (without surgery) was lower, so benefit took longer to accrue.

2.2.3.1.3.3 Stenosis severity. Unlike symptomatic patients in ECST/NASCET (Section 2.3.3), ACST-1 and ACAS reported that increasing stenosis severity (including bilateral stenoses and contralateral occlusion) were not associated with increased rates of late stroke in patients randomised to BMT. A meta-analysis involving 41 studies (6 RCTS, 35 observational studies) reported that ipsilateral stroke risk was 1.9/100 person years in patients with 50—70% stenoses at baseline, compared with 2.1/100 person years in those with 70—99% stenoses (p = .427).

2.2.3.1.4 Controversy over modern medical therapy. ACAS, ACST-1, and VACS are the only RCTs to compare CEA with BMT, but they recruited patients from 1983—2003 when, for most of the time, the concept of “BMT” did not include statins and a greater proportion of patients smoked. Some now question whether their data remain relevant in the modern era. Several studies suggest that the annual risk of stroke may be less than when ACAS and ACST-1 were recruiting. In a meta-analysis of 41 studies, the rate of ipsilateral stroke was 2.3/100 person years in studies completing recruitment before 2000, compared with 1.0/100 person years in studies completing between 2000 and 2010 (p < .001). The 39% decline in ipsilateral stroke per decade was attributed to improvements in BMT and smoking cessation. In studies where >25% of participants took statins, ipsilateral stroke was 1.2/100 person years, compared with 2.3/100 person years where <25% of participants took statins (p = .009). Another review has reported that the temporal trend towards declining annual stroke rates in medically treated patients was consistent across all grades of stenosis at baseline (50—99%, 60—99%, and 70—99%) and was also apparent in ACAS and ACST.

In 1995, ACAS reported a 17.5% 5-year risk of “any” stroke in patients with a 60—99% stenosis who were treated

### Table 5. Clinical/imaging features associated with an increased risk of late stroke in patients with asymptomatic 50—99% stenoses treated medically.

<table>
<thead>
<tr>
<th>Imaging/clinical parameter and stenosis severity</th>
<th>Type of study</th>
<th>Annual rate of ipsilateral stroke</th>
<th>OR/HR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silent infarction on CT</td>
<td>Multicentre, observational</td>
<td>Yes = 3.6%</td>
<td>3.0 (1.46—6.29)</td>
</tr>
<tr>
<td>Multicentre, RCT</td>
<td></td>
<td>No = 1.0%</td>
<td>p = .002</td>
</tr>
<tr>
<td>Stenosis progression</td>
<td>Multicentre, observational</td>
<td>Regression = 0.0%</td>
<td>1.92 (1.14—3.25)</td>
</tr>
<tr>
<td>Stenosis progression</td>
<td>Multicentre, observational</td>
<td>No change</td>
<td>0.7 (0.4—1.3)</td>
</tr>
<tr>
<td>Stenosis progression</td>
<td>Multicentre, observational</td>
<td>Progression 1</td>
<td>1.6 (1.1—2.4)</td>
</tr>
<tr>
<td>Stenosis progression</td>
<td>Multicentre, observational</td>
<td>Progression 2</td>
<td>4.7 (2.3—9.6)</td>
</tr>
<tr>
<td>Plaque area on computerised plaque analysis</td>
<td>Multicentre, observational</td>
<td>&lt;40 mm²</td>
<td>HR 1.0</td>
</tr>
<tr>
<td>Plaque area on computerised plaque analysis</td>
<td>Multicentre, observational</td>
<td>40—80 mm²</td>
<td>2.08 (95% CI 1.05—4.12)</td>
</tr>
<tr>
<td>Plaque area on computerised plaque analysis</td>
<td>Multicentre, observational</td>
<td>&gt;80 mm²</td>
<td>5.81 (95% CI 2.67—12.67)</td>
</tr>
<tr>
<td>JBA on computerised plaque analysis</td>
<td>Multicentre, observational</td>
<td>T &lt; 4 mm²</td>
<td>Trend p &lt; .001</td>
</tr>
<tr>
<td>JBA on computerised plaque analysis</td>
<td>Multicentre, observational</td>
<td>8—10 mm²</td>
<td>3.2% (95% CI 1.0—10.5)</td>
</tr>
<tr>
<td>JBA on computerised plaque analysis</td>
<td>Multicentre, observational</td>
<td>&gt;10 mm²</td>
<td>5.0% (95% CI 1.3—17.5)</td>
</tr>
<tr>
<td>Meta-analysis</td>
<td></td>
<td>Yes vs. no</td>
<td>OR 3.66 (2.77—4.95)</td>
</tr>
<tr>
<td>Meta-analysis</td>
<td></td>
<td>p &lt; .01</td>
<td></td>
</tr>
<tr>
<td>Impaired CVR</td>
<td>Multicentre, observational</td>
<td>Yes vs. no</td>
<td>OR 6.14 (95% CI 1.27—29.5)</td>
</tr>
<tr>
<td>Metanalysis</td>
<td></td>
<td>p = .02</td>
<td></td>
</tr>
<tr>
<td>Plaque lucency on Duplex US</td>
<td>Multicentre, observational</td>
<td>Predominantly echolucent</td>
<td>OR 2.61 (95% CI 1.47—4.63)</td>
</tr>
<tr>
<td>Predominantly echolucent</td>
<td></td>
<td>p = .001</td>
<td></td>
</tr>
<tr>
<td>Spontaneous embolisation on TCD</td>
<td>Multicentre, observational</td>
<td>Yes vs. no</td>
<td>OR 7.46 (95% CI 2.24—24.89)</td>
</tr>
<tr>
<td>Spontaneous embolisation on TCD</td>
<td></td>
<td>p = .001</td>
<td></td>
</tr>
<tr>
<td>Spontaneous embolisation plus uniformly or</td>
<td>Multicentre, observational</td>
<td>Yes = 8.9%</td>
<td>OR 10.61 (95% CI 2.98—37.82)</td>
</tr>
<tr>
<td>predominantly echolucent plaque</td>
<td></td>
<td>No = 0.8%</td>
<td>p = .0003</td>
</tr>
<tr>
<td>Contralateral TIA/stroke</td>
<td>Multicentre, observational</td>
<td>Yes = 3.4%</td>
<td>OR 3.0 (95% CI 1.9—4.73)</td>
</tr>
<tr>
<td>Contralateral TIA/stroke</td>
<td></td>
<td>No = 1.2%</td>
<td>p = .0001</td>
</tr>
</tbody>
</table>
medically (3.5% per year). The 5-year risk of “any stroke” in patients randomised to medical therapy then decreased to 11.8%, when ACST reported its first 5-year data in 2004 (2.4% per year). When ACST reported its second 5-year data (i.e. years 5–10), the five-year risk of any stroke on medical therapy had declined to 7.2% (1.4% per year), part of which may be attributable a proportion of patients randomised to BMT undergoing deferred CEA.\textsuperscript{13,35,54,79} The same phenomenon was evident in the 5-year incidence of ipsilateral stroke in medically treated patients. ACAS reported a 5-year rate of ipsilateral stroke of 11.0% in medically treated patients in 1995 (2.2% per year). By 2004, when ACST reported its first 5-year data, the 5-year risk of ipsilateral stroke had fallen to 5.3% (1.1% per year). When ACST reported its 10-year data, the rate of ipsilateral stroke for the second 5-year period had decreased even further to 3.6% (0.7% per year).\textsuperscript{13,35,54,79} Overall, this represents a 60% decline in annual stroke rates between 1995 and 2010. It could be argued that patients at “high risk for stroke” in ACST might already have had outcome events in the first 5 years and were thus censored from further trial follow-up, potentially leaving “lower risk” patients in the 5–10 year cohort. However, the decline at 5 and 10 years in ACST exactly parallels the decline in the 5-year rates of “any” stroke in two entirely independent cohorts observed by ACAS in 1995 and ACST-1 in 2004.

Awareness that the risk of stroke in asymptomatic patients treated medically may be less than previously thought, has led to calls for contemporary RCTs evaluating management strategies in asymptomatic patients to include an additional limb for BMT. The second Stent Protected Angioplasty versus Carotid Endarterectomy trial (SPACE-2) planned to randomise patients to CEA, CAS, and BMT, but was abandoned after randomising only 513 patients because of slow recruitment.\textsuperscript{80} The second Carotid Revascularization versus Stenting Trial (CREST-2) has started randomising asymptomatic patients to CEA vs. BMT and CAS vs. BMT, while the second ECST trial (ECST-2) includes a medical limb for asymptomatic patients. The French randomised trial (Asymptomatic Severe Atherosclerotic Carotid Artery Stenosis at Higher than average Risk of Ipsilateral Stroke [ACTRIS]) has not yet started but will exhibit one or more features suggestive of them being at higher risk of suffering a late ipsilateral stroke\textsuperscript{81} (Section 2.2.3.1.5). The second ACST trial (ACST-2) has been randomising asymptomatic patients to CAS or CEA and should complete recruitment in 2019. It is hoped that all surgeons and interventionists will support these RCTs.

2.2.3.1.5. Who is at higher risk for stroke on medical therapy? The AHA has repeatedly advised that only “highly selected” asymptomatic patients should undergo CEA,\textsuperscript{71,82} but never defined what “highly selected” means. An alternative interpretation of ACST-1 is that (at 10 years) only 46 strokes will be prevented at 5 years per 1000 CEAs (i.e. 95% of all CEAs were ultimately unnecessary). This, along with evidence that the annual risk of stroke on BMT may be declining, suggests that there is a need to develop clinical/imaging algorithms for identifying a smaller, but higher-risk for stroke cohort in whom CEA/CAS might be targeted. This is important as multi-state audits have suggested that CEA was being performed in asymptomatic patients with 30-day death/stroke rates that often exceeded the 3% threshold,\textsuperscript{63} while a recent systematic review observed that 9/21 (43%) registries reported 30-day death/stroke rates that exceeded 3% after CAS.\textsuperscript{70} Accordingly, an uncritical recommendation to revascularise “highly selected” patients without defining who these patients might be, cannot be justified. It is inevitable that a smaller subgroup with clinical and/or imaging features that make them “higher risk for stroke” on BMT will benefit from carotid revascularisation. While awaiting data from CREST-2, ECST-2, ACST-2, and ACTRIS and the development of validated algorithms for patient selection, the presence of one or more clinical and/or imaging features such as silent infarction on CT/MRI, stenosis progression, large plaque area, large juxta-luminal black area (JBA) on computerised plaque analysis, plaque echolucency, intra-plaque haemorrhage on MRI, impaired cerebral vascular reserve (CVR), and spontaneous embolisation on transcranial Doppler (TCD) monitoring, might be useful for selecting “higher-risk for stroke” patients for revascularisation (Table 5).

2.2.3.2. Randomised trials: endarterectomy versus stenting

2.2.3.2.1. ‘Average’ risk for surgery patients. Five RCTs have published outcomes comparing CEA with CAS in “average-risk for CEA” patients.\textsuperscript{80,95–98} Lexington, Mannheim, SPACE-2, and the Asymptomatic Carotid Trial (ACT-1) randomised asymptomatic patients from the outset. CREST-1 was originally a symptomatic RCT, but a protocol change enabled them to randomise asymptomatic patients because of sluggish recruitment. Table 6 details 30-day death/stroke rates from the five RCTs. A meta-analysis of data from four of the five RCTs shown in Table 6 (Lexington was excluded as there were no early or late strokes) observed a 30-day death/stroke rate of 1.6% after CEA (95% CI 1.02–2.45) versus 2.7% (95% CI 2.1–3.6%) after CAS (OR 1.71, 95% CI 0.99–2.94; \(p = .0553\)). Fig. 4 provides a forest plot of a meta-analysis of all five RCTs.

In the Lexington RCT, no strokes or recurrent stenoses were reported at 4 years. In CREST-1, the 4-year rate of ipsilateral stroke (including the perioperative risk) was 8% following CAS, versus 6.7% after CEA. Restenosis (>70%) was 6.7% at 4 years after CAS and 6.2% after CEA.\textsuperscript{96,99} In ACT-1, including perioperative stroke/death/MI, the 1-year

<table>
<thead>
<tr>
<th>Table 6. 30-day death/stroke in randomised trials comparing CEA and CAS in asymptomatic patients.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>30-day outcomes</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Death/stroke</td>
</tr>
<tr>
<td>Death/disabling stroke</td>
</tr>
<tr>
<td>Death/stroke/MI</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

In ACT-1, including perioperative stroke/death/MI, the 1-year...
Figure 4. Forest Plot comparing 30-day death/stroke in four randomised trials comparing carotid endarterectomy and carotid artery stenting in asymptomatic patients.

<table>
<thead>
<tr>
<th>Study</th>
<th>CAS Events</th>
<th>Total Events</th>
<th>CEA Events</th>
<th>Total Events</th>
<th>Odds Ratio</th>
<th>95%-CI W(fixed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brooks</td>
<td>2</td>
<td>68</td>
<td>1</td>
<td>42</td>
<td>2.03</td>
<td>[0.10; 22.93]</td>
</tr>
<tr>
<td>Manheim</td>
<td>15</td>
<td>594</td>
<td>8</td>
<td>587</td>
<td>1.88</td>
<td>[0.79; 4.46]</td>
</tr>
<tr>
<td>CREST</td>
<td>31</td>
<td>1072</td>
<td>6</td>
<td>348</td>
<td>1.70</td>
<td>[0.70; 4.10]</td>
</tr>
<tr>
<td>ACT1</td>
<td>5</td>
<td>197</td>
<td>4</td>
<td>203</td>
<td>1.30</td>
<td>[0.34; 4.90]</td>
</tr>
<tr>
<td>SPACE2</td>
<td>1</td>
<td>14</td>
<td>5</td>
<td>197</td>
<td>1.00</td>
<td>[0.01; 10.00]</td>
</tr>
</tbody>
</table>

Fixed effect model 1974 1248

Heterogeneity: squared-0, tau-squared-0, p-0.3726

Figure 5. Algorithm detailing management strategies in patients with symptomatic and asymptomatic atherosclerotic extracranial carotid artery stenoses. Green boxes denote Level I recommendations, yellow boxes denote level IIa and IIb recommendations.

BMT = best medical therapy; CAS = carotid artery stenting; CEA = carotid endarterectomy; CTA = computed tomography angiography; MRA = magnetic resonance angiography; TIA = transient ischaemic attack.

a = post-stenotic internal carotid artery narrowed to the point of near occlusion.
b = clinical/imaging features that might be associated with an increased risk of late stroke on BMT in asymptomatic patients (see Table 5).
c = clinical/imaging features that might make a patient ‘high risk for CEA’ (see Section 2.3.9).

* denotes recommendation for CAS in symptomatic patients with 70—99% stenoses deemed ‘high-risk for CEA’.

** denotes recommendation for CAS in symptomatic patients with 70—99% stenoses deemed ‘average risk for CEA’.

rate of ipsilateral stroke was 3.8% after CAS versus 3.4% after CEA. The 5-year rate of ipsilateral stroke (excluding perioperative events) was 2.2% after CAS and 2.7% after CEA ($p = .51$). The 5-year rate of “any” stroke (excluding perioperative events) was 6.9% after CAS, versus 5.3% after CEA. At 1 year, freedom from “target-lesion” revascularization was 99.4% after CAS and 97.4% after CEA.

Despite protocol amendments, SPACE-2 stopped in 2015 after recruiting 513 patients. The 30-day stroke/death rate was 1.97% in 203 patients randomised to CEA vs. 2.54% in 197 patients randomised to CAS. No strokes occurred <30 days of randomisation in the 113 BMT patients. Follow-up will continue to 5 years, with data being available for future meta-analyses. In Mannheim’s RCT, there were no late strokes at a mean follow-up of 26 months; 3/68 CEA patients (4.4%) developed a 70–99% restenosis, versus 1/68 (1.5%) after CAS.

Only experienced and credentialed CAS interventionists participated in CREST and ACT-1. In ACT-1 (the largest completed RCT), the 2.9% rate of death/stroke after CAS only just fell within the accepted 3% risk threshold, which many now believe to be too high, given the apparent reductions in stroke on BMT (Section 2.2.3.1.4). In addition, because of the learning curve associated with CAS, as well as it being performed in low numbers by multiple specialties with different patient selection criteria, there are concerns as to whether death/stroke rates in RCTs can be replicated in “real world” practice. While some national CAS registries have published death/stroke rates <3%, others have reported wide variations in practice. In a review of 19,381 CAS procedures in the USA, there was a fourfold variation in in-hospital death/stroke, despite adjusting for case-mix.

A systematic review of large administrative dataset registries (>1.5 million procedures) found that 40% of registries reported death/stroke rates after CAS in excess of 3% in asymptomatic patients, while 14% reported death/stroke rates >5%. In some large registries, the median annual number of CAS procedures in asymptomatic patients may only be one to two per interventionist, which is known to be associated with higher rates of perioperative stroke/death (Section 2.5.7).

2.2.3.2. ‘High-risk’ for surgery patients. The Stenting and Angioplasty With Protection in Patients at High Risk for Endarterectomy (SAPPHIRE) study randomised 334 patients deemed “high-risk for CEA” to either CEA or CAS. The criteria for defining a “high-risk for CEA” asymptomatic patient included an asymptomatic 70–99% stenosis in the presence of one or more of: clinically significant cardiac disease (congestive heart failure, abnormal stress test, or need for open-heart surgery); severe pulmonary disease; contralateral carotid occlusion; contralateral laryngeal nerve palsy; previous radical neck surgery; cervical radiation therapy; recurrent stenosis after CEA and age >80 years. However, the majority of SAPPHIRE patients (70%) were asymptomatic, in whom 30-day death/stroke was 5.8% after CAS and 6.1% after CEA.

An algorithm for managing asymptomatic patients with carotid disease is presented in Fig. 5.

<table>
<thead>
<tr>
<th>Recommendation 17</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>In “average surgical risk” patients with an asymptomatic 60–99% stenosis, carotid endarterectomy should be considered in the presence of one or more imaging characteristics that may be associated with an increased risk of late ipsilateral stroke, provided documented perioperative stroke/death rates are &lt;3% and the patient’s life expectancy exceeds 5 years.</td>
<td>IIa</td>
<td>B</td>
<td>13,35,54,84–94, 96,97</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 18</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>In “average surgical risk” patients with an asymptomatic 60–99% stenosis in the presence of one or more imaging characteristics that may be associated with an increased risk of late ipsilateral stroke, carotid stenting may be an alternative to carotid endarterectomy, provided documented perioperative stroke/death rates are &lt;3% and the patient’s life expectancy exceeds 5 years.</td>
<td>IIb</td>
<td>B</td>
<td>80,84–98</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 19</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carotid stenting may be considered in selected asymptomatic patients who have been deemed by the multidisciplinary team to be “high-risk for surgery” and who have an asymptomatic 60–99% stenosis in the presence of one or more imaging characteristics that may be associated with an increased risk of late ipsilateral stroke, provided documented procedural risks are &lt;3% and the patient’s life expectancy exceeds 5 years.</td>
<td>IIb</td>
<td>B</td>
<td>84–94,104,105</td>
</tr>
</tbody>
</table>

* Imaging/clinical criteria that might confer an increased risk of stroke on BMT include silent infarction on CT, stenosis progression, large plaque area, large JBA, plaque echolucency, intra-plaque haemorrhage on MRI, impaired CVR, spontaneous embolisation on TCD, and history of contralateral TIA (Table 5).
2.2.3.3. Carotid revascularisation to prevent dementia

2.2.3.3.1. Alzheimer’s, vascular, and “mixed” dementias. Worldwide, 44 million people have dementia. In 2012, the cost of treating dementia in the UK exceeded £23 billion (27 billion Euros). In 20% of dementia sufferers, the underlying cause is atherosclerosis or other occlusive diseases affecting cerebral blood vessels (vascular dementia), while 20–30% have a mixture of vascular dementia and Alzheimer’s disease. Important risk factors for dementia include poor diet, mid-life hypertension, hypercholesterolaemia, diabetes, smoking, and excess alcohol intake.110

2.2.3.3.2. Dementia and carotid disease. Cognitive impairment is relatively common in stroke patients, attributed to the site and extent of the underlying brain injury. However, there has been interest in whether there is a causal association between ACS and cognitive impairment. In a recent systematic review, 9 out of 10 observational studies reported a significant association between ACS and cognitive impairment.111 However, many of the risk factors for ACS are the same as for dementia. The Baltimore Longitudinal Study of Ageing observed that patients in the upper quintile of carotid IMT or who had bilateral carotid plaques (of any severity) had a doubling of dementia rates at 14 years, compared with patients in the lower quintiles.109 In the Framingham Offspring Study, which included 1975 participants who were free of stroke and dementia at the time of study entry, ICA IMT thickness (but not CCA IMT thickness) was associated with MRI-derived indices of brain ischaemia as well as cognitive impairment.109

Buratti undertook serial DUS in 159 patients with bilateral, 70–99% ACS over a 3-year period. Cognitive decline was lowest in patients with no evidence of impaired CVR at baseline, becoming more apparent in patients with unilateral CVR impairment. The highest levels of cognitive impairment were in patients with bilaterally impaired CVR.110 Similar findings were reported by Balucani in a cohort of 333 asymptomatic patients with unilateral (n = 150), or bilateral (n = 127) carotid stenoses >60% and patients with no carotid stenosis (n = 56) who acted as controls. Patients with unilateral or bilateral ACS were more likely to have cognitive impairment, compared with those with no stenoses.111 Cognitive impairment was maximal in patients with impaired CVR. Interestingly, there was no difference in cognitive impairment in controls compared with patients with bilateral ACS who had no evidence of impaired CVR.

In the Cardiovascular Health Study Group, a high-grade stenosis of the left ICA (>75%) was associated with cognitive decline using the modified Mini-Mental State Examination (MMSE) test, which is more specific for testing dominant hemisphere cognitive function.112 The Tromso study also observed that the presence of a carotid stenosis (defined as >35%) was associated with impaired neuropsychological performance.113

2.2.3.3.3. How might carotid stenoses cause cognitive decline? Cognitive decline may be a result of “silent embolisation,” with the development of cerebral infarctions and increasing subcortical deep white matter and cortical lesions, which have been associated with cognitive impairment.113 Chronic hypoperfusion, especially in patients with impaired CVR, may also be responsible. However, an alternative explanation may be that because patients with ACS share the same risk factors as those who develop dementia, the presence of ACS may simply be a risk marker, rather than a cause of cognitive decline.

In the Cardiovascular Health Study, the persistence of a significant association between severe left-sided ACS and impaired cognitive function, after adjustment for the presence of right-sided carotid stenosis, was interpreted as meaning that the association could not be attributed to underlying vascular risk factors or atherosclerosis in general.114 However, interpretation of the data was limited by the small number of patients with severe stenoses (n = 35). Silent embolisation has long been associated with cognitive decline, but the evidence supporting this is limited. In the Tromso study, impaired cognition could not be attributed to embolisation, because there was no increase in silent ischaemic lesions on MRI.113

In a series of projects from Manchester UK, spontaneous embolisation on TCD was detected in 43% of patients with Alzheimer’s disease and 45% with vascular dementia.115 The presence of microemboli was associated with faster deterioration in cognitive function during 2 years of surveillance. However, only 8% of Alzheimer’s patients had ACS on DUS, compared with 21% of vascular dementia patients. Microemboli were associated with elevated BP and a high prevalence of venous to arterial shunts (detected in 26% of dementia patients), which may be indicative of an underlying patent foramen ovale.116 The investigators identified >50% ICA stenoses in only 13% of dementia patients who had microemboli on TCD, compared with 14% of patients without emboli. By contrast, a venous to arterial shunt was identified in 18% of dementia patients who were microemboli negative, compared with 35% who were microemboli positive.116 In the Manchester series, a >70% stenosis was present in only 2% of dementia patients who were microemboli positive, compared with 0% of microemboli negative patients.116 In addition, in a series of 96 healthy older people (median age 77 years) with no history of dementia or stroke, microemboli were detected in 12%.116 In this cohort, cognitive decline over a 2.5-year period was not associated with microemboli after correcting for age, gender and baseline cognition.116 These data, therefore, support Johnston’s hypothesis that silent embolisation from an underlying ACS is unlikely to be an important cause of dementia.117

There is probably more evidence supporting the hypothesis that chronic hypoperfusion, in association with impaired CVR, is associated with a higher prevalence of cognitive impairment. As a carotid stenosis becomes more severe, patients with inadequate collateralisation via the circle of Willis compensate by progressive dilatation of arteries/arterioles in the ipsilateral hemisphere. This maintains cerebral blood flow, but a point is reached where the vessels cannot vasodilate any more; that is they are now in a state of impaired CVR with no capacity to compensate further. CVR can be measured in several ways. One method is to measure the increase in MCA velocities using TCD at baseline and...
then after breath holding (which raises CO₂ levels), or after the inhalation of 5% CO₂ or by the administration of acetazolamide. Patients with exhausted CVR cannot increase their MCA velocities, because they are already maximally vasodilated. Interestingly, Fearn observed that CEA was able to improve postoperative cognitive function in patients who had evidence of impaired preoperative CVR.¹¹⁷

### 2.2.3.3.4. Do carotid interventions improve cognitive function?

It is hypothesised that CEA/CAS have the potential to improve cognitive function by increasing brain perfusion, as well as by removing a source of embolisation. In a systematic review of 15 studies on the effect of CEA on cognitive function, there was no change in six studies, there was a deterioration in five studies and an improvement in four. Four studies reported on the effect of CAS on cognitive function, with no change in cognition post-CAS in one study, while in three, there was an improvement.¹¹⁸ A subsequent systematic review compared changes in postoperative cognitive function after CEA versus CAS.¹¹⁹ Six studies reported no difference, three reported that cognitive function deteriorated more significantly after CAS (than CEA), whereas in one study, cognitive function deteriorated after both CEA and CAS with the effect being more persistent after CEA.¹¹⁹

To date, there is no compelling evidence that carotid interventions either improve or prevent cognitive impairment. However, there are a number of reasons why a beneficial effect might have been missed, including a “learning effect” through repeated patient testing; the type of neuropsychological test employed; the lack of involvement of a specialised neuropsychologist; the hemisphere being tested (MMSE mainly tests dominant hemispheric function); the type of patient (symptomatic/asymptomatic); a lack of controls; short duration of follow-up (most studies focused on the early perioperative period); small sample size and underpowered studies; and the lack of standardised timing of postoperative assessments.

Further data will be available from CREST-2, which is randomising asymptomatic patients to CEA or CAS versus BMT and which plans to include serial cognitive function testing. In addition, ACST-1 (with extended follow-up to 22 years in some patients) is comparing rates of dementia between patients who underwent CEA with those who remained on medical treatment alone.

### Recommendation 20

<table>
<thead>
<tr>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>B</td>
<td>118,119</td>
</tr>
</tbody>
</table>

**Until a causal association between severe asymptomatic carotid stenoses and cognitive decline has been established, carotid interventions are not recommended for the prevention of cognitive impairment in patients with severe asymptomatic carotid stenoses.**

### 2.3. Tertiary prevention in recently symptomatic patients

#### 2.3.1. Symptoms attributable to carotid artery disease

For the purpose of these guidelines, the term “symptomatic” refers to any patient who has suffered a carotid territory symptom within the preceding 6 months. Carotid territory symptoms include (i) hemi-sensory impairment (numbness, paraesthesia of face/arm/leg); (ii) hemi-motor deficits (weakness of face/arm/leg, or limb clumsiness), and (iii) higher cortical dysfunction (dysphasia/aphasia, visuospatial problems). Most symptoms are “negative” (i.e. loss of function), but occasionally a “limb-shaking” TIA can occur, characterised by involuntary limb movements caused by haemodynamic failure in patients with severe carotid stenoses (or occlusion). “Crescendo TIAs” involve multiple TIAs within a short time period, with full recovery in between. The exact number and/or frequency has never been defined, but at least three events in 7 days would seem reasonable. “Stroke-in-evolution” refers to a fluctuating deficit (never fully back to normal) or a progressively worsening neurological deficit.

Amaurosis Fugax (transient monocular blindness) refers to transient impairment or loss of vision in one eye. Occasionally, visual loss can be permanent because of retinal infarction (analogous to stroke). Patients with retinal infarction are still candidates for revascularisation to prevent hemispheric stroke. Ocular ischaemia syndrome is rare and involves a spectrum of clinical findings secondary to chronic ocular hypoperfusion (progressive visual loss, pain, dilated conjunctival/episcleral vessels, ruberosis iridis, narrowing of retinal arteries, retinal haemorrhages, and microaneurysms). In rare patients, entering a brightly lit room will trigger transient visual loss or “whiteout” of vision.¹²⁰ Ocular ischaemia syndrome is nearly always associated with severe extracranial ICA stenotic/occlusive disease, although if collateralisation via the circle of Willis is extremely poor, it can occur in patients with 50% stenoses.¹²¹ Important differential diagnoses include diabetic retinopathy and central retinal vein occlusion. Treatment involves local ophthalmic measures to control anterior segment inflammation, raised intra-ocular pressures and neovascular glaucoma. Medical treatment should focus on traditional risk factor control and optimal medical therapy, while the aim of CEA is to try and prevent further deterioration in visual acuity by preventing further neovascularisation, which is prone to haemorrhage onto the retinal surface. Carotid endarterectomy is probably less likely to be successful in patients who already have neovascularisation-related glaucoma or iris neo-vascularisation, as this indicates more severe longer-term ocular hypoperfusion.¹²²

#### 2.3.2. Optimal medical therapy

**2.3.2.1. Risk factor control.** The control of modifiable risk factors including smoking, exercise, diet, and obesity are the same as for Section 2.2.1.1.
2.3.2.2. Antiplatelet therapy

2.3.2.2.1. Antiplatelet therapy as tertiary prevention.

Table 7 summarises key RCT findings regarding roles for mono or DAPT in patients with TIA or ischaemic stroke, including the European Stroke Prevention Study-2 (ESPS-2), the Clopidogrel versus Aspirin in Patients at Risk of Ischaemic Events (CAPRIE), the European-Australasian Stroke Prevention in Reversible Ischaemia Trial (ESPRIT).

### Recommendation 21

<table>
<thead>
<tr>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>B</td>
<td>24–27</td>
</tr>
</tbody>
</table>

**A healthy diet, smoking cessation and physical activity are recommended for all patients with symptomatic carotid disease.**

### Table 7

**RCTs of antiplatelet therapy for tertiary prevention in patients with TIA and/or minor ischaemic stroke.**

<table>
<thead>
<tr>
<th>Study</th>
<th>Inclusion criteria</th>
<th>Antiplatelet therapya</th>
<th>Endpoint</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean follow-up</td>
<td>(n = )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ESPS-2</strong>&lt;sup&gt;121&lt;/sup&gt; 1996</td>
<td>TIA or ischaemic stroke in preceding 3 months</td>
<td>Dipyridamole 200 mg bd&lt;sup&gt;b&lt;/sup&gt; vs. aspirin 25 mg bd vs. aspirin 25 mg bd plus dipyridamole 200 mg bd vs. placebo</td>
<td>2-year stroke</td>
<td>Relative risk reduction (all p &lt; .05) dipyridamole vs. placebo: 16% aspirin vs. placebo: 18% aspirin + dipyridamole vs. placebo: 37% aspirin + dipyridamole vs. dipyridamole: 25% aspirin + dipyridamole vs. aspirin: 23%</td>
</tr>
<tr>
<td>2 years</td>
<td>(n = 6602)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ESPRIT</strong>&lt;sup&gt;122&lt;/sup&gt; 2006</td>
<td>TIA or minor ischaemic stroke &lt;6 months but not if urgent CEA planned</td>
<td>Aspirin 30—325 mg daily vs. aspirin 30—325 mg daily and dipyridamole 200 mg bd</td>
<td>Non-fatal stroke or MI/non-fatal major bleeding/vascular death</td>
<td>Aspirin and dipyridamole vs. aspirin (HR 0.80, 95% CI 0.66—0.98) Aspirin and dipyridamole vs. aspirin (HR 0.78, 95% CI 0.63—0.97)</td>
</tr>
<tr>
<td>3.5 years</td>
<td>(n = 2739)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CAPRIE</strong>&lt;sup&gt;123&lt;/sup&gt; 1996</td>
<td>Ischaemic stroke, MI, or PAD &lt;6 months</td>
<td>Clopidogrel 75 mg daily vs. aspirin 325 mg daily</td>
<td>Ischaemic stroke, MI, or vascular death</td>
<td>RRR with clopidogrel vs. aspirin for overall vascular disease population = 8.7% (p = .043)</td>
</tr>
<tr>
<td>3 years</td>
<td>(n = 19,185)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PRoFESS</strong>&lt;sup&gt;124&lt;/sup&gt; 2008</td>
<td>TIA or minor ischaemic stroke &lt;4 months and &gt;50 years old</td>
<td>Aspirin 25 mg bd + dipyridamole 200 mg bd vs. clopidogrel 75 mg</td>
<td>Recurrent stroke</td>
<td>Aspirin and dipyridamole vs. clopidogrel (HR 1.10, 95% CI 0.92—1.11, p = .8)</td>
</tr>
<tr>
<td>2.5 years</td>
<td>(n = 20,332)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CHANCE</strong>&lt;sup&gt;125&lt;/sup&gt; 2013</td>
<td>High-risk TIA or minor ischaemic stroke &lt;24 hours</td>
<td>75—300 mg aspirin on day 1, then 75 mg aspirin for 21d PLUS clopidogrel 300 mg, then clopidogrel 75 mg for 90 days vs. 75—300 mg aspirin on day 1, then aspirin 75 mg for 90 days</td>
<td>New ischaemic stroke or tissue-defined TIA or haemorrhagic stroke at 90 days</td>
<td>Aspirin and clopidogrel vs. aspirin (HR 0.68, 95% CI 0.57—0.81, p &lt; .01)</td>
</tr>
<tr>
<td>90 days</td>
<td>(n = 5170)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Modified release form of dipyridamole was used in the various RCTs unless specified.

<sup>b</sup> bd = twice daily (12 hourly).
the Prevention Regimen for Effectively Avoiding Second Strokes (PROFESS), and the Clopidogrel in High-risk patients with Acute Non-disabling Cerebrovascular Events (CHANCE). These studies did not specifically include patients with symptomatic carotid stenoses, but it is reasonable to extrapolate the data in the absence of large studies in patients with symptomatic carotid disease. NICE (National Institute for Health and Care Excellence) concluded that in patients with stroke or TIA, clopidogrel should be the first-line antiplatelet agent, followed by aspirin and dipyridamole (if clopidogrel intolerant), followed by aspirin monotherapy, followed by modified release dipyridamole monotherapy, if aspirin and clopidogrel intolerant.

Most of the trials in Table 7 recruited patients some time after the index event. This is important as observational studies suggest that the risk of recurrent stroke is highest in the first few days/weeks after symptom onset (Section 2.3.5). The importance of starting antiplatelet therapy early was illustrated in a meta-analysis of 12 RCTs (n = 15,778) comparing aspirin started in the first few days after symptom onset, versus control. Early aspirin therapy reduced the 6-wk risk of recurrent stroke by 60% (HR 0.42, 95% CI 0.32–0.55, p < .0001) as well as disabling or fatal stroke by 70% (HR 0.29, 95% CI 0.2–0.42, p < .0001).

There is also considerable interest in whether there is a role for starting DAPT in the very early time period after symptom onset. Spontaneous microembolic signals (MES), detected using TCD, are a recognised marker of an increased risk of recurrent stroke in symptomatic patients. Table 8 details the findings from several RCTs and observational studies, which evaluated the role of DAPT in reducing spontaneous embolisation in symptomatic patients.

Phase-2 trials support the hypothesis that aspirin + clopidogrel might be more effective than either alone in early stroke prevention. The CHANCE trial recruited 5170 patients in China within 24 hours of suffering a minor stroke.

### Table 8. Antiplatelet strategies for reducing recurrent stroke and spontaneous embolisation in recently symptomatic patients.

<table>
<thead>
<tr>
<th>Study (year)</th>
<th>Inclusion criteria</th>
<th>Intervention</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payne128 (2004)</td>
<td>100 consecutive CEA patients with ≥50% stenosis (≥70% asymptomatic)</td>
<td>Aspirin 150 mg daily for 4 wks preop vs. aspirin 150 mg daily for 4 wks preop plus a single 75 mg dose of clopidogrel 12 hours preop</td>
<td>After 3 hours of postoperative TCD monitoring, aspirin + clopidogrel was associated with a tenfold reduction in the proportion of patients with ≥20 emboli detected: (OR 0.10, 95% CI 0.01–0.77, p = .01)</td>
</tr>
<tr>
<td>CARESS129 (2005)</td>
<td>107 patients with &gt;50% symptomatic carotid stenosis with ≥1 micro-emboli detected on TCD</td>
<td>Aspirin 75 mg daily + clopidogrel 300 mg on day 1, followed by 75 mg of clopidogrel daily until day 7 vs. aspirin 75 mg daily</td>
<td>At 7 days, aspirin + clopidogrel was associated with a significant reduction in proportion of patients with persistent embolisation: (43.8% vs. 72.7%, p = .0046)</td>
</tr>
<tr>
<td>CLAIR130 (2010)</td>
<td>100 recently symptomatic patients with intra- or extra-cranial large artery stenosis</td>
<td>Aspirin 75–160 mg daily for 7 days vs. aspirin 75–160 mg daily for 7 days + clopidogrel 300 mg on day 1, followed by 75 mg of clopidogrel daily for 6 days</td>
<td>Aspirin + clopidogrel associated with significant reductions in persistent embolisation: at day 2 (31% vs. 54%, p = .025) at day 7 (23% vs. 51%, p = .006)</td>
</tr>
<tr>
<td>AMBDAP131 (2011)</td>
<td>60 recently symptomatic patients with ≥50% carotid stenosis</td>
<td>Aspirin 300 mg, then 75 mg daily + dipyridamole 200 mg bd for 30 days vs. aspirin 300 mg, then 75 mg daily + 300 mg clopidogrel, then 7 5 mg daily for 30 days</td>
<td>At 48 hours, there was a similar reduction in the frequency of microembolisation for: aspirin + dipyridamole (75.5%) aspirin + clopidogrel (77.5%, p = .77)</td>
</tr>
<tr>
<td>Batchelderm132 (2015)</td>
<td>100 consecutive symptomatic patients undergoing CEA within 8 days of symptom onset, compared with preceding 212 CEA patients</td>
<td>Aspirin 300 mg, then 75 mg daily + 75 mg clopidogrel 12 hours preop vs. aspirin 300 mg, then 75 mg daily + 75 mg clopidogrel 48–72 hours preop</td>
<td>Starting aspirin and clopidogrel 48–72 hours preop (compared with 12 hours preop) was associated with significant reductions in: recurrent TIA/stroke prior to CEA (3% vs. 13%) (OR 0.20, 95% CI 0.06–0.66, p = .01) spontaneous embolisation (5% vs. 21%) (OR 0.24, 95% CI 0.09–0.66, p = .0047)</td>
</tr>
</tbody>
</table>
or high-risk TIA, who were randomised to clopidogrel (300 mg, then 75 mg daily for 90 days) plus aspirin (75 mg daily for first 21 days) or aspirin alone (75 mg daily for 90 days). A “high-risk TIA” patient was defined as having an ABCD² score ≥4 (based on Age, Blood pressure, Clinical features, Duration of TIA, and presence or absence of Diabetes). There was a significant (32%) RRR in recurrent stroke in patients receiving early DAPT, versus aspirin alone (8.2% vs. 11.7%, p < .001), with no excess risk of moderate/severe haemorrhage (0.3% in both groups). A subgroup analysis involving >1000 subjects with imaging observed that the benefit conferred by DAPT was particularly marked in patients with extracranial ICA or MCA stenoses. A meta-analysis, which included the CHANCE data, reported that in patients with acute, non-cardioembolic ischaemic stroke/TIA, DAPT conferred a 31% RRR in stroke, compared with monotherapy.

Further data supporting a beneficial role for DAPT in the early time period after onset of symptoms comes from analyses of recurrent TIA/stroke rates prior to urgent CEA. In audits involving 198 symptomatic patients with ipsilateral 50–99% ICA stenoses who were admitted within 5 days of symptom onset, 13% suffered recurrent TIA/stroke in the 2–3 day period between transfer from the daily TIA clinic to undergoing CEA, despite being preloaded with 300 mg aspirin daily. Starting 75 mg clopidogrel daily in the TIA clinic (in addition to regular aspirin) prior to transfer to the surgical unit (once parenchymal haemorrhage was excluded on CT/MRI) was associated with significant reductions in spontaneous embolisation from 21% down to 5% (OR 0.24, 95% CI 0.09–0.66) and a significant reduction in recurrent events prior to CEA, down from 13% to 3% (OR 0.20, 95% CI 0.06–0.66) p = .01). A similar reduction in recurrent events following early introduction of DAPT prior to expedited CEA has been reported by a Danish group.

2.3.2.2.2. Antiplatelet therapy during carotid endarterectomy. Boysen reported that starting antiplatelet therapy after CEA did not reduce late stroke, compared with patients receiving placebo. In a RCT, Lindblad demonstrated that starting 75 mg aspirin prior to CEA reduced disabling stroke without increasing bleeding complications. Kretschmer showed that long-term aspirin therapy after CEA was associated with significantly better long-term survival.

In NASCET, patients were advised to take 1300 mg aspirin daily. In an unplanned post-hoc analysis, patients taking 81–325 mg of aspirin had a 30-day stroke/death rate of 6.9% compared with 1.8% in those taking 650–1300 mg doses, suggesting that higher-dose aspirin might be beneficial. The Aspirin and Carotid Endarterectomy trial thereafter randomised 2849 CEA patients to 81 mg, 325 mg, 650 mg, or 1300 mg of aspirin throughout the perioperative period. Aspirin doses of 81–325 mg were termed “low dose,” whereas 650–1300 mg were termed “high dose.” The risk of stroke, MI, or death at 30 days was non-significantly lower in patients randomised to low-dose (5.4%) vs. high-dose aspirin (7.0%, p = .07). However, it was noted that the data were biased by the inclusion of patients taking >650 mg aspirin before randomisation, alongside patients who only started aspirin the day before CEA. In an efficacy analysis that excluded the latter, the risk of stroke, MI, or death at 30 days was 3.7% on low-dose vs. 8.2% on high-dose aspirin (p = .002).

Increasing embolisation on TCD in the early postoperative period after CEA increases the risk of postoperative thrombotic stroke. A small RCT (n = 22) reported that preoperative treatment with aspirin plus dipyridamole was associated with a significant reduction in the accumulation of indium-labelled platelets to the endarterectomy zone in the first few hours after CEA, compared with placebo. In a larger RCT, Payne demonstrated that regular administration of 150 mg aspirin daily plus a single 75 mg dose of clopidogrel the night before surgery significantly reduced embolisation rates in the first 3 hours after CEA, compared with aspirin plus placebo (OR 0.1, 95% CI 0.01–0.77, p = .01).

2.3.2.2.3. Antiplatelet therapy during carotid artery stenting. Virtually every guideline recommends that CAS patients should receive DAPT throughout the perioperative period. However, this is largely based on the coronary literature, with no data from large RCTs in CAS patients. Intimal injury after CAS releases pro-coagulant factors and exposes subendothelial collagen, which acts as a nidus for platelet adhesion and secondary thrombus formation. Meta-analyses of RCTs suggested that aspirin plus clopidogrel were as effective as aspirin and ticlopidine in preventing in-stent thrombosis after coronary artery stenting. In the only RCT in CAS patients, aspirin plus heparin was associated with significantly more perioperative neurological events (25 vs. 0%, p = .02), and a non-significantly higher risk of bleeding complications compared with aspirin plus clopidogrel. No RCT has randomised CAS patients to aspirin and clopidogrel vs. aspirin and dipyridamole. Notwithstanding this, most investigators advise at least 4 wks of treatment with aspirin and clopidogrel after CAS.

Long term aspirin plus clopidogrel confers no additional benefit over antiplatelet monotherapy, unless indicated for cardiac reasons.

2.3.2.2.4. When to prescribe gastric protection medications? There was a substantial reduction in gastrointestinal bleeding when clopidogrel was co-prescribed with a proton pump inhibitor (PPI). However, studies suggest that PPIs, such as omeprazole, may reduce clopidogrel’s effectiveness. Accordingly, current advice is that in the absence of risk factors, it is reasonable to prescribe clopidogrel without a PPI. However, if the patient has one or more risk factors, they should be prescribed an agent for gastric protection along with clopidogrel. These risk factors include a prior history of gastrointestinal bleeding, older age, Helicobacter pylori infection, and concomitant use of aspirin or other non-steroidal anti-inflammatory agents, anticoagulants, selective serotonin re-uptake inhibitors, or...
steroids. In these circumstances, one could empirically consider ranitidine as an agent for gastric protection. If a PPI is preferred, then it may be preferable to use pantoprazole, which does not appear to interact with clopidogrel.

<table>
<thead>
<tr>
<th>Recommendation 22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antplatelet therapy is recommended in symptomatic patients with 50–99% stenoses not undergoing carotid endarterectomy or carotid stenting. First choice therapy is clopidogrel 75 mg daily or aspirin 75 mg daily plus modified release dipyridamole 200 mg twice daily. If intolerant of dipyridamole or clopidogrel, aspirin monotherapy (75–325 mg) should be used. If aspirin and clopidogrel intolerant, use modified release dipyridamole 200 mg twice daily.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 23</th>
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</thead>
<tbody>
<tr>
<td>It is recommended that all patients undergoing carotid endarterectomy should receive antplatelet therapy throughout the perioperative period and also in the long term.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Recommendation 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-dose aspirin (75–325 mg daily) is recommended rather than higher doses (&gt;625 mg daily) in patients undergoing carotid endarterectomy.</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Recommendation 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early institution of aspirin + clopidogrel (or aspirin plus modified release dipyridamole) after transient ischaemic attack or minor stroke may be considered to reduce early recurrent events in patients with a &gt;50% carotid stenosis awaiting carotid endarterectomy.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that patients undergoing carotid stenting should receive dual antplatelet therapy with aspirin (75–325 mg daily) and clopidogrel (75 mg daily). Clopidogrel should be started at least 3 days prior to stenting or as a single 300 mg loading dose in urgent cases. Aspirin and clopidogrel should be continued for at least 4 wks after stenting and then optimal long-term secondary preventive antplatelet therapy should be continued indefinitely.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term aspirin plus clopidogrel therapy is not recommended in patients undergoing carotid endarterectomy or carotid stenting unless indicated for cardiac reasons.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrent gastro-protection treatment or proton pump inhibition with pantoprazole should be considered in patients prescribed clopidogrel who have one or more risk factors that increase the patient’s risk of gastrointestinal bleeding (prior history of gastrointestinal bleeding, older age, Helicobacter pylori infection, and concomitant use of aspirin, or other non-steroidal anti-inflammatory agents, anticoagulants, selective serotonin re-uptake inhibitors or steroids).</td>
</tr>
</tbody>
</table>

### 2.3.2.3. Lipid-lowering therapy.

Most of the available data comes from RCTs that included carotid stenosis patients within larger cohorts of patients with vascular disease.

#### 2.3.2.3.1. Statins as tertiary prevention.

SPARCL included 4731 patients with a prior TIA/stroke 1–6 months before randomisation, of whom 966 had a median ICA stenosis of 51%. Within 30 days of screening, patients were randomised to 80 mg atorvastatin or placebo. The primary endpoint was time to fatal or non-fatal stroke. Patients with carotid stenoses who were randomised to atorvastatin had a 33% RRR in fatal/non-fatal stroke, as well as a 42% RRR in cardiovascular events. A subgroup analysis from the Heart Protection Study included 3280 patients with a TIA or non-disabling ischaemic stroke who were
randomised to 40 mg of simvastatin daily (n = 1055) or placebo (n = 1052). The mean interval from the most recent TIA/stroke was 4.3 years and patients were excluded if they had been hospitalised for stroke within 6 months. Simvastatin conferred a 20% RRR in stroke, MI, or vascular death (p = .001).

2.3.2.3.2. Statins during carotid endarterectomy. Several studies have reported that statin therapy (started preoperatively) was associated with significant reductions in 30-day death/stroke.\textsuperscript{156–158} This may be mediated via their pleiotropic effects in reducing inflammation, direct plaque stabilisation, and a general reduction in the inflammatory response to surgery.\textsuperscript{159} Interestingly, patients receiving statin therapy prior to CEA may have significantly lower rates of preoperative spontaneous embolisation than those not taking statins.\textsuperscript{160} However, in a 2013 Cochrane review on the role of perioperative statin therapy for improving outcomes after “non-cardiac vascular surgery procedures” the findings were inconclusive. This was probably because of the relatively small number of patients who had not been taking statins prior to their operation.\textsuperscript{161} In a much larger, multicentre study involving 15,478 patients undergoing a variety of vascular, general surgical, thoracic, gynaecological, and urological procedures, multivariable logistic modelling observed that patients who started statins preoperatively had significant reductions in 30-day myocardial injury, stroke, or death.\textsuperscript{162} Patients prescribed statin therapy should not have this medication withdrawn acutely, because this may be associated with significant increases in perioperative cardiovascular morbidity and mortality.\textsuperscript{163}

2.3.2.3.3. Statins during carotid artery stenting. As with CEA (Section 2.3.2.3.2), studies have reported that statin therapy started prior to CAS was associated with significant reductions in 30-day risk.\textsuperscript{164–166} Groschel reported that 30-day death/stroke/MI risk was significantly lower in CAS patients who were pre-treated with statins (4%), versus 15% in patients who were not on statins (OR 0.23, 95% CI 0.05—0.99, p = .049).\textsuperscript{164} A similar finding was reported by Reiff who observed that preoperative statin therapy was associated with significant reductions in perioperative death/stroke/MI (6.8%) versus 13.9% in those not taking statins pre-CAS (OR 0.31, 95% CI 0.3—0.71, p = .006).\textsuperscript{166} Finally, Verzini observed that pre-treatment with statins was associated with a significant reduction in 30-day death/stroke, compared with no statin therapy (OR 0.33, 95% CI 0.13—0.80, p = .016).\textsuperscript{165} Statin usage has not been evaluated in RCTs, but the evidence would suggest that pre-treatment with statins prior to undergoing CAS is desirable.

<table>
<thead>
<tr>
<th>Recommendation 29</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statin therapy is recommended for the prevention of long-term stroke, myocardial infarction, and other cardiovascular events in patients with symptomatic carotid disease</td>
<td>I</td>
<td>A</td>
<td>36,154,155</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 30</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that patients start statin therapy prior to endarterectomy or stenting and that statins should not be stopped during the perioperative period and should be continued long term</td>
<td>I</td>
<td>B</td>
<td>156–159,162, 164–166</td>
</tr>
</tbody>
</table>

2.3.2.4. Treatment of hypertension

2.3.2.4.1. Tertiary prevention in patients with symptomatic carotid stenoses. No RCT has evaluated the role of antihypertensive therapy in patients with symptomatic carotid stenoses. However, a meta-analysis of 13 BP treatment trials in patients with a history of stroke reported a significant RRR in stroke with antihypertensive therapy (34%, 95% CI 15–32).\textsuperscript{15} A recent Cochrane review concluded that there was insufficient evidence to support lowering BP during the acute phase of stroke, because there was no improvement in functional outcome.\textsuperscript{167} In addition, in recently symptomatic patients with severe bilateral ICA stenoses, aggressive BP lowering before revascularization may not be advisable.\textsuperscript{168} However, in patients being considered for early CEA, a balance must be struck. This is because a systolic BP <180 mmHg is an independent predictor for stroke after CEA.\textsuperscript{169} Accordingly, it is reasonable to perform an urgent CEA in symptomatic patients whose preoperative BP is <180 mmHg. Symptomatic patients with a preoperative BP >180 mmHg should receive urgent antihypertensive treatment to reduce this to <180 mmHg before proceeding with CEA. Persisting or worsening hypertension after CEA should be actively treated post- operatively, as post-CEA hypertension is associated with an increased risk of hyperperfusion syndrome (HS), intracranial haemorrhage (ICH), bleeding complications, and cardiac events in the early postoperative period.\textsuperscript{170} This will be discussed in Section 2.6.1.3.3.
2.3.2.5. Treatment in diabetic patients. The management of patients with diabetes is the same as for asymptomatic patients (see Section 2.2.1.5).

2.3.2.6. Compliance with medical treatment. This subject has been reviewed in Section 2.2.1.6.

2.3.3. Randomised trials comparing endarterectomy with medical therapy. The three most important RCTs comparing CEA with BMT were NASCET, ECST, and the Symptomatic Veterans Affairs Co-operative Study (SVACS) Trial.9,10,171 The SVACS trial was discontinued following publication of NASCET/ECST in 1991.171 NASCET randomised 2905 patients who reported symptoms within the preceding 6 months and who had 30–99% carotid stenoses to BMT or CEA (plus BMT). ECST randomised 3024 patients who reported symptoms within the preceding 6 months and who had 0–99% stenoses to BMT or CEA (plus BMT). To standardise stenosis measurement for individual patient meta-analyses, the pre-randomisation angiograms for the 6092 patients randomised within NASCET, ECST, and SVACS were remeasured using the NASCET method (Table 9). CEA (plus BMT) did not prevent stroke in recently symptomatic patients with <50% stenoses. CEA conferred significant benefit in patients with moderate (50–69%) and severe (70–99%) stenoses (Table 9). The benefit conferred by CEA increased with increasing stenosis severity, with the exclusion of “near-occlusion.” Patients with chronic near occlusion (defined as a 95–99% stenosis with distal ICA collapse or a narrow calibre lumen with "trickle flow") gained no obvious benefit from CEA.172,173

Because of the large number of randomised patients included within ECST, NASCET, and SVACS, it was possible to perform meaningful subgroup analyses to establish who gained greater (lesser) benefit from CEA.175 The principle findings are summarised in Table 10. Clinical predictors of an increased stroke risk on BMT include

Table 9. Individual patient meta-analysis of the 5-year risk of any stroke (including the perioperative risk) from pooled ESCT, NASCET, and SVACS Trial data.174

<table>
<thead>
<tr>
<th>Stenosis severity (NASCET)</th>
<th>n</th>
<th>5-year risk of any stroke (inc. perioperative)</th>
<th>ARR @5 years</th>
<th>RRR @5 years</th>
<th>NNT to prevent one stroke @5 years</th>
<th>No. of strokes prevented per 1000 CEAs @5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–30%</td>
<td>1746</td>
<td>18.4%</td>
<td>15.7%</td>
<td>−2.7%</td>
<td>No benefit</td>
<td>No benefit</td>
</tr>
<tr>
<td>30–49%</td>
<td>1429</td>
<td>22.8%</td>
<td>25.5%</td>
<td>+2.7%</td>
<td>No benefit</td>
<td>No benefit</td>
</tr>
<tr>
<td>50–69%</td>
<td>1549</td>
<td>20.0%</td>
<td>27.8%</td>
<td>+7.8%</td>
<td>28%</td>
<td>13</td>
</tr>
<tr>
<td>70–99%</td>
<td>1095</td>
<td>17.1%</td>
<td>32.7%</td>
<td>+15.6%</td>
<td>48%</td>
<td>6</td>
</tr>
<tr>
<td>Near occlusion</td>
<td>262</td>
<td>22.4%</td>
<td>22.3%</td>
<td>−0.1%</td>
<td>No benefit</td>
<td>No benefit</td>
</tr>
</tbody>
</table>

ARR = Absolute Risk Reduction in stroke; RRR = Relative Risk Reduction in stroke; NNT = number needed to treat to prevent one stroke at 5 years.

Data derived from the Carotid Endarterectomy Trialists Collaboration.172–174
increasing age, male gender, recent symptoms, a hemispheric TIA/stroke, a cortical stroke, and increasing medical comorbidities. Imaging predictors of an increased risk of stroke on BMT include irregular stenoses, increasing stenosis severity (but not subocclusion), contralateral occlusion, tandem intracranial disease, and a failure to recruit intracranial collaterals.

2.3.4. Randomised trials comparing endarterectomy with stenting. Eighteen RCTs (9492 patients) have published outcomes comparing CEA with CAS or carotid angioplasty since 1998. Nine included symptomatic patients only, while four randomised asymptomatic patients only. Five RCTs included both symptomatic and asymptomatic patients, but did not always stratify outcomes for symptom status. Meta-analyses have combined data from all RCTs or focused on RCTs with >50 patients. Outcomes from the four largest symptomatic RCTs comprise the main evidence base in these guidelines; including the Endarterectomy versus Stenting in patients with Symptomatic Severe carotid Stenosis (EVA-3S), the SPACE trial, the International Carotid Stenting Study (ICSS), and CREST. The RCTs involving symptomatic patients used a 6-month threshold for inclusion.

2.3.4.1. 30-day procedural risks

2.3.4.1.1. Principle outcomes. Table 11 details 30-day risks following CEA and CAS in RCTs that randomised >500 symptomatic patients, while Table 12 summarises...
statistically significant differences between CEA and CAS in symptomatic patients.

The higher rates of perioperative stroke after CAS were largely a result of higher rates of non-disabling stroke. There was no difference in 30-day death/disabling stroke in symptomatic patients (HR 1.28, 95% CI 0.93–1.77).

2.3.4.1.2. Outcomes stratified for age. A meta-analysis of ICSS, CREST, EVA-3S, and SPACE data in symptomatic patients showed a strong association between increasing age and higher rates of death/stroke after CAS, but not after CEA (Table 13). In CAS patients, the risk increased with age (compared with patients aged <60 years), CAS patients aged >80 years were four times more likely to suffer a procedural stroke/death (OR 4.15, 95% CI 2.20–7.84). In CEA patients, increasing age was not associated with an increased risk of perioperative stroke/death. When CAS was compared with CEA, the age effect started to become apparent in patients aged 60–65, while CEA was clinically superior to CAS in patients aged >70 years (HR 2.09, 95% CI 1.32–2.32). Interestingly, the same finding (no association between age and procedural risk after CEA) was reported by NASCET in 2001.

2.3.4.2. Long-term outcomes in the randomised trials

2.3.4.2.1. Late ipsilateral stroke. A 2015 meta-analysis reported that CAS was associated with a significantly increased risk of late ipsilateral stroke and/or peri-procedural stroke/death (OR 1.45, 95% CI 1.20–1.75). However, most strokes after CEA occurred in the perioperative period. CREST, ICSS, SPACE, and EVA-3S have now shown that once the 30-day perioperative period has elapsed, late ipsilateral stroke rates are no different between CEA and CAS, that is CAS appears durable after 30 days has elapsed. Accordingly, the key consideration in deciding whether to recommend CEA or CAS in individual patients will be to identify features which increase or lessen the procedural risk (e.g. recency of symptoms, surgeon/interventionist experience, patient age, plaque length, sequential plaque, heavily calcified plaques, tortuous arteries, overall burden of cardiovascular risk, nature of presenting event, crescendo symptoms, contralateral occlusion, likelihood of overlying thrombus, type III arch, bovine arch, arch atheroma, and (of course) patient preference). For a more detailed review of factors associated with higher procedural risks after CEA and CAS, see Sections 2.6.1.1.3 and 2.6.1.2.2.

2.3.4.2.2. Quality of life. Health Related Quality of life (HRQoL) was assessed among 2502 CREST patients. CAS was associated with better HRQoL in the postoperative period (compared with CEA), especially for physical limitation and pain (p = .01). These differences were significant at 4 wks, but not at 1 year. Using disease-specific scales, CAS patients reported fewer problems with driving, eating/swallowing, neck pain, and headaches, but greater difficulty with walking and leg pain (p < .05). However, by 1 year, there was no difference in any HRQoL measure. Peri-procedural stroke was associated with poorer 1-year HRQoL scores across all SF-36 domains, while periprocedural MI and CNI were not.

2.3.4.2.3. Survival following perioperative stroke or myocardial infarction. A meta-analysis of seven observational studies and two RCTs (5959 patients) observed that CAS was associated with a significant reduction in ECG diagnosed MI or non-ST elevation MI (NSTEMI) with troponin elevation (OR 0.37, 95% CI 0.22–0.61, p = .0001). The significance of perioperative MI (especially NSTEMI with biomarker elevation) has been a source of controversy since its inclusion within the primary endpoint in SAPPHIRE and CREST. The rationale for including perioperative MI was because historical studies had suggested that it was associated with poorer long-term survival.

In a CREST subgroup analysis, patients suffering a perioperative MI faced a threefold increase in late mortality (HR 3.4, 95% CI 1.7–6.0, p = .001), while patients with biomarker elevation alone faced a near fourfold increase in late death (HR 3.6, 95% CI 1.5–8.7, p = .023). However, poorer survival after suffering a perioperative MI must be balanced against the findings of a further subgroup analysis from CREST, which showed that the adjusted risk of
death at 4 years was significantly higher (by a factor of almost three) in patients suffering a perioperative stroke (HR 2.78, 95% CI 1.63–4.76). Meta-analyses confirm the increased risk of peri-operative MI after CEA. However, in a further meta-analysis, Vincent calculated that CAS was associated with a 0.3% absolute reduction in perioperative MI, which was offset by a 1.8% increase in perioperative stroke. Accordingly, long-term survival appears to be similarly reduced in CEA or CAS patients suffering either a perioperative MI or stroke.

An algorithm for managing recently symptomatic patients with carotid disease is presented in Fig. 5.

### 2.3.5. Timing of interventions after onset of symptoms

There is confusion over the definition of “first event,” “index event,” and “most recent event.” The “first event” is the first symptom to affect the patient. The “index event” is the symptom that led the patient to seek medical advice. The “most recent event” is the symptom that occurred most recently. These terms have been misused in the past and must be interpreted carefully when analysing the literature on the risks/benefits of intervening early.

#### 2.3.5.1. Carotid endarterectomy

CEA has often been delayed because of a perception that this reduces procedural risk. However, there is increasing evidence that CEA confers maximum benefit if performed <14 days, and there is compelling evidence that the risk of early, recurrent stroke after TIA onset may be much higher than previously thought. Contemporary natural history studies report that the incidence of recurrent stroke after the index TIA ranges from 5% to 8% at 48 hours, 4% to 17% at 72 hours, 8% to 22% at 7 days, and 11% to 25% at 14 days (Table 14). Note that recurrent stroke rates at 14 days are similar to those observed at 5 years in patients who were randomised to BMT in ECST, NASCET, and VA, suggesting that many patients destined to suffer an early stroke after onset of symptoms were never randomised within these landmark RCTs.

Few studies have reported risks after CEA, stratified for delay. In a single-centre series involving 475 patients from Leicester, UK, 30-day death/stroke rate was 2.4% when CEA...
was performed <48 hours of symptom onset, 1.8% when CEA was performed at 3–7 days, 0.8% where CEA was performed between 8 and 14 days, and 0.7% when CEA was performed after 14 days.216 An Austrian audit, involving 761 patients, corroborated the Leicester findings, observing that CEA was associated with a 4.4% risk of death/stroke when performed <48 hours of the index symptom, 1.8% when CEA was performed within 3–7 days, 4.4% for operations between 8 and 14 days, and 2.5% when >14 days had elapsed.217 Only three countries (worldwide) have published national audit data on the effect of delay to CEA on 30-day death/stroke rates after CEA. The principle findings are detailed in Tables 15 and 16.

Only a minority underwent CEA <48 hours (6% Sweden, 3% UK, and 9% Germany). However, a higher proportion underwent CEA <7 days of symptom onset (37% Sweden, 25% UK, and 43% Germany), while 63% underwent CEA within 14 days in Sweden, compared with 52% in the UK and 72% in Germany. The median delay from symptom to underгоing CEA was 12 days in the UK, 9 days in Germany, and 8 days in Sweden.218–220 Table 16 details 30-day rates of death/stroke in national audits, stratified for delay to surgery. The paper associated with the most controversy was the 2012 Swedish Report, which observed that when CEA was performed <48 hours of the first symptom, 30-day death/stroke was 11.5%.218 However, only 148 patients underwent CEA during this time period. Thereafter, procedural risks were 3.6% at 3–7 days, 4.0% at 8–14 days, and 5.4% after 14 days had elapsed.216 By contrast, 30-day death/strokes rates were 3% (Germany) and 3.7% (UK) when CEA was performed <48 hours of symptom onset.219,220 After 48 hours had elapsed, each of the national audits showed that CEA could be performed within 3–7 days and 14 days with low procedural risks.218–220

### 2.3.5.2. Carotid artery stenting

Performing CAS in the early time period after symptom onset is controversial and the literature contains conflicting data. A pooled series from four industry-sponsored registries (n = 2104) reported higher 30-day stroke rates (8.8%) when CAS was performed <14 days, compared with 5.9% when CAS was performed >14 days.221 A doubling of stroke risk was also reported in the CAPTURE Registry (n = 3500) when CAS was performed <14 days of symptom onset.223

The Carotid Stenosis Trialists’ Collaboration (CSTC) has published an individual patient meta-analysis involving 4138 symptomatic patients who were randomised to CEA or CAS within the four major multicentre RCTs (CREST, ICSS, EVA-3S, and SPACE).224 Only a relative minority underwent CEA (11%) or CAS (14%) <48 hours of symptom onset. Among patients who were treated within 7 days of symptom onset, those treated by CAS were significantly more likely to suffer an adverse outcome (30-day death/stroke, 30-day any stroke, 30-day fatal or disabling stroke), compared with CEA (Table 17). The 30-day rate of death/stroke when CAS was performed within 7 days of symptom onset was 9.4%, versus 3.8% after CEA (OR 3.4 (95%CI 1.01—11.8)). The CSTC concluded that for patients undergoing a carotid intervention within 7 days of symptom onset, CEA was significantly safer than CAS.224 In an earlier individual patient meta-analysis of procedural risks in recently symptomatic patients randomised within EVA-3S, SPACE, and ICSS, patients undergoing CAS within 8–14 days of the most recent symptom incurred significantly higher 30-day death/stroke rates (8.1) versus 3.4% after CEA (p = .04).225

Very few CAS studies have published 30-day death/stroke rates stratified for delays from most recent symptom to underгоing CAS. Those that have published are summarised in Table 18. There are no data relating to outcomes after CAS using proximal flow reversal in large cohorts of recently symptomatic patients, especially in the first 7 days after symptom onset. However, surgeons/interventionists participating in the RCTs were credentialed and may not represent “real world” practice. In a recent systematic review, Parasekhas observed that 72% of administrative dataset registries reported 30-day death/stroke rates in excess of the 6% threshold after CAS, while 28% reported stroke rates in excess of 10%.70 Given that the term “recently symptomatic” includes any patient undergoing CAS/CEA <6 months

### Table 15. Proportion of patients undergoing CEA in national audits within 0–2, 3–7, 8–14, and >15 days after onset of symptoms.

<table>
<thead>
<tr>
<th>National Audit</th>
<th>0–2 days</th>
<th>3–7 days</th>
<th>8–14 days</th>
<th>≥15 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden218</td>
<td>148/2596 (6%)</td>
<td>804/2596 (31%)</td>
<td>677/2596 (26%)</td>
<td>967/2596 (37%)</td>
</tr>
<tr>
<td>n = 2596</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK219</td>
<td>780/23,235 (3%)</td>
<td>5126/23,235 (22%)</td>
<td>6292/23,235 (27%)</td>
<td>11,037/23,235 (48%)</td>
</tr>
<tr>
<td>n = 23,235</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany220</td>
<td>5198/56,279 (9%)</td>
<td>19,117/56,279 (34%)</td>
<td>16,205/56,279 (29%)</td>
<td>15,759/56,279 (28%)</td>
</tr>
<tr>
<td>n = 56,279</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 16. 30-day death/stroke risks after CEA, stratified for delay from symptom onset to CEA in national audits of practice.

<table>
<thead>
<tr>
<th>National Audit</th>
<th>0–2 days % (95% CI)</th>
<th>3–7 days % (95% CI)</th>
<th>8–14 days % (95% CI)</th>
<th>≥15 days % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden218</td>
<td>17/148</td>
<td>29/804</td>
<td>27/677</td>
<td>52/967</td>
</tr>
<tr>
<td>n = 2596</td>
<td>11.5% (6.8–17.8)</td>
<td>3.6% (2.4–5.1)</td>
<td>4.0% (2.6–5.8)</td>
<td>5.4% (4.0–7.0)</td>
</tr>
<tr>
<td>UK219</td>
<td>29/780</td>
<td>128/5126</td>
<td>132/6292</td>
<td>254/11,037</td>
</tr>
<tr>
<td>n = 23,235</td>
<td>3.7% (2.5–5.3)</td>
<td>2.5% (2.1–3.0)</td>
<td>2.1% (1.8–2.5)</td>
<td>2.3% (2.0–2.6)</td>
</tr>
<tr>
<td>Germany220</td>
<td>157/5198</td>
<td>480/19,117</td>
<td>427/16,205</td>
<td>370/15,759</td>
</tr>
<tr>
<td>n = 56,279</td>
<td>3.0% (2.6–3.5)</td>
<td>2.5% (2.3–2.7)</td>
<td>2.6% (2.4–2.9)</td>
<td>2.3% (2.1–2.6)</td>
</tr>
</tbody>
</table>
Table 17. 30-day outcomes following CEA and CAS, stratified for timing of the carotid intervention after symptom onset in a pooled meta-analysis of symptomatic patients randomised within CREST, ICSS, EVA-3S, and SPACE.a

<table>
<thead>
<tr>
<th>30-day outcomes</th>
<th>CEA</th>
<th>CAS</th>
<th>OR (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any stroke/death</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;7 days</td>
<td>3/226 (1.3%)</td>
<td>24/287 (8.4%)</td>
<td>6.51 (2.00–21.21)</td>
<td>.002</td>
</tr>
<tr>
<td>&gt;7 days</td>
<td>65/1819 (3.6%)</td>
<td>129/1806 (7.1%)</td>
<td>2.00 (1.49–2.67)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Any stroke</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;7 days</td>
<td>3/226 (1.3%)</td>
<td>23/287 (8.0%)</td>
<td>6.27 (1.92–20.44)</td>
<td>.002</td>
</tr>
<tr>
<td>&gt;7 days</td>
<td>62/1819 (3.4%)</td>
<td>122/1806 (6.8%)</td>
<td>1.98 (1.47–2.67)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Fatal/disabling stroke</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;7 days</td>
<td>1/226 (0.4%)</td>
<td>9/287 (3.1%)</td>
<td>8.29 (1.07–64.28)</td>
<td>.04</td>
</tr>
<tr>
<td>&gt;7 days</td>
<td>26/1819 (1.4%)</td>
<td>46/1806 (2.5%)</td>
<td>1.77 (1.10–2.85)</td>
<td>.02</td>
</tr>
</tbody>
</table>

a Based on data derived from Rantner et al.224

Table 18. 30-day death stroke risks following CAS, stratified for time from index symptom to intervention.

<table>
<thead>
<tr>
<th>0–2 days</th>
<th>3–7 days</th>
<th>8–14 days</th>
<th>&gt;14 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setacci 2010226</td>
<td>1/26 (4.0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moratto 2012227</td>
<td>3/78 (3.8%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al-Mubarak 1999228</td>
<td>3/44 (6.8%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wach 2014229</td>
<td>5/70 (7.1%)</td>
<td>4/88 (4.5%)</td>
<td>1/36 (2.8%)</td>
</tr>
<tr>
<td>SwedVasc 2015230</td>
<td>0/13 (0.0%)</td>
<td>4/85 (4.7%)</td>
<td>5/80 (6.3%)</td>
</tr>
</tbody>
</table>

However, in selected patients with an area of infarction involving less than one-third of the MCA territory, emergency CEA can be performed with 2–8% rates of death/stroke for stroke-in-evolution and 0–2% for crescendo TIA.235–237 These results compare favourably with the otherwise poor natural history of these conditions.

There are no RCT data for determining whether intravenous heparin administration is superior to antiplatelet therapy in preventing early recurrent stroke in patients with stroke in evolution or crescendo TIs. In a series of 144 patients suffering a non-disabling stroke and who had a 50–99% stenosis and TCD evidence of embolisation, spontaneous embolisation rates were diminished in patients started on antiplatelet therapy, but not in those receiving heparin.238 In two RCTs, comparing low molecular weight heparin (LMWH) versus aspirin monotherapy in acute stroke patients where antiplatelet/antithrombotic therapy was commenced within 48 hours of symptom onset, there was no compelling evidence that LWMH conferred any significant benefit over aspirin.239,240 However, in a post-hoc analysis looking specifically at the prevalence of neurologic deterioration at 10 days, LMWH was associated with a significant reduction in ischaemic stroke progression (5%), compared with aspirin (12.7%), (OR 0.36, 95% CI 0.16–0.81), without an excess risk of cerebral haemorrhage.241

Other therapeutic strategies that might reduce spontaneous microembolisation in patients with recurrent TIs or crescendo TIs include TCD titrated intravenous dextran therapy242 or tirofiban (intravenous glycoprotein IIb/IIIa receptor antagonist).243 Batchelder et al. showed that early institution of aspirin and clopidogrel (once parenchymal haemorrhage was excluded on CT/MRI) was associated with...
significant reductions in spontaneous embolisation (21% down to 5%, OR 0.20, 95% CI 0.06–0.66, \( p = .0047 \)) and a significant reduction in recurrent events prior to CEA, (13% down to 3%, OR 0.20, 95% CI 0.06–0.66, \( p = .01 \)).132

In the absence of quality evidence, it would seem reasonable to offer heparin (plus aspirin) or dual antiplatelet therapy in patients with recurrent TIA’s or crescendo TIA’s prior to urgent CEA.

### 2.3.6. Timing of carotid interventions after intravenous thrombolysis

An important concern when performing CAS/CEA after intravenous thrombolysis (IVT) is an increased risk of ICH following reperfusion of ischaemic cerebral tissue. A review of 13 series (361 patients), observed that the 30-day death/stroke rate was 3.6%, while the prevalence of ICH was 2.5%.244 These outcomes were not significantly different to historical series (where thrombolysis was not used), suggesting publication bias. To achieve such low procedural risks, strict selection criteria for early CEA should be followed. These include (1) rapid neurological recovery of the patient after IVT (modified Rankin 0–2); (2) area of infarction less than one-third of the MCA territory; (3) recanalisation of a previously occluded MCA mainstem; (4) ICA stenosis 50–99%; and (5) no evidence of parenchymal haemorrhage or significant brain oedema.244–246 Careful postoperative BP monitoring is mandatory170 (Section 2.6.1.3.3). Contraindications to early CEA after IVT include (1) severe persistent neurological deficit (modified Rankin score \( \geq 3 \)); (2) anticipated high surgical risk; and (3) the presence of parenchymal haemorrhage and previous radical neck dissection or radiotherapy.244 Given these strict selection criteria and contraindications, only 2–6% of patients undergoing acute IVT may be eligible for CEA.245,247

The optimal timing of CEA after IVT remains unknown, but antiplatelet and heparin therapy should be withheld for 24 hours after cessation of IVT247 because of the heightened risk of haemorrhagic complications during this time period. The literature review observed delays ranging from 48 hours to 8 days, with one small study reporting higher rates of ICH if CEA was performed within 72 hours of IVT completion.248 The largest published series (202 cases) reported 30-day death/stroke rates of 3.4% among patients who underwent CEA <14 days of IVT, compared with 5.1% in those undergoing CEA <7 days.249 It is essential, however, that CEA patients who undergo treatment within a few days of completing IVT are monitored carefully and treated actively for post-CEA hypertension (Section 2.6.1.3.3).170

Only one study (involving six patients) has reported outcomes following early CAS after IVT.250

### Recommendations

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revascularisation should be deferred in patients with 50–99% stenoses who suffer a disabling stroke (modified Rankin score ( \geq 3 )), whose area of infarction exceeds one-third of the ipsilateral middle cerebral artery territory, or who have altered consciousness/drowsiness, to minimise the risks of postoperative parenchymal haemorrhage</td>
<td>I</td>
<td>C</td>
<td>231,232</td>
</tr>
<tr>
<td>Patients with 50–99% stenoses who present with stroke-in-evolution or crescendo transient ischaemic attacks should be considered for urgent carotid endarterectomy, preferably &lt;24 hours</td>
<td>IIA</td>
<td>C</td>
<td>233–237</td>
</tr>
<tr>
<td>Early carotid endarterectomy (within 14 days) should be considered after intravenous thrombolysis in symptomatic patients if they make a rapid neurological recovery (Rankin 0–2), the area of infarction is less than one-third of the ipsilateral middle cerebral artery territory, a previously occluded middle cerebral artery mainstem has recanalised, there is a 50–99% carotid stenosis and no evidence of parenchymal haemorrhage or significant brain oedema</td>
<td>IIA</td>
<td>C</td>
<td>244–246</td>
</tr>
<tr>
<td>It is recommended that intravenous heparin and antiplatelet therapy be withheld for 24 hours after completion of intravenous thrombolysis, but antiplatelet therapy should then be commenced before any carotid intervention is undertaken</td>
<td>I</td>
<td>C</td>
<td>247</td>
</tr>
<tr>
<td>It is recommended that patients undergoing early carotid interventions after thrombolysis should have post-interventional hypertension actively treated to reduce the risks of parenchymal haemorrhage</td>
<td>I</td>
<td>C</td>
<td>244</td>
</tr>
</tbody>
</table>
2.3.7. Timing of carotid interventions after intracranial endovascular therapies. A meta-analysis of five randomised trials reported that emergency endovascular treatment of acute ischaemic stroke (mechanical thrombectomy [stent retrieval] and/or intra-arterial thrombolysis) was associated with a twofold improvement in functional outcome, compared with patients randomised to BMT. Interestingly, endovascular therapy was not associated with reduced mortality or an increased risk of symptomatic intracerebral haemorrhage. A proportion of patients undergoing an emergency intracranial endovascular intervention will be found to have a significant extracranial ICA stenosis. There are currently no data to guide clinicians as to whether adjuvant CEA or CAS should be performed as a synchronous or staged intervention in these patients, but neuro-interventionists were advised not to “routinely” perform CAS at the time of mechanical thrombectomy in the ESCAPE trial. In the Multicentre Randomised Clinical Trial of Ischaemic Stroke in the Netherlands (Mr CLEAN) study, 13% of patients underwent stent retrieval plus simultaneous CAS, but no data were provided about whether this strategy was associated with higher or lower procedural risks.

2.3.8. Is there a subgroup with <50% stenosis who might benefit from surgery? An individual patient meta-analysis of symptomatic patients with <50% stenoses who were randomised within ECST, NASCET, and the VA trials showed that CEA conferred no benefit over BMT (Section 2.3.3). The 5-year risk of stroke in 1746 patients with <30% stenoses who were randomised to CEA was 18.4%, compared with 15.7% on BMT. The 5-year risk of stroke in 1429 patients with 30—49% stenoses who were randomised to CEA was 22.8%, compared with 25.5% on BMT. However, a small cohort of patients with <50% stenoses will still continue to suffer recurrent symptoms (despite BMT). In a recent review of outcomes in previously symptomatic patients with 20—49% stenoses at baseline, the risk of recurrent ipsilateral stroke at 3 years was 7.4%.

In patients with <50% stenoses who report recurrent symptoms, it is important to ensure that medical treatment really has been optimised and that no other cause for the recurrent TIAs can be identified. If symptoms persist, despite optimal medical therapy, it may be reasonable to consider CEA/CAS, but this should not be undertaken without independent neurologist or stroke physician review.

<table>
<thead>
<tr>
<th>Recommendation 47</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carotid endarterectomy or carotid stenting may be considered in recently symptomatic patients with &lt;50% stenoses if they suffer recurrent symptoms despite best medical therapy and following multidisciplinary team review</td>
<td>IIb</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

2.3.9. “High-risk for surgery” symptomatic patients. In patients considered high-risk for mortality/morbidity after CEA, CAS has been proposed as an alternative. “High-risk for CEA” is generally defined as anatomical and/or clinical factors that have the potential to increase complications following CEA, ranging from death, stroke, through to cranial nerve injury (CNI). The concept of “high-risk” is, however, open to misuse. This is because being “high-risk for CEA” can occasionally be misinterpreted as being “high-risk for stroke.” Criteria that are currently used to define a patient as being “high-risk for CEA” are based on those adopted by SAPHIRE. SAPHIRE advised that the patient should have carotid territory symptoms within the preceding 180 days and have a 50—99% stenosis, plus at least one of the following: clinically significant cardiac disease (congestive heart failure, abnormal stress test, or need for open-heart surgery); severe pulmonary disease; contralateral carotid occlusion; contralateral laryngeal-nerve palsy; previous radical neck surgery, cervical radiation therapy; recurrent stenosis after CEA; and age >80 years. While severe cardiac or pulmonary artery disease might increase the risk of CEA and the presence of a contralateral recurrent laryngeal nerve palsy is accepted contraindication to CEA, the validity of certain “high-risk for CEA” criteria are open to debate. In addition, no RCT has evaluated whether CEA under locoregional anaesthesia is equivalent to (or safer) than CAS in symptomatic patients with severe cardiac or pulmonary disease.

2.3.9.1. Age. Age >80 is often cited as a “high-risk for CEA” criterion. However, meta-analyses of data from symptomatic patients in ICSS, CREST, EVA-3S, and SPACE showed that increasing age (especially ≥70) was associated with increased stroke rates after CAS, but not CEA (Section 2.3.4.1.2). Possible explanations for the higher stroke rates after CAS in older patients include increased atherosclerotic burden, increased aortic arch calcification and wall disease, changes in vascular anatomy, and increasing carotid plaque vulnerability.

2.3.9.2. Radiation therapy. Previous cervical radiation therapy is often cited as being associated with poorer outcomes after CEA. However, in a systematic review of 27 studies (533 patients) who underwent CAS (n = 361) or CEA (n = 172), the perioperative risk for “any cerebrovascular adverse event” was 3.9% (95% CI 2.3%—6.7%) following CAS versus 3.5% (95% CI 1.5%—8.0%) after CEA (p = .77). However, the risk of temporary CNI after CEA was 9.2% (95% CI 3.7%—21.1%) versus none after CAS. After the perioperative period, recurrent TIA/stroke was significantly more common after CAS (4.9/100 person years) versus 2.8/100 person years after CEA (p = .014). In addition, restenosis >50% was significantly more common after CAS (p < .003).

2.3.9.3. Restenosis after carotid endarterectomy. A meta-analysis of observational patient data observed that in...
patients with restenosis after CEA, CAS was not superior to redo CEA regarding perioperative stroke/death rate or further restenosis.\textsuperscript{258} Thirteen studies involving 1132 patients who were treated by CAS ($n = 653$) or redo CEA ($n = 479$) reported that perioperative death/stroke did not differ between CAS and redo CEA (2.3% vs. 2.7%, OR 0.8, 95% CI 0.4–1.8). The risk of developing a second restenosis (median follow-up 13 months) was similar for both groups (HR 1.4, 95% CI 0.9–2.2). The prevalence of CNI was 5.5% after redo CEA, but the rate of permanent CNI was less than 1%. Restenosis after CEA is discussed in greater detail in Section 2.6.2.2.

2.3.9.4. “High-risk” criteria in population studies. The Centre for Medicare and Medicaid Services (CMS) defines physiologic high-risk variables as age >80 years, New York Heart Association class III, CCF, left ventricular ejection fraction <30%, unstable angina, MI ≤ 30 days, contralateral ICA occlusion, recent coronary artery bypass grafting or valve repair, and haemodialysis. Anatomical risk factors include contralateral laryngeal nerve palsy, restenosis after CEA, a history of cervical radiotherapy, high or low placed carotid lesions, and previous neck surgery.\textsuperscript{259}

Symptomatic “high-risk” patients had a 9.1% risk of death/stroke or MI following CAS vs. 7.3% after CEA (OR 1.3, 95% CI 0.95–1.73, $p = .11$). Among CEA patients, age >80 (OR 1.4, 95% CI 1.02–1.8), congestive heart failure (OR 1.7, 95% CI 1.03–2.8), ejection fraction <30% (OR 3.5, 95% CI 1.6–7.7), angina (OR 3.9, 95% CI 1.6–9.9), contralateral occlusion (OR 3.2, 95% CI 2.1–4.7), and high anatomic lesions (OR 2.7, 95% CI 1.33–5.6) predicted an increased risk of perioperative stroke, MI, or death. The authors observed that while certain CMS “high-risk” criteria could identify patients at higher-risk for suffering adverse events after CEA, some “high-risk” criteria were more important than others. They concluded that CEA appeared safer than CAS for the majority of “high-risk for CEA” patients, while the benefits for CAS appeared to be limited to patients with restenosis and prior radiation therapy.\textsuperscript{260}

The Vascular Study Group of New England (VSGNE) performed a multivariate analysis, which showed that independent risk factors for an increased risk of stroke, MI, or death at 1 year in CEA patients included increasing age, preadmission residence in a nursing home, CHF, diabetes, chronic pulmonary disease, any prior history of cerebrovascular disease, and contralateral ICA occlusion. Three SAPPHIRE criteria (abnormal stress test, restenosis after CEA, and history of radiotherapy) were not associated with an increased late risk.\textsuperscript{261} These conflicting data, therefore, suggest that there is still no consensus regarding what constitutes being “high-risk for CEA.” SAPPHIRE criteria should not be used uncritically to exclude symptomatic patients from CEA. Management decisions must be made on an individual patient basis, based on patient comorbidities, anatomical features, and the experience of CAS practitioners locally.

<table>
<thead>
<tr>
<th>Recommendation 48</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>In recently symptomatic patients with 50–99% stenoses and anatomical and/or medical comorbidities that are considered by the multidisciplinary team to make them “higher-risk for carotid endarterectomy,” carotid stenting should be considered as an alternative to endarterectomy, provided the documented procedural death/stroke rate is &lt;6%</td>
<td>IIa</td>
<td>B</td>
<td>104,105,189,198</td>
</tr>
</tbody>
</table>

2.4. Carotid surgical techniques

2.4.1. Carotid endarterectomy

2.4.1.1. Preoperative checklist. The surgeon should ensure that the answers to a number of key questions are documented in the patient’s case notes before performing CEA.\textsuperscript{262} The aim is to minimise avoidable morbidity/mortality and to lessen the risk of medico-legal censure. Questions to be answered include: Has the indication for surgery been documented? Are there atypical symptoms that require further investigation? Is the degree of stenosis appropriate for recommending CEA? Have the procedural risks quoted to the patient been documented? Is the patient receiving optimal BMT? Is high carotid disease anticipated? Are there any pre-existing CNIs? Has the operative side been marked with an indelible pen?

Of these, four are particularly important. First, did the surgeon quote his/her own perioperative risks to the patient during the consent process, rather than using outcome data from RCTs? Second, if the patient has previously undergone carotid surgery (especially to the contralateral side), a total/partial thyroidectomy, or radical neck surgery, it is essential that the patient undergoes indirect laryngoscopy to ensure there is no evidence of a contralateral vocal cord palsy. Bilateral recurrent laryngeal nerve palsies can be fatal (as can bilateral hypoglossal nerve palsies). If a contralateral vocal cord palsy is identified, the reason for performing CEA should be urgently reviewed. If the patient was asymptomatic, the procedure should be cancelled and CAS considered as an alternative. If the patient was recently symptomatic, then CAS should still be considered. If it is not possible to perform CAS and the indication for intervening remains compelling, the patient should be warned about the consequences of bilateral recurrent laryngeal nerve palsies (permanent tracheostomy) and an Ear, Nose, and Throat (ENT) surgeon should be present at the time of extubation. In addition, the surgeon should not use a retrograde approach to the bifurcation, as this is associated with a significantly higher risk of recurrent laryngeal nerve injury (Section 2.4.1.6). Third, it is important to ensure that
the patient is receiving appropriate antiplatelet and statin therapy and that systolic BPs >180 mmHg have been excluded (Section 2.3.2.4.1). Finally, it is essential that the surgeon anticipates the likelihood of having to mobilise the upper ICA. If this is anticipated, the surgeon should take steps to ensure that this can be achieved safely. For less experienced surgeons, it might be appropriate to ask a more experienced colleague to either assist or take over the case. Alternatively, it may be necessary to plan for a more complicated exposure technique (Section 2.4.1.14). The risks associated with dissection of the upper ICA are higher (especially CNI) and this needs to have been discussed with the patient beforehand.

2.4.1.2. Staged or synchronous bilateral carotid interventions. A proportion of patients will present with bilateral 70–99% stenoses. Almost all will be either totally asymptomatic, or have one stenosis symptomatic and the other asymptomatic. It is extremely rare for bilateral severe ICA stenoses to be symptomatic, either simultaneously or within a short period of each other. The question arises whether synchronous bilateral CEAs should ever be considered. While it is feasible to undertake bilateral synchronous CEAs, the most dangerous complication is inadvertent injury to both recurrent laryngeal and/or hypoglossal nerves, which can be fatal. Accordingly, if bilateral (synchronous) revascularisation is deemed absolutely necessary, it may be better to consider bilateral CAS. For most patients, however, staged bilateral CEAs would seem more appropriate, especially in the patient with a symptomatic 50–99% stenosis on one side and an asymptomatic 70–99% stenosis on the other.

2.4.1.3. General versus locoregional anaesthesia. A meta-analysis of 41 non-randomised studies (25,000 CEAs) reported that CEA under locoregional anaesthesia (LRA) was associated with a 40% RRR in 30-day death/stroke, compared with CEA under general anaesthesia (GA), as well as significant reductions in MI and respiratory complications. The General Anaesthesia Local Anaesthesia (GALA) trial (3526 patients) is the largest RCT to date and reported no significant difference regarding perioperative death, stroke, or MI between GA (4.8%) and LRA (4.5%). An updated Cochrane review, which combined data from 14 RCTs (4596 patients), showed that CEA under LRA did not confer significant reductions in 30-day stroke (3.2%), compared with CEA under GA (3.5%).

Most studies on CEA under LRA include patients on aspirin monotherapy. However, with the increasing use of DAPT (especially in the early time period after onset of symptoms), there are concerns about haematoma formation. In a systematic review of 69 studies (n = 10,081 patients), combined deep and superficial cervical plexus blockade was associated with a significantly higher risk of major complications (OR 2.13, p = .006), when compared with superficial/intermediate blockade. However, the “major complications” were inadvertent intravascular injection and respiratory failure/distress secondary to phrenic nerve and/or recurrent laryngeal nerve paralysis. There was no specific mention as to whether deep cervical plexus blockade was associated with an increased risk of haematoma formation. In UK guidelines on CEA patients with coagulation abnormalities, there was no mention about any adverse effect relating to DAPT and no specific mention about whether it was safe to undertake deep cervical plexus blockade in CEA patients. Moreover, guidelines published by the American Society of Regional Anesthesia refer mainly to spinal/epidural anaesthesia (with no reference to deep cervical plexus blockade) and they provide no advice regarding DAPT. In most clinical situations, the guidelines recommended cessation of antiplatelet therapy (especially clopidogrel) wherever possible.

Accordingly, there are no published data on whether it is safe to perform deep cervical plexus blockade in CEA patients on DAPT. With the likelihood that an increasing proportion of recently symptomatic patients will undergo CEA, while on DAPT, surgeons and anaesthetists who choose to perform CEA under LRA must establish local protocols regarding perioperative antiplatelet strategies and choice of anaesthesia. It would, however, be inappropriate to stop clopidogrel and delay CEA for 7–10 days, as this will increase the likelihood of the patient suffering an early recurrent embolic stroke (Section 2.3.5). Intraoperative ultrasound may enable safer infiltration of local anaesthetic, as it permits visualisation of the cervical transverse processes and VA.

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<th>Recommendation 49</th>
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<tbody>
<tr>
<td>It is recommended that choice of anaesthesia for carotid endarterectomy (general versus locoregional) be left to the surgical team’s discretion</td>
<td>I</td>
<td>A</td>
<td>264–266</td>
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2.4.1.4. Volume outcome relationship. A meta-analysis of 25 studies (>900,000 CEAs, mainly from the USA) found a significant relationship between CEA in higher-volume centres and lower rates of 30-day death, stroke, and death/stroke, with a critical threshold of 79 cases per year per unit. In another study, analysing outcomes following 18,248 CEAs in England, there was also a significant volume outcome relationship favouring higher-volume centres, with respect to lower mortality and reduced length of stay. In the latter meta-analysis, the critical threshold was 35 CEAs per centre, per year. The most likely explanation for the difference between 35
CEAs per year in the UK analysis and 79 in the previous meta-analysis is probably because about 85% of CEAs in the UK are undertaken in symptomatic patients (associated with higher procedural risks), while the former meta-analysis will have included a greater proportion of asymptomatic patients (associated with lower procedural risks).

AbuRahma analysed the effect of surgeon volume on 30-day stroke/death in 953 CEAs. High-volume surgeons (>30 CEAs per year) had significantly lower 30-day stroke/death rates, compared with lower-volume surgeons. Death/stroke was significantly higher in non-vascular surgeons (general/cardiac surgeons vs. vascular surgeons) in asymptomatic patients (3.2% vs. 0.72%).

In a meta-analysis looking at outcomes stratified by hospital and surgeon volume, seven out of nine studies showed a significant inverse relationship for individual surgeon volume, while seven out of eight studies reported that specialist vascular training was associated with significantly lower death/stroke rates after CEA, compared with general, cardiac and neurosurgical specialties, but only for lower volume surgeons. For high-volume surgeons, surgical specialty had no impact on outcome.

2.4.1.6. Antegrade versus retrojugular exposure. Retrojugular exposure avoids mobilising the hypoglossal nerve and may be associated with shorter operating times and may optimise access to the upper ICA. A retrojugular approach facilitates access to the upper ICA by sweeping anteriorly structures such as the sternocleidomastoid artery, hypoglossal nerve, and ansa cervicalis. A meta-analysis of four non-randomised trials and two RCTs (740 CEAs) found no evidence that retrojugular (versus antegrade) exposure was associated with reductions in perioperative death (0.6% vs. 0.5%) or stroke (0.9% vs. 0.7%). However, the retrojugular approach was associated with significantly higher rates of recurrent laryngeal nerve palsy (8.1% vs. 2.2%), with no evidence of reduced rates of hypoglossal nerve injury (1.3% vs. 1.3%).

2.4.1.7. Carotid sinus nerve blockade. The rationale that routine carotid sinus nerve (CSN) blockade reduces haemodynamic instability during/after CEA, was not supported by a meta-analysis of four RCTs, which reported no evidence that CSN blockade reduced hypotension, hypertension, or arrhythmias after CEA.

2.4.1.8. Anticoagulation and protamine reversal. In an ECST subgroup analysis, “no heparin” administration prior to carotid clamping was associated with a significant increase in perioperative stroke. There has been much controversy about whether it is safe to reverse heparin (using protamine), the concern being that any reduction in neck haematomas might be offset by a higher risk of postoperative thrombotic stroke. Only one, small RCT addressed this question, but was abandoned after recruiting only 64 patients because two patients randomised to protamine suffered a stroke because of early thrombosis.

The proportion of US surgeons using protamine increased from 43% in 2003 to 62% by 2010 and the VSGNE Registry (10,059 CEAs) reported that heparin reversal with protamine was associated with significant reductions in re-exploration for neck haematoma (0.6% vs. 1.4%; p = .001), without any increase in perioperative stroke/death (1.1% vs. 1.0%) or perioperative MI (1% vs. 1.2%). A similar finding was
made in a post-hoc analysis of 2107 CEA patients randomised within the GALA trial.284 A systematic review and meta-analysis of outcomes in 3817 CEA patients receiving protamine and 6070 CEA patients not receiving protamine observed that protamine administration was associated with a significant reduction in the prevalence of neck haematoma requiring re-exploration (OR 0.42, 95% CI 0.22–0.8, \( p = .008 \)) and no evidence that protamine was associated with an increased risk of perioperative stroke (OR 0.71, 95% CI 0.49–1.03, \( p = .07 \)).285

2.4.1.9. Shunting: routine, never, selective? Temporary interruption of cerebral perfusion during carotid clamping can cause haemodynamic neurological deficits, which can be avoided by shunt insertion. Surgeons tend to be “routine,” “selective,” or “never” shunters, usually based on their training. There is a paucity of quality data for guiding practice.281 While there are various methods for monitoring cerebral perfusion during carotid clamping (electroencephalography [EEG], stump pressure, back flow, TCD), the only modality that is 100% reliable is the patient’s neurological status when CEA is performed under LRA. A Cochrane review of six RCTs (1270 CEAs) concluded that (based on poor quality data) no meaningful recommendations could be made regarding routine, selective, or never shunting.286 Bennett evaluated 2081 CEA patients from the National Surgical Quality Improvement Programme (NSQIP) database (1368 without and 713 with a shunt) and found no differences regarding perioperative TIA/stroke (1.7% without vs. 2.4% with shunt).287

2.4.1.10. Carotid patching: routine, never, selective? Surgeons tend to be “routine,” “selective,” or “never” patchers. A meta-analysis of 10 RCTs (2157 patients), comparing routine patching with routine primary closure, observed that (i) routine patching was associated with significant reductions in perioperative ipsilateral stroke (patch 1.5% vs. 4.5% primary closure; OR 0.31, 95% CI 0.15–0.63, \( p = .001 \)); (iii) routine patching was associated with significant reductions in 30-day ICA thrombosis (0.5% patch vs. 3.1% primary closure; OR 0.18, 95% CI 0.08–0.41, \( p < .0011 \)); (iii) patients randomised to primary closure were three times more likely to return to theatre within 30 days (3.1% primary closure vs. 1.1% patched; OR 2.9, 95% CI 1.3–6.3, \( p = .01 \)); (iv) there was no significant difference between routine patching and routine primary closure regarding perioperative death, fatal stroke, death/stroke, and CNI; and (v) patch type (polyester, polytetrafluoroethylene (PTFE), autologous vein, bovine pericardium) did not influence early outcomes.288,289 Vein patch rupture is an extremely rare complication and is more likely if smaller calibre saphenous veins have been harvested from the ankle.290

With regard to long-term outcomes, routine patching (versus routine primary closure) was associated with significant reductions in (i) late ipsilateral stroke (1.6% patch vs. 4.8% primary closure; OR 0.3, 95% CI 0.2–0.6, \( p = .001 \)); (i) any stroke (2.4% patch vs. 4.6% primary closure; OR 0.49, 95% CI 0.3–0.9, \( p = .002 \)); and (ii) restenosis (4.3% patch vs. 13.8% primary closure; OR 0.2, 95% CI 0.2–0.3, \( p < .01 \)). No RCTs have compared routine with selective patching,288,289 and there is no consensus on criteria for selective patching.

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<th>Recommendation 52</th>
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<tbody>
<tr>
<td>Protamine reversal of heparin should be considered to prevent neck haematomas requiring re-exploration</td>
<td>IIa</td>
<td>B</td>
<td>283–285</td>
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<tr>
<th>Recommendation 53</th>
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<tr>
<td>It is recommended that the choice of shunting (routine, selective, never) be left to the discretion of the operating surgeon</td>
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<td>C</td>
<td>286</td>
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<th>Recommendation 54</th>
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<tr>
<td>Routine patching is recommended, rather than routine primary closure. There is no evidence that patch type influences outcome</td>
<td>I</td>
<td>A</td>
<td>288,289</td>
</tr>
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2.4.1.11. Eversion vs. traditional endarterectomy. During eversion CEA (eCEA), the ICA is transected obliquely at its origin and a cylinder of atheroma “expelled” via eversion of the outer media and adventitia. The distal intimal step is examined for residual flaps, which are then excised. The ICA is shortened (as required) and reanastomosed to the CCA. Advantages include no risk of prosthetic infection, it is quicker than patched CEA, bifurcation geometry is preserved, and it is possible to shorten the distal ICA where necessary. Disadvantages are that a shunt cannot be inserted until eversion is completed and there may be problems accessing the upper ICA (if distal disease has been underestimated). A meta-analysis has reported that eCEA was associated with a significantly higher incidence of post-CEA hypertension (OR 2.75, 95% CI 1.82–4.16), compared with conventional CEA (cCEA). By contrast, cCEA was associated with a significantly higher incidence of perioperative hypotension (OR 11.37, 95% CI 1.95–66.46). 291

In a meta-analysis of 21 randomised and non-randomised studies comparing cCEA (n = 7721) with eCEA (n = 8530), eCEA was associated with significant reductions in perioperative stroke (OR 0.46, 95% CI 0.35–0.62), perioperative death (OR 0.49, 95% CI 0.34–0.69), and a significant reduction in late carotid occlusion (OR 0.48, 95% CI 0.25–0.90). 292 However, in a Cochrane review of five RCTs (2590 CEAs), 293 there were no statistically significant differences regarding (i) 30-day death/stroke, (ii) perioperative thrombosis, and (iii) late stroke. However, patients randomised to eCEA had a twofold reduction in late restenosis >50% (2.5%), compared with patients undergoing cCEA (5.2%) (OR 0.48, 95% CI 0.3–0.7). When the meta-analysis compared eCEA with patched CEA, however, there were no differences in late restenosis (2.5% eversion vs. 3.9% patched (HR 0.52, 0.2–1.7)). 294 These data would, therefore, suggest that eCEA provides equivalent outcomes to cCEA, provided the arteriotomy is closed with a patch.

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<th>Recommendation 55</th>
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<tr>
<td>Eversion endarterectomy is recommended over routine primary arteriotomy closure</td>
<td>I</td>
<td>A</td>
<td>293</td>
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<th>Recommendation 56</th>
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<tr>
<td>The choice between eversion or patched endarterectomy should be left to the discretion of the operating surgeon</td>
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<td>A</td>
<td>293</td>
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2.4.1.12. Treatment of coils and kinks. The management of patients with ICA coils/kinks in the absence of significant stenoses is controversial. Incidental coils/kinks are found in up to 16% of patients and half will have histological features consistent with fibromuscular dysplasia. 294 One RCT compared surgical correction versus BMT in 182 patients with hemispheric/non-hemispheric symptoms with an isolated coil/kink of the ICA, where neurologists performed postoperative assessments. 294 Patients randomised to surgical correction had a 0% rate of occlusion at a mean of 5.9 years follow-up, compared with 5.5% in those treated medically (p = .02). The risk of late stroke was 0% in surgically treated patients, compared with 6.6% in medically treated patients (p = .01). Unfortunately, meaningful interpretation of the data was confounded by 41% of the medically treated patients crossing over to surgical treatment because of recurrent hemispheric or ongoing non-hemispheric symptoms.

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<th>Recommendation 57</th>
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<tbody>
<tr>
<td>Surgical intervention for asymptomatic isolated coils/kinks of the internal carotid artery is not recommended</td>
<td>III</td>
<td>C</td>
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<th>Recommendation 58</th>
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<tr>
<td>Symptomatic patients with isolated coils/kinks may be considered for surgical correction, but only following multidisciplinary team review and provided no other cause for transient ischaemic attack or stroke symptoms can be identified</td>
<td>IIb</td>
<td>B</td>
<td>294</td>
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2.4.1.13. Role of monitoring and quality control. There is no consensus as to whether a policy of monitoring or quality control reduces 30-day death/stroke after CEA. 170,295 Quality control is not the same as monitoring. The role of monitoring is to ensure adequate brain perfusion, especially during carotid clamping and shunting. This can be achieved using TCD, or by performing CEA under LRA, measuring stump pressure, performing a subjective assessment of ICA backflow following carotid clamping, and near infra-red spectroscopy. Loss of cerebral electrical activity is assessed by somatosensory evoked potentials and EEG. The onset of any intraoperative neurological deficit can be accurately identified by performing CEA under LRA.
Quality control techniques aim to modify operative strategies to prevent technical error, including embolisation during carotid dissection (TCD), to ensure that the shunt is functioning (TCD, CEA under LRA), to identify residual luminal thrombus before flow restoration (angioscopy), to identify residual luminal thrombus after flow restoration (DUS, angiography), to diagnose large intimal flaps (angioscopy, DUS, angiography) to diagnose residual (untreated) stenoses (DUS, angiography), and to diagnose the very rare patient who thromboses the operated ICA during neck closure (diagnosed by increasing rates of embolisation followed by declining MCAV using TCD).170

Evidence suggests that targeted monitoring and quality control strategies may reduce perioperative death/stroke,170,296 but reliance on a single monitoring or quality control strategy is unlikely to make any difference, because of the multiple causes of perioperative stroke (hypoperfusion, embolism, thrombosis, intracranial haemorrhage, hyperperfusion syndrome).

### 2.4.1.14. Treatment of high internal carotid artery lesions.

A high bifurcation or a stenosis extending behind the jaw can represent a technical challenge and increase the risk of CNI. If the person performing DUS assessment cannot image above the lesion, corroborative CTA/MRA imaging must be performed to evaluate operability. The presence of distal disease extension should prompt the surgeon to reconsider whether CEA is appropriate (e.g. in asymptomatic patients).

In the presence of distal disease extension, advance planning is essential. Nasolaryngeal intubation enables the mouth to be closed, which then opens up the angle between jaw and mastoid process to facilitate distal access. Subluxation of the temporomandibular joint has to be undertaken preoperatively as it cannot be performed once the operation is under way. An alternative strategy (which can be performed once the operation is under way) involves extending the incision anterior to the ear with mobilisation of the superficial lobe of the parotid. This greatly increases access to the upper ICA, but usually requires the assistance of a specialist ENT or parotid surgeon.

Intraoperatively, there are several techniques for optimising access to the upper ICA, including division of the sternocleidomastoid artery (which tethers the hypoglossal nerve), division of the occipital branch of the external carotid artery (ECA), transection of the ansa cervicalis (which also tethers the hypoglossal nerve), and division of digastic and transection of the styloid process.

### 2.4.1.15. Role of wound drainage.

The rationale for placing a wound drain following CEA is that it should prevent haematoma formation, which could compromise the airway in the early postoperative period and also predispose to abscess formation and/or late patch infection. There is, however, controversy as to whether drains make any difference. A RCT observed that routine drainage yielded a mean volume of 42 mL of blood, plus a median residual neck haematoma volume of 25 mL on DUS assessment (range 5–65). By contrast, the median residual haematoma volume in patients randomised to “no drains” was 31 mL (range 3–72).298 Observational studies have reported that small calibre drains (10F) are ineffective, while 14F drains significantly reduce neck haematoma formation.299 This is another area of surgical practice where surgeons tend to practice what they were taught, rather than being based on evidence. Despite the single RCT (which suggested that routine drainage was ineffective), it is likely that most surgeons remain “more comfortable” about routinely or selectively inserting a wound drain after CEA.

### 2.4.1.16. Ward, high dependency or intensive care postoperatively?

All CEA and CAS patients benefit from 3–6 hours neurological and intra-arterial BP monitoring in the recovery area of theatre or angio suite following CEA/CAS. Relatively few patients require routine postoperative monitoring in a high dependency unit (HDU) or intensive care unit (ICU). The majority can be transferred back to the vascular ward for ongoing surveillance, involving hourly non-invasive BP and neurological monitoring for the first 24 hours and 4-hourly thereafter until discharge.

Evidence suggests that up to 40% of patients may require treatment for post-CEA hypertension in the early postoperative period.300 Half of these will require treatment in the first 3 postoperative hours, but most require only a single bolus of intravenous labetalol to control their BP (Section 2.6.1.3.3). If there are no further spikes of hypertension, these patients can usually return to the vascular ward 2–3 hours later. Patients who require intravenous therapy to control BP should either remain in the recovery area of theatre (with ongoing intra-arterial BP monitoring) or be transferred to the HDU for continued intra-arterial BP monitoring. Two hours after intravenous treatment has completed and with no further surges in BP, it is reasonable to transfer the patient back to the vascular ward for ongoing monitoring. Any patient who suffers a major intraoperative cardiac event should, however, be transferred to the ICU or coronary care unit for further evaluation.

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<td>IIb</td>
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<td>170, 296</td>
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<tr>
<td>The surgeon should anticipate the presence of distal disease extension preoperatively and plan for this in advance</td>
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2.4.2. Carotid bypass

2.4.2.1. Indications. Bypass is indicated in the following situations: extensive atherosclerotic disease, excessive coiling/kinking of the ICA above a stenosis, previous radiotherapy causing fibrosis of the ICA, excessive arterial wall thinning after CEA, large intimal flap on completion imaging, revascularisation following embloc excision of a carotid body tumour, treatment of prosthetic patch infection, treatment of restenosis after CEA, treatment of fibromuscular dysplasia, and treatment of aneurysms.\(^{301-307}\)

2.4.2.2. Technique. Options include an interposition graft; end-to-side anastomosis to the distal CCA with end-to-side or end-to-end anastomosis to the distal ICA with a distal end-to-end anastomosis to the ICA. Conduits include reversed saphenous vein harvested from the thigh,\(^{302,303,306}\) PTFE,\(^{301,302,304,305}\) or polyester.\(^{307}\) Early and late outcomes are summarised in Table 19. These data suggest that carotid bypass can be performed with low procedural risks and with good long-term patency. Notwithstanding the lack of RCTs, late patency with prosthetic conduits appear to be as good as with vein (possibly better). Interestingly, only three late graft infections were reported in the 594 patients (0.5%) with prosthetic conduits.\(^{302,307}\)

2.4.3. Extracranial to intracranial bypass. The rationale underpinning extracranial to intracranial bypass (EC-IC) is that in patients with an extracranial ICA occlusion, a bypass (usually from the superficial temporal artery to the MCA) will reduce the long-term risk of ipsilateral ischaemic stroke. A 1985 RCT concluded that EC-IC bypass conferred no benefit over BMT.\(^{308}\) The trial was, however, criticised regarding selection criteria, method of randomisation, the large number of patients operated upon outwith the trial and the lack of haemodynamic criteria for trial entry. A subsequent Cochrane review, which included two RCTs and 19 observational studies \(n = 2591\), concluded that EC-IC bypass conferred no benefit over BMT in terms of late stroke prevention \(\text{RCTs: OR 0.99, 95\% CI 0.79–1.23, } p = .91\); \text{non-RCTs: OR 0.80, 95\% CI 0.54–1.18, } p = .25\).\(^{309}\) A third RCT was undertaken in 2011, which included only patients with a recently symptomatic extracranial ICA occlusion plus evidence of haemodynamic impairment in the ipsilateral cerebral hemisphere \(\text{increased oxygen extraction fraction using positron}\)

emission tomography).\(^{310}\) The 2-year risk of ipsilateral stroke \(\text{including perioperative stroke/death} \) was 21.0\% \(\text{95\% CI 12.8–29.2} \) after EC-IC bypass, versus 22.7\% \(\text{95\% CI 13.9–31.6}\) in patients randomised to BMT \(p = .78\). Accordingly, there is still no role for EC-IC bypass in the routine management of patients with atherosclerotic ICA occlusion. The only exception might be the patient with persisting clinical and haemodynamic insufficiency, despite BMT, in whom the MDT has advised that EC-IC bypass might be appropriate.

### Table 19

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<tr>
<td>Extracranial to Intracranial bypass surgery is not recommended in patients with an extracranial internal carotid occlusion</td>
<td>III</td>
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<td>308–310</td>
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2.5. Carotid artery stenting

2.5.1. Adjuvant medical therapy. Pre-intervention statin therapy may reduce procedural complications (Section 2.3.2.3.3). It is recommended to start DAPT with aspirin \(300 \text{ mg initially for up to 14 days followed by 75 mg daily if not already taking aspirin}\) and clopidogrel \(75 \text{ mg daily}\) 3 days prior to CAS. Aspirin and clopidogrel should be continued for at least 1 month, followed by clopidogrel thereafter, unless the treating physician opts for an alternative long-term antiplatelet regimen (Section 2.3.2.1.3). Most operators administer 5000 IU of intravenous heparin prior to the procedure and 0.6–1.2 mg of atropine (or 0.6 mg glycopyrrolate) to prevent hypotension and bradycardia/asystole prior to balloon inflation.\(^{311,312}\)

### Table 20

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<th>Recommendation 62</th>
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<tr>
<td>It is recommended that atropine or glycopyrrolate be administered prior to balloon inflation during carotid stenting to prevent hypotension, bradycardia, or asystole</td>
<td>I</td>
<td>B</td>
<td>311,312</td>
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</table>

2.5.2. Access (femoral, cervical, radial). The most common access is via the common femoral artery (CFA), although direct CCA and brachial/radial artery access are alternatives. The latter may be preferable in patients with aorto-iliac tortuosity/occlusion. Direct CCA access via a cut down has recently been advocated as this avoids manipulation of wires and catheters within the aortic arch.

2.5.3. Choice of wires, access catheters, stent design. For access into the CCA, a 0.035\(^{\text{fl}}\) guide wire is used. For stent placement and balloon angioplasty \(\text{requiring rapid exchange systems}\) 0.014\(^{\text{fl}}\) floppy tip guide wires are advised. Long sheaths or guiding catheters \(6F–8F\) are used to obtain a stable position in the CCA. ICSS reported significantly lower 30-day risks of death/stroke in CAS patients where closed cell designed stents were used \(5.1\%\), versus 9.5\% in patients where open cell designed stents were used \(OR 10.53, 95\% CI 0.31–0.91, p = .024\).\(^{313}\) There is currently no evidence that micromesh or dual layer stents reduce procedural risks after CAS.
2.5.4. Role of predilatation. Predilation is only undertaken in patients with high-grade stenoses (>80%), when it is anticipated that the stent or filter protection device cannot cross the lesion, because predilatation may be associated with higher procedural stroke rates.

2.5.5. Use of cerebral protection devices. There is conflicting evidence (and opinion) regarding the role of cerebral protection devices (CPDs) in preventing stroke after CAS, despite it not being unusual to find embolic material in retrieved distal filters. A meta-analysis of 22 studies (n = 11,655) reported significantly lower rates of perioperative stroke/death favouring the use of CPDs (OR 0.57, 95% CI 0.43—0.76, p < .01). In addition, the best CAS results within RCTs were reported in CREST and ACT-1, where CPDs were mandatory and CAS practitioners were trained in their use. By contrast, a meta-analysis of 30-day stroke in patients randomised to CAS within EVA-3S, SPACE, and ICSS found no evidence that CPD usage was associated with reduced perioperative stroke rates (OR 0.57, 95% CI 0.38—1.91, p < .01). In a very large single-centre series involving 2124 patients from 2006 to 2010, greater operator volume was associated with a lower rate of postoperative mortality and haemodynamic monitoring should be continued for at least 6 hours after the procedure.

2.5.6. Role of peri-procedural monitoring. The presence of an experienced anaesthesiologist or physician capable of maintaining haemodynamic stability is mandatory and haemodynamic monitoring should be continued for at least 6 hours after the procedure.

2.5.7. Learning curve and the volume:outcome relationship. As with CEA, there are conflicting data regarding a volume:outcome relationship following CAS. In a systematic review of outcomes from four large case series and one registry, it was observed that in “active” CAS centres, it took almost 2 years of experience before 30-day death/stroke rates fell below 5%. In an analysis of data derived from the Healthcare Cost and Utilization Project’s Nationwide Inpatient Sample from 2006 to 2010, greater operator volume was associated with a lower rate of postoperative mortality and complications, as well as shorter lengths of stay and lower hospitalisation costs. In a large “high-risk for CEA” registry, a lifetime experience of 72 CAS procedures was necessary to achieve a 30-day death/stroke rate <3% in asymptomatic non-octogenarian patients. In an analysis of outcomes in Medicare beneficiaries, 30-day mortality was significantly higher when practitioners performed fewer than six CAS procedures per year, compared with ≥24 (OR 1.9, 95% CI 1.4—2.7, p < .001). In a very large single-centre series involving 2124 patients, a broad consensus among CAS practitioners that CPDs should be considered when performing CAS.

Table 19. Early and late outcomes following carotid interposition bypass grafting.

<table>
<thead>
<tr>
<th>Author</th>
<th>n =</th>
<th>Conduit type</th>
<th>30-day death/stroke</th>
<th>Primary patency</th>
<th>Late infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricco</td>
<td>198</td>
<td>PTFE</td>
<td>1/198 (0.5%)</td>
<td>98% @ 10 y</td>
<td>None</td>
</tr>
<tr>
<td>Dorafshar</td>
<td>31</td>
<td>PTFE</td>
<td>1/31 (3.2%)</td>
<td>90% @ 4 y</td>
<td>1/31</td>
</tr>
<tr>
<td>Roddy</td>
<td>22</td>
<td>PTFE</td>
<td>0/22 (0.0%)</td>
<td>95% @ 2 y</td>
<td>None</td>
</tr>
<tr>
<td>Veldenz</td>
<td>51</td>
<td>PTFE</td>
<td>1/51 (1.9%)</td>
<td>96% @ 2 y</td>
<td>None</td>
</tr>
<tr>
<td>Dorafshar</td>
<td>10</td>
<td>Vein</td>
<td>1/10 (10%)</td>
<td>80% @ 4 y</td>
<td>n/a</td>
</tr>
<tr>
<td>Lauder</td>
<td>50</td>
<td>Vein</td>
<td>3/50 (6.0%)</td>
<td>83% @ 3 y</td>
<td>n/a</td>
</tr>
<tr>
<td>Koncar</td>
<td>292</td>
<td>Polyester</td>
<td>19/292 (6.5%)</td>
<td>96% @ 32 m</td>
<td>2/292</td>
</tr>
<tr>
<td>Branchereau</td>
<td>212</td>
<td>Vein</td>
<td>14/212 (6.6%)</td>
<td>92% @ 10 y</td>
<td>n/a</td>
</tr>
</tbody>
</table>

y = years.
successful CAS procedures, a lifetime experience of >100 CAS interventions was associated with significantly fewer perioperative strokes (OR 0.81, 95% CI 0.67—0.95), while a lifetime experience of <50 CAS procedures was a significant predictor of an increased risk of perioperative stroke (p < .001).323 Finally, in a post-marketing evaluation of outcomes in 5841 patients in the CHOICE Registry (carotid stenting for high surgical risk patients: evaluating outcomes), the most important predictive feature for 30-day death/stroke/MI was an increased time interval between individual CAS procedures.324 An individual patient meta-analysis was undertaken in recently symptomatic patients who were randomised to CAS in EVA-3S, SPACE, and ICSS.325 In contrast to what was reported (above), the 30-day risk of death/stroke was not influenced by lifetime CAS experience (p = .8). However, compared with high annual volume CAS operators (mean >5.6 cases per year) who incurred a 5.1% risk of death/stroke, 30-day death/stroke was significantly higher in operators with low annual CAS experience (mean 3.2 cases per year), who incurred a 10% rate of death/stroke (OR 2.3, 95% CI 1.36—3.87). Intermediate volume operators (mean 3.2—5.6 cases per year) incurred an 8.4% risk of death/stroke (OR 1.93, 95% CI 1.14—3.27).325 The authors of the pooled individual patient meta-analysis of 1546 recently symptomatic patients randomised within ICSS, EVA-3S, and SPACE concluded that CAS practitioners should be performing at least six CAS procedures each year.326 By contrast, the Society for Cardiovascular Angiography and Interventions and the Society for Vascular Medicine advise that “in an era of low CAS volumes,” 25 lifetime CAS procedures is reasonable for achieving competency, along with 10—15 CAS procedures annually to maintain competency,326 provided that the 3% (asymptomatic) and 6% (symptomatic) thresholds are maintained.

2.6. Complications following carotid interventions

2.6.1. The first 30 days

2.6.1.1. Stroke after carotid endarterectomy

2.6.1.1.1. Intraoperative stroke. An intraoperative stroke is defined as any new focal neurological deficit (or worsening of a pre-existing deficit), which is apparent immediately following recovery from anaesthesia and with symptoms lasting for >24 hours. In practice, the majority follow intraoperative embolisation (during carotid dissection/mobilisation, after shunt insertion, after restoration of flow, after accumulation of platelet thrombi on the endarterectomy zone during neck closure) or (less commonly) hypoperfusion, which may be associated with carotid clamping or shunt malfunction. In a recent 25-year audit, most intraoperative strokes appeared to follow embolisation of retained luminal thrombus after restoration of flow, despite irrigation with heparinised saline prior to flow restoration.170 The source of the embolus was bleeding from transected vasa vasorum following plaque removal. The ensuing thrombus is often densely adherent to the endarterectomy zone and can be resistant to blind irrigation. It can, however, be identified using completion angiography (prior to flow restoration) and removed.170 One of the advantages of performing CEA under LRA is that the timing of any new neurological deficit can be accurately determined. For patients undergoing CEA under GA, an abrupt change in the EEG may also predict the most likely time of onset of a new neurological deficit.327 If the patient exhibits the triad of hemiplegia, homonymous hemianopia, and higher cortical dysfunction (aphasia/visuospatial neglect) upon recovery from anaesthesia, it is highly likely that either the ICA or MCA mainstem is occluded. If only one or two components of the triad are present, this is more likely to represent occlusion of one or more MCA branches.328

It is currently accepted practice that anyone recovering from anaesthesia with a new neurological deficit should undergo immediate re-exploration, to exclude accumulation of thrombus within the endarterectomy zone.329 In a sub-analysis of the causes of stroke in ACST-1, the rate of disabling/fatal stroke in patients who underwent immediate re-exploration was similar to those who did not undergo re-exploration.330 However, the immediate priority is to identify patients with ICA thrombosis, as they will benefit from immediate exploration. Provided flow is restored within 1 hour, good neurological recovery can be expected. Although re-exploration will not benefit patients with MCA mainstem or branch embolism or haemodynamic stroke (other than being able to remove a source of embolisation), this cannot be avoided. For those with access to TCD, decision-making is easier as ICA occlusion will be associated with MCA velocities identical to those seen during carotid clamping.170 DUS can assist in confirming whether there is flow within the endarterectomy zone, but air in the subcutaneous tissues often makes it difficult to interpret the findings in the early post-operative period. At re-exploration, the artery should be opened carefully and thrombus removed. If thrombus extends distally, this may be retrieved by careful retraction. If a Fogarty catheter is used, care must be taken to avoid distal trauma. Following thrombectomy, any technical errors should be corrected and a completion angiogram performed to ensure distal patency. Several small series have suggested that patients suffering embolic occlusion of the ipsilateral anterior or MCA arteries during (or immediately after) CEA can be treated by re-exploration (to remove any residual thrombus within the endarterectomy zone) followed by an intraoperative intra-arterial infusion of 500,000331,332 or 1 million units of urokinase,333 without incurring significant bleeding complications (Section 2.6.1.2.1). Urgent mechanical thrombectomy should also now be considered in patients with embolic occlusion of the MCA mainstem, especially as some CEA patients may not be eligible for intravenous thrombolysis (Section 2.6.1.2.1).

It would clearly be preferable to prevent intraoperative stroke. While no RCTs have been undertaken, targeted monitoring (TCD, EEG) and quality control assessment (completion angiography, DUS, angiography) have been associated with significant reductions in intraoperative embolisation, identification of luminal thrombus prior to restoration of flow and a decline in intraoperative stroke rates.170,296,327

2.6.1.1.2. Postoperative stroke. This is defined as any new focal neurological deficit (or worsening of a pre-existing deficit), following full recovery from anaesthesia and whose symptoms last more than 24 hours. The aetiology varies with
the time interval from surgery. In the first 6 hours, the most likely cause is ICA thrombosis or embolism from mural thrombus in the endarterectomy zone. After 12–18 hours have elapsed, stroke caused by the hyperperfusion syndrome (HS) or ICH beco... time interval from surgery. In the first 6 postoperative hours, thromboembolic stroke should be assumed and the patient should return immediately to theatre for re-exploration, the rationale and management being the same as for intraoperative stroke. 

A number of studies have shown that it may be possible to prevent early postoperative thromboembolic stroke by starting DAPT preoperatively (aspirin 75 mg, clopidogrel 75 mg). However, patients developing new neurological symptoms after 6 hours have elapsed require emergency extra-crani al and intracranial CTA. This will exclude ICA thrombus (which should be removed at re-exploration) or (more likely), intracerebral oedema, ICH, or parenchymal haemorrhage. ICH may require craniotomy in selected cases, but the majority are managed conservatively. Hyperperfusion syndrome stroke complicates about 1% of CEAs and is usually associated with post-CEA hypertension, headache, atypical migrainous phenomena, and focal onset seizures. The neurological deficit with HS can either be caused by breakthrough oedema or haemorrhage, or it can be ischaemic, possibly because of activation of the coagulation cascade and inhibition of endothelial fibrinolysis. HS is often associated with the development of patchy white matter oedema on CT/MRI. This is sometimes mistaken for evolving ischaemia on CT, but DWI-MRI will show that the oedema is vasogenic (as opposed to cytotoxic) and MRI perfusion imaging will show normal perfusion within the area of white matter oedema. For some reason, patchy white matter vasogenic oedema may also affect the vertebrobasilar territory. Patients exhibiting symptoms suspicious of HS will usually have elevated BP and this should be actively treated (Section 2.6.1.3.3). Seizures should be controlled with intravenous titrated doses of lorazepam and appropriate anti-epileptic drugs under the supervision of a neurologist.

2.6.1.1.3. Predictors of stroke after carotid endarterectomy. ECST reported various features that were associated with an increased risk of perioperative stroke including (i) female gender (10.4% vs. 5.8%, p = .0001); (ii) peripheral vascular disease (12.0% vs. 6.1%, p = .0001); (iii) systolic BP (<120 mmHg = 3.4%; 121–159 = 6.5%; 160–180 = 7.7%; >180 mmHg = 13.0%, p = .04); and (iv) the type of presenting cerebrovascular event (retinal [3.2%], hemispheric stroke [6.3%], hemispheric TIA [9.1%], p = .006).

NASCET also reported clinical/imaging features associated with a significant increase in stroke after CEA including (i) hemispheric versus retinal events (6.3% vs. 2.7%; OR 2.3, 95% CI 1.1–5.0); (ii) left vs. right CEA (6.7% vs. 3.0%; OR 2.3, 95% CI 1.4–3.6); (iii) contralateral occlusion (9.4% vs. 4.4%; OR 2.2, 95% CI 1.1–4.5); (iv) ipsilateral CT/MR infarct (6.3% vs. 3.5%; OR 1.8, 95% CI 1.2–2.8); and (v) irregular as opposed to smooth plaque (5.5% vs. 3.7%; OR 1.5, 95% CI 1.1–2.3). A meta-analysis of 170 studies (>70,000 patients) observed that contralateral occlusion was associated with higher procedural stroke rates after CEA, but not after CAS.

2.6.1.2. Stroke after carotid artery stenting. Although CPDs are often used, intra-procedural strokes can still occur from embolization into the contralateral hemisphere (from the aortic arch), or because of incomplete CPD deployment and/or malpositioning of the filter, or because of incomplete aspiration of debris when using balloon protection devices. In a limited number of cases, CPDs cannot be used because of technical reasons or patient intolerance.

2.6.1.2.1. Mechanical thrombectomy and thrombolysis. Techniques for treating patients who develop a new neurological deficit during CAS include mechanical thrombectomy and/or intra-arterial thrombolysis. Safe mechanical removal of embolic material from the main branches of the ICA (out to the distal M2-segment) is possible using dedicated neuro-interventional retrieval devices. With the recently published positive results of various RCTs evaluating mechanical thrombectomy in acute ischaemic stroke, most interventionists now advocate the use of stent-retrievers or thrombus aspiration in patients who experience an acute, new stroke during CAS secondary to acute ICA, M1, or M2 branch occlusion (Section 2.3.5.3).

Thrombolysis in the setting of acute distal ICA occlusion because of embolisation during CAS is rarely beneficial, because the embolus usually comprises plaque, rather than fibrin clot. In the event of acute stent thrombosis, thrombolysis should be considered. Thrombolytic agents currently in use include urokinase and recombinant tissue plasminogen activator (rTPA), which are delivered through the guiding catheter, diagnostic catheter, or a super-selectively placed microcatheter (ensuring that the catheter is positioned within the thrombus). High-dose urokinase regimens are generally administered (500,000 units of urokinase), with half being administered as an initial bolus. Alternatively, a continuous infusion (without bolus) of up to 1,250,000 units of urokinase over 90 min can be performed.

rTPA can be given as a 5-mg bolus, followed by slow infusion (maximum dose 20 mg). If any of the proximal thrombus dissolves, the tip of the microcatheter must be advanced into the proximal portion of any residual thrombus. Selective intra-arterial administration of 5-mg abciximab followed by a bolus of 5-mg abciximab intravenously has been effective in the treatment of neurological sequelae because of distal embolisation after CAS.

No RCTs have addressed the treatment of acute stroke caused by ICA thrombosis, or M1/M2 segment embolic occlusions after CAS. The management should, however, be no different to stroke occurring without a prior carotid intervention. Accordingly, eligible patients with thromboembolic, ischaemic stroke after CAS should be considered for mechanical thrombectomy using neuro-interventional thrombectomy devices, provided they fulfil the criteria for inclusion in those trials (Section 2.3.5.3).

2.6.1.2.2. Predictors of stroke after carotid artery stenting. A Delphi consensus identified various imaging criteria that were associated with an increase in difficulty for “novices”
undertaking CAS including (i) type III aortic arch; (ii) bovine arch; (iii) arch atheroma; (iv) diseased ECA; (v) markedly angulated distal ICA; (vi) a long stenosis; and (vii) a pinhole stenosis. In CAVATAS, increasing stenosis length was an independent risk factor for procedural stroke/death. In a pooled analysis from EVA-3S, SPACE, and ICSS, CAS was associated with a threefold excess risk of death/stroke (compared with CEA) when performed in the first 7 days after onset of symptoms (9.4% vs. 2.8%; OR 3.4, 95% CI 1.01–11.8) after adjusting for age, sex, and nature of qualifying event. A post-hoc analysis of ICSS data showed that CAS patients who had an age-related white-matter change (ARWMC) score of ≥7 on preoperative CT/MRI faced an increased risk of perioperative stroke, compared with patients whose ARWMC score was <7 (HR 2.76, 95% CI 1.17–6.51, p = .021). There was no association between ARWMC scores and perioperative stroke in patients treated with CEA (HR 1.18, 0.4–3.55, p = .76). CAS was associated with a significantly higher risk of perioperative stroke (compared with CEA) in patients with an ARWMC score of ≥7 or more (HR 2.98, 1.29–6.93, p = .011), but there was no difference in risk between CEA and CAS in patients whose ARWMC score was <7. More recently, CREST has reported that perioperative stroke rates were significantly higher after CAS in patients whose lesion length was >13 mm and sequential lesions extending remotely from the main ICA stenosis.

2.6.1.3. Haemodynamic instability

2.6.1.3.1. Post-stenting hypotension. In a meta-analysis of 27 studies (n = 4204), 12% (95% CI 7–18) required treatment for peri-procedural hypotension, 12% (95% CI 7–19) required treatment for bradycardia, while 13% (95% CI 8–17) were treated for both hypotension and bradycardia. Persistent haemodynamic instability (>1 hour vasopressor support) affected 19% (95% CI 13–27) of CAS patients. There was a statistically significant association between increasing age and haemodynamic instability. Lesions within 10 mm of the carotid bifurcation and the site of minimum lumen diameter were associated with bradycardia and there was a statistically significant association between a history of ipsilateral CEA and persistent haemodynamic instability after CAS. Haemodynamic instability after CAS usually resolves and its clinical significance seems relatively minor. Meta-analyses have not shown any statistically significant differences between patients with or without haemodynamic instability after CAS in terms of perioperative death (OR 2.99, 95% CI 0.34–26.06); stroke (OR 1.0, 95% CI 0.57–1.75); stroke/death (OR 1.51, 95% CI 0.98–2.33); TIA (OR 0.86, 95% CI 0.47–1.61); or any major adverse event rate (OR 1.31, 95% CI 0.73–2.34). Measures for preventing haemodynamic instability include adequate hydration and withholding antihypertensive medications on the morning of CAS. Continuous ECG monitoring, invasive BP monitoring and venous access are mandatory. Glycopyrrolate (a synthetic atropine derivative) was compared with atropine in a retrospective study (115 CAS procedures) and found to be more effective in preventing postoperative bradycardia and hypotension (30% vs. 72%, p = .002, and 2.5% vs. 36%, p = .001), respectively. In addition, there were lower rates of postoperative hypotension (2.5% vs. 16%, p = .047). However, glycopyrrolate conferred no benefit regarding peri-procedural tachycardia, BP changes, vasopressor use, or cardiac complications. No significant differences in procedural neurologic and access site complications were observed.

The treatment of post-CAS hypotension requires administration of i.v. crystalloids plus volume expanders. This strategy may, however, be inadequate because of decreased peripheral vascular resistance (secondary to loss of sympathetic tone) and not underlying hypovolaemia. Titrated intravenous vaspressors (dobutamine, dopamine, norepinephrine, phenylephrine) may be necessary to maintain systolic BP >90 mmHg. The influence of vasopressor type (on outcome) was evaluated in a retrospective study involving 42 patients requiring vasopressor treatment after CAS. The mean vasopressor infusion time was 32 hours for dopamine, compared with 24 hours for norepinephrine (p = .052) and 22 hours (p = .028) for phenylephrine. The mean length of stay in the coronary care unit was 47 hours for dopamine, compared with 37 hours for the norepinephrine/phenylephrine groups combined (p = .056). Major adverse events, including MI, arrhythmias, and cardioversion were significantly more common in patients receiving dopamine, than in patients receiving norepinephrine or phenylephrine (p = .04). Midodrine (a selective α-1 agonist) that causes arteriolar and venous vasconstriction without stimulating cardiac β-adrenergic receptors is well tolerated and is as effective as intravenous dopamine in the treatment of hypotension after CAS.

2.6.1.3.2. Post-endarterectomy hypotension. Post-CEA hypotension has been attributed to exposure of carotid sinus baroreceptors to the pulse pressure, without the damping effect of the excised plaque. The clinical relevance of post-CEA hypotension is variable, with some reporting that it increases perioperative stroke and MI, whereas others believe it to be a benign phenomenon. There is no consensus regarding what BP threshold should be used for treatment. The management of post-CEA hypotension is the same as for post-CAS hypotension.

<table>
<thead>
<tr>
<th>Recommendation 65</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-line treatment of post-carotid intervention hypotension should be the administration of intravenous crystalloids together with volume expanders. If this fails to improve blood pressure, titrated intravenous vaspressors (dobutamine, dopamine, noradrenaline, phenylephrine) should be considered to maintain systolic blood pressure &gt;90 mmHg.</td>
<td>IIA</td>
<td>C</td>
<td>346</td>
</tr>
</tbody>
</table>
2.6.1.3.3. Post-endarterectomy hypertension. Postoperative hypertension affects up to two-thirds of patients undergoing CEA, depending on the definition used.\textsuperscript{300} Several theories have been proposed, including denervation of the carotid bulb and increased cerebral norepinephrine and/or renin production by the central nervous system.\textsuperscript{300–352}  

Post-CEA hypertension is associated with preoperative hypertension,\textsuperscript{300,353} GA,\textsuperscript{264} and eCEA.\textsuperscript{291} The association between GA and post-CEA hypertension is attributed to increased neuroendocrine stress hormone levels. The association between eversion CEA and post-CEA hypertension is attributed to denervation of the carotid bulb, via circumferential transection at the origin of the ICA.\textsuperscript{354} In a systematic review and meta-analysis, patients undergoing eCEA were significantly more likely to require vasodilator therapy for the treatment of post-CEA hypertension compared to patients undergoing cCEA (OR 2.75 (95% CI 1.82–4.16) \( p < .0001 \)).\textsuperscript{291} In a recent prospective study involving 100 CEA patients, Newman observed that poorly controlled preoperative BP and impaired baroreceptor function (but not impaired autoregulation) were associated with a significantly higher prevalence of post-CEA hypertension.\textsuperscript{360} Intraoperative variables that predicted a significantly increased risk of post-CEA hypertension included poorly controlled or labile hypertension at induction of anaesthesia. No other variable (including the magnitude of MCA velocity increase with flow restoration) was predictive of post-CEA hypertension.\textsuperscript{355}  

Poorly treated post-CEA hypertension has been associated with postoperative TIA/stroke,\textsuperscript{353,356} and is a risk factor for neck haematoma formation, HS, and ICH.\textsuperscript{300,334,357} There are a variety of strategies for treating post-CEA hypertension,\textsuperscript{170,358} but the need for intravenous antihypertensive therapy becomes less common once the patient resumes their normal antihypertensive medications. Vascular units should have written guidance for treating post-CEA hypertension so that treatment decisions are not delayed.

2.6.1.3.4. Post-stenting hypertension. As with CEA, most patients with post-CAS hypertension were treated with antihypertensive drugs prior to the procedure. Symptomatic post-CAS hypertension (HS, ICH) is reported in up to 3% of patients.\textsuperscript{359} The management is the same as for CEA.

<table>
<thead>
<tr>
<th>Recommendation 66</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that intra-arterial blood pressure monitoring be continued for the first 3–6 hours after carotid endarterectomy and carotid stenting, followed by hourly noninvasive blood pressure monitoring for the first 24 hours</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 67</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that vascular units have written criteria for treating post-carotid intervention hypertension</td>
<td>I</td>
<td>C</td>
<td>170</td>
</tr>
</tbody>
</table>

2.6.1.4. Wound haematoma after carotid endarterectomy. VSGNE reported that re-exploration for neck haematoma was required in 1.2% of CEA patients on aspirin, 0.7% on clopidogrel, and 1.4% in patients taking aspirin and clopidogrel.\textsuperscript{360} ICSS reported that the prevalence of haematoma requiring re-exploration was 3.4%.\textsuperscript{361} There is no evidence that DAPT significantly increases the risk of neck haematoma formation.\textsuperscript{132,360,362} The role of protamine reversal in reducing re-exploration for neck haematoma formation after CEA has been discussed in Section 2.4.1.8. Small calibre suction drains do not appear to reduce the prevalence of haematoma, whereas larger calibre drains may help.\textsuperscript{295} (Section 2.4.1.15). Most haematomas occur in the first 6 hours after CEA, often after a period of untreated hypertension.\textsuperscript{357} Any evidence of stridor or tracheal deviation mandates immediate evacuation.

<table>
<thead>
<tr>
<th>Recommendation 68</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any patient who develops a postoperative neck haematoma in association with stridor or tracheal deviation must be re-explored immediately</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

2.6.1.5. Cranial nerve injury. In a meta-analysis of 16,749 CEA patients from four RCTs, eight prospective, and 14 retrospective studies, the prevalence of CNI was 4.2% for the recurrent laryngeal nerve, 3.8% for the hypoglossal nerve, 1.6% for the mandibular branch of the facial nerve, 0.2% for the glossopharyngeal nerve, and 0.2% for the spinal accessory nerve.\textsuperscript{362} Significant predictors for CNI were urgent procedures and re-exploration for bleeding/neurological deficit. The meta-analysis observed that the prevalence of CNI had diminished over the last 30 years.\textsuperscript{363} In ICSS, the incidence of CNI was 5.5% in 821 CEA patients.\textsuperscript{361} However, only 11 (1.3%) had symptoms at 30 days and the CNI was disabling in only one patient (0.12%) at 6 months (modified Rankin Score >3). In CREST, the prevalence of CNI was 4.3% in 1151 patients, the most common injuries being glossopharyngeal/vagus (41%), mandibular branch of the facial nerve (30%), and hypoglossal (25%). Horner’s syndrome complicated 4% of CEAs. In CREST, one-third of CNIs resolved within 30 days, with 81%
resolved by 1 year. In terms of HRQoL analyses in CREST, CNI had an impact on eating and swallowing at 2–4 wks, but not thereafter. This would suggest that although CNI is more common after CEA and is responsible for eating/swallowing problems in the first 2–4 wks, few are disabling in the long term.

CNIs can be avoided by good anatomical knowledge, by dissecting close to the arterial wall and by careful use of forceps, retractors, cautery, and clamps. A useful manoeuvre to minimise injury to the hypoglossal nerve is division of the sternocleidomastoid artery, which tethers the nerve. The hypoglossal nerve can then be indirectly retracted by applying a tie to the divided ansa cervicalis. Injuries to the mandibular branch of the facial nerve can be minimised by avoiding jaw retraction and by curving the skin incision posteriorly toward the mastoid process. In a RCT involving 1126 CEA patients, perioperative administration of dexamethasone reduced temporary CNIs, without reducing the prevalence of permanent CNIs.

2.6.1.6. New postoperative cerebral ischaemic lesions. ICSS undertook a substudy in which CEA and CAS patients underwent DWI-MRI 1–7 days before treatment, followed by a second scan 1–3 days after treatment, and a third scan 27–33 days after treatment, each analysed by blinded investigators. Sixty-two of 124 CAS patients (50%) and 18/107 CEA patients (17%) had at least one new DWI lesion on the first post-treatment scan (OR 5.21, 95% CI 2.78–9.79, \( p < .0001 \)). When the scans were repeated at 1 month, there were persisting changes on fluid-attenuated inversion recovery (FLAIR) MR sequences in 28/86 CAS patients (33%), compared with 6/75 CEA patients (8%) (OR 5.93, 95% CI 3.31–11.26, \( p = .0003 \)). In a meta-analysis of two RCTs and 18 non-randomised studies (CAS = 989; CEA = 1115), the incidence of new DWI-MRI cerebral lesions was significantly greater after CAS than CEA (40% vs. 12%; OR 5.17, 95% CI 3.31–8.06, \( p < .00001 \)).

<table>
<thead>
<tr>
<th>Recommendation 69</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patch excision and autologous venous reconstruction is recommended for most patients with prosthetic patch infection</td>
<td>I</td>
<td>C</td>
<td>369,371</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 70</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion of a covered stent may be considered in selected “high-risk for surgery” patients with suspected prosthetic patch infection</td>
<td>IIb</td>
<td>C</td>
<td>369</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 71</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patch excision and prosthetic reconstruction is not recommended for patients with patch infection after carotid endarterectomy</td>
<td>III</td>
<td>C</td>
<td>369</td>
</tr>
</tbody>
</table>

The clinical relevance of new DWI-MRI lesions is unknown. There is no evidence that these lesions predispose towards cognitive impairment, but this would require long-term studies and large numbers of patients. ICSS published follow-up data in the cohort who underwent pre- and post-operative MRI imaging. The 5-year incidence of recurrent stroke/TIA was 22.8% in CAS patients with new DWI lesions, compared with 8.8% in CAS patients with no new DWI-MRI lesions (HR 2.85, 95% CI 1.05–7.72, \( p = .04 \)). ICSS concluded that new ischaemic brain lesions after CAS may be a marker for an increased risk of recurrent cerebrovascular events and that DWI-positive patients might benefit from more aggressive and prolonged DAPT.

2.6.2. Late complications

2.6.2.1. Prosthetic patch infection. In a review of 30 published case series (130 patients), patch infection complicated 0.4–1.8% of CEAs. One-third presented within 2 months of the original procedure (usually with a preceding wound complication), while two-thirds presented after 6 months had elapsed, usually with a chronic sinus or pseudoaneurysm formation. Patch rupture or anastomotic dehiscence was relatively rare and mostly involved infections occurring within the first 2 months. Staphylococci and streptococci were the underlying infective organisms in 90% of cases. Because an increasing proportion of coagulase-negative staphylococci are resistant to flucloxacillin, it is reasonable to start patients on intravenous vancomycin (or teicoplanin) while awaiting definitive cultures.

DUS is the first-line investigation and can reveal patch corrugation (which may precede the diagnosis of overt infection by 11 months), the presence of deep collections, and/or pseudoaneurysm formation. DUS should, however, be supplemented by CTA in patients being considered for open exploration or insertion of a covered stent. Patch excision and arterial reconstruction with autologous vein (patch/bypass) is the “gold standard” treatment. There have been limited reports ( \( n = 5 \)) of using covered stents to treat patch infection (good initial results), but no long-term data are available.

2.6.2.2. Restenosis after carotid interventions

2.6.2.2.1. Pathophysiology. “Recurrent” lesions within 4–6 wks of CEA represent residual atherosclerotic lesions, rather than restenoses. Restenosis usually begins 3–6 months postoperatively, secondary to neointimal hyperplasia. Restenoses developing after 24 months most likely
represent recurrent atherosclerosis. Factors associated with restenosis include smoking, hypertension, female gender, diabetes, small carotid diameter, residualstenoses, and primary closure after CEA. 73,99

2.6.2.2.2. Surveillance for restenosis after endarterectomy and stenting. DUS criteria for diagnosing restenoses after CEA and CAS are different to imaging an untreated carotid artery (Section 2.1.5). Following CEA, it has been proposed that the PSV threshold for diagnosing a >50% restenosis should be 213 cm/s and 274 cm/s for diagnosing a >70% restenosis. 372 DUS criteria for diagnosing “in-stent restenosis” after CAS are summarised in Table 20. As can be seen, PSV threshold velocities are much higher than after CEA for diagnosing >50% and >70% restenoses. 373,374 However, the need to use higher PSV thresholds for diagnosing >50% ICA restenoses after CAS was not confirmed in a recent substudy from ICSS. 375

DUS surveillance enables monitoring of disease progression in the contralateral ICA, which is more common than ipsilateral restenosis, with progression being dependent on disease severity at the time of CEA. The data are, however, conflicting as to its benefit. Patients with >50% contralateral stenoses have been reported to be five times more likely to progress during follow-up. 376,377 Ballotta undertook serial surveillance of contralateral ACS following CEA and reported that progression from a moderate (50–69%) to a severe (70–99%) stenosis was associated with an increased risk of TIA/stroke, with >80% of events occurring in the latter patient group. 378 No data, however, were provided for ipsilateral stroke rates alone.

By contrast, in a series of 151 CEA patients who underwent serial postoperative imaging of the non-operated ICA, cumulative freedom from stroke in the non-operated hemisphere was 99%, 96%, and 86% at 1, 5, and 10 years, respectively (mean stroke incidence = 1% per annum). Only one stroke in the contralateral hemisphere was preceded by a TIA and no stroke was associated with a severe (>70%)

Table 20. Duplex velocity criteria for diagnosing in-stent restenosis after CAS.

<table>
<thead>
<tr>
<th>In-stent restenosis</th>
<th>Peak systolic velocity</th>
<th>End diastolic velocity</th>
<th>ICA/CCA ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;50%</td>
<td>&gt;220 cm/s</td>
<td></td>
<td>≥2.5</td>
</tr>
<tr>
<td>&gt;70%</td>
<td>≥300 cm/s</td>
<td>≥90 cm/s</td>
<td>≥3.8</td>
</tr>
</tbody>
</table>

Based on data from Lal 373 and Stanziale. 374

ICA stenosis. 379 Ten patients (7%) whose contralateral stenosis was <50% at baseline progressed to a severe stenosis during follow-up, but only three became symptomatic. In each case, however, onset of symptoms preceded recognition of disease progression. The study concluded that none of the observed strokes could have been prevented by postoperative surveillance. 379

2.6.2.2.3. Prevalence of restenosis. A recent meta-analysis identified 11 RCTs which reported rates of restenosis >70% or occlusion after CEA and CAS. 380 RCTs were used (rather than observational studies) because they are prospective, they are conducted with greater scientific rigour, selection bias is reduced through randomisation and independent observers adjudicate most endpoints. 380 The weighted incidence of “restenosis >70% or occlusion” is detailed in Table 21.

A previous meta-analysis reported that CAS was associated with significantly higher >70% restenosis rates than after CEA (OR 2.41, 95% CI 1.28–4.53, p = .007). 195 In CAVATAS, however, most patients randomised to endovascular therapy were treated by balloon angioplasty. When the meta-analysis was confined to the five RCTs using primary stenting, the difference in severe restenosis rates between CEA and CAS was not statistically significant (OR 1.97, 95% CI 0.67–5.79). 195

2.6.2.2.4. Restenosis and recurrent ipsilateral symptoms. There are conflicting data about whether there is any association between restenosis after CEA or CAS and recurrent ipsilateral symptoms. Table 22 summarises surveillance data from seven RCTs involving CEA patients (n = 2839) and four RCTs involving CAS patients (n = 1964). The principal investigators of each RCT were asked to check whether the diagnosis of restenosis >70% or occlusion was made before or after stroke onset and to provide details about the status of the asymptomatic ipsilateral ICA stenosis on the last DUS surveillance scan immediately preceding stroke onset. 380 There was no association between a previously asymptomatic “restenosis >70%” and late ipsilateral stroke in CAS patients. Only 1/125 patients with a restenosis >70% after CAS (0.8%) at 50 months’ follow-up suffered a late ipsilateral stroke, compared with 37/1839 (2.0%) in CAS patients who did not develop a restenosis >70% (OR 0.87, 95% CI 0.24–3.21, p = .8339). Overall, 97% of all late ipsilateral strokes after CAS occurred in patients without a restenosis >70%. 380

Table 21. Meta-analysis of the prevalence of restenosis >70% or occlusion in surveillance data from RCTs involving CEA and CAS. a

<table>
<thead>
<tr>
<th></th>
<th>No. of RCTs</th>
<th>No. of patients</th>
<th>Mean follow-up (months)</th>
<th>Restenosis &gt;70% or occlusion % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any CEA</td>
<td>11</td>
<td>4249</td>
<td>47</td>
<td>5.8% (4.1–8.2)</td>
</tr>
<tr>
<td>Patched CEA</td>
<td>5</td>
<td>1078</td>
<td>32</td>
<td>4.1% (2.0–8.4)</td>
</tr>
<tr>
<td>CAS or angioplasty</td>
<td>6</td>
<td>2916</td>
<td>60</td>
<td>10.3% (6.4–16.4)</td>
</tr>
<tr>
<td>CAS</td>
<td>5</td>
<td>2716</td>
<td>62</td>
<td>10.0% (6.0–16.3)</td>
</tr>
</tbody>
</table>

* Data derived from Kumar et al. 380
Management of Atherosclerotic Carotid and Vertebral Artery Disease

Table 22. Meta-analysis of the prevalence of late ipsilateral stroke in CEA/CAS patients with and without an asymptomatic “restenosis >70% or occlusion” in the constituent RCTs.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Mean follow-up (months)</th>
<th>Stroke ipsilateral to &gt;70% restenosis</th>
<th>Stroke ipsilateral to restenosis &lt;70%</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any CEA</td>
<td>37</td>
<td>7/135 (5.2%)</td>
<td>40/2704 (1.2%)</td>
<td>4.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(95% CI 2.29–9.92, ( p &lt; .0004 ), ( I^2 = 0 % ))</td>
<td></td>
</tr>
<tr>
<td>7 RCTs ( (n = 2810) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAS</td>
<td>50</td>
<td>1/125 (0.8%)</td>
<td>37/1839 (2.0%)</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.24–3.21, ( p = .8339 ), ( I^2 = 0 % ))</td>
<td></td>
</tr>
<tr>
<td>4 RCTs ( (n = 1964) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( a \) Data derived from Kumar et al.380

\( b \) All restenoses had been asymptomatic prior to stroke onset.

By contrast, a severe asymptomatic restenosis >70% after CEA did appear to be associated with a significantly higher risk of late ipsilateral stroke. Seven of 135 patients (5.2%) with a previously asymptomatic restenosis >70% prior to stroke onset suffered a late ipsilateral stroke at a median of 37 months’ follow-up, compared with 40/2704 (1.2%) in patients without a restenosis >70% (OR 4.77, 95% CI 2.29–9.92, \( p < .0001 \)).380 However, 85% of late ipsilateral strokes after CEA occurred in patients without a restenosis >70%.380 There were insufficient data to perform subgroup analyses in patients undergoing patched or eversion CEA.

2.6.2.2.5. Management of restenoses

2.6.2.2.5.1. Symptomatic restenoses. No RCTs have evaluated whether symptomatic restenoses should be treated medically or by redo CEA/CAS. It has, however, become customary to adopt the same treatment criteria that are used to select symptomatic patients with primary atherosclerotic stenoses (Section 2.3.3). Accordingly, if a patient reports ipsilateral carotid territory symptoms and has a 50–99% restenosis after CEA or CAS, they should undergo redo CEA or CAS within 14 days of symptom onset. Supervising clinicians should ensure that all patients receive optimal medical treatment (Section 2.2.1). Patients with recent symptoms with a <50% ipsilateral restenosis should be treated medically, in much the same manner as if they had presented without having undergone a previous CEA or CAS (Section 2.3.3). The choice of redo CEA or CAS should be based on MDT review, local surgeon/interventionist experience, and patient choice. In a meta-analysis of 13 studies \( (n = 1132 \) patients), there was no difference in 30-day death/stroke between CAS (3.1%) and redo CEA (3.7%) when treating recently symptomatic patients with 50–99% restenoses (OR 0.8, 95% CI 0.3–2.6).258

2.6.2.2.5.2. Asymptomatic restenoses. This remains a highly controversial subject. No RCT has evaluated whether BMT or redo CEA/CAS (+BMT) is the optimal treatment strategy for patients with asymptomatic >70% restenoses after CEA or CAS. Despite an intuitive belief that most asymptomatic restenoses are benign, a recent meta-analysis reported that two-thirds of patients undergoing treatment for restenoses were asymptomatic,258 suggesting that many surgeons and interventionists were uncomfortable about not intervening in asymptomatic patients with restenoses >70%.

Kumar’s meta-analysis suggested that patients developing an asymptomatic restenosis >70% after CAS would gain little or no benefit from reintervention, as the risk of stroke is very small (0.8% over 4 years)380 (Table 22). However, the presence of an asymptomatic >70% restenosis after CEA was associated with a significantly higher risk of late ipsilateral stroke, compared with patients without a severe restenosis (Table 22).

The meta-analysis observed that, based on the data in Table 22, approximately 6% of patients undergoing CEA will develop a restenosis >70% (or occlusion) over a mean of 47 months. This means that approximately 1700 CEA patients would need to undergo DUS surveillance to identify 100 patients with an asymptomatic restenosis >70%. The presence of an untreated, asymptomatic restenosis >70% after CEA was associated with a 5% risk of late ipsilateral stroke (Table 22). If one assumes that all undergo reintervention, a maximum of five ipsilateral strokes will be prevented. However, 95/100 would ultimately undergo an unnecessary reintervention, two to three would suffer a perioperative stroke following CAS or redo CEA258 and about 5% would suffer a CNI after redo CEA.258 In effect, a policy of aggressively intervening in 100 patients with an asymptomatic >70% restenosis after CEA could only ever prevent about two to three ipsilateral strokes in the long term. Moreover, despite serial surveillance and reintervention in all patients with asymptomatic 70–99% restenoses after CEA, 85% of all late ipsilateral strokes destined to happen would still occur in patients with no evidence of a restenosis >70% (Table 22).

However, two subgroups with asymptomatic restenoses >70% do warrant DUS surveillance and reintervention. The first would be any patient developing neurological symptoms with carotid clamping during CEA under LRA, or during balloon inflation (proximal flow reversal) during CAS. The second would be patients who developed significant electrophysiological changes during carotid clamping or whose mean MCA velocities fell below 15 cm/s on TCD monitoring.
during carotid clamping under GA. A threshold of 15 cm/s has been shown to correlate with loss of cerebral electrical activity.\(^{381}\) In both subgroups, progression to occlusion may be more likely to be associated with a major haemodynamic stroke.

2.6.2.2.5.3. Redo endarterectomy or stenting? If a decision has been made to intervene, there are two options including surgery (redo CEA, bypass) or CAS, neither of which have been subject to randomised comparison. In a 2015 meta-analysis of 13 observational studies, where redo CEA was compared with CAS,\(^{257}\) there was no difference in 30-day stroke/death (2.3% after CAS vs. 2.7% after redo CEA, OR 0.8, 95% CI 0.4–1.8). There was also no difference in the prevalence of recurrent restenosis >70% (4% after CAS vs. 7.7% after redo CEA). Redo CEA was associated with a 5.5% risk of CNI (mostly temporary) and a 2.7% risk of bleeding complications. CAS was associated with access site complications (1.9%), arrhythmia (1.4%), technical failure (1.3%), and residual stenosis (0.3%).\(^{258}\)

### Recommendations

**Recommendation 72**  
Patients suffering a late ipsilateral stroke/TIA in the presence of an ipsilateral 50–99% restenosis should undergo redo carotid endarterectomy or carotid artery stenting  
Class I  
Level A  
References 172

**Recommendation 73**  
It is recommended that patients suffering a late ipsilateral stroke/transient ischaemic attack in the presence of an ipsilateral <50% restenosis should be treated medically  
Class I  
Level A  
References 172

**Recommendation 74**  
Reintervention may be considered in carotid endarterectomy patients with an asymptomatic 70–99% restenosis, following multidisciplinary team review  
Class IIb  
Level B  
References 380

**Recommendation 75**  
It is recommended that carotid stent patients who develop an asymptomatic restenosis >70% are treated medically  
Class I  
Level A  
References 380

**Recommendation 76**  
Serial surveillance and reintervention for asymptomatic restenoses >70% is recommended in patients who developed neurological symptoms during carotid clamping under local anaesthesia, or during balloon inflation (or proximal flow reversal) during carotid stenting  
Class I  
Level C

**Recommendation 77**  
Serial surveillance and reintervention for asymptomatic restenoses >70% is recommended in carotid endarterectomy patients who developed significant electrophysiological changes during carotid clamping or whose mean middle cerebral artery velocities fell below 15 cm/s on transcranial Doppler monitoring during carotid clamping under general anaesthesia  
Class I  
Level C

**Recommendation 78**  
When a decision has been made to undertake revascularisation in patients with a restenosis, it is recommended that the choice of redo endarterectomy or stenting should be based on multidisciplinary team review, local surgeon/interventionist preference, and patient choice  
Class I  
Level C

### 2.7. Management of concurrent coronary and carotid disease

The presence of carotid stenosis/occlusion is associated with an increased risk of perioperative stroke in patients undergoing coronary artery bypass (CABG), but whether carotid disease is a risk factor, rather than an aetiological factor, has been the subject of considerable debate.

**2.7.1. Is carotid disease an important cause of stroke during cardiac surgery?** The prevalence of stroke after CABG is 1–2%.\(^{382}\) The prevalence of carotid “stenosis >50%” in unselected CABG patients is 9%, while the prevalence of “stenosis >80%” is 7%.\(^{382}\) A meta-analysis reported that CABG patients with “50–100%” carotid stenoses faced a 7% risk of perioperative stroke, increasing to 9% in patients with 80–100% stenoses.\(^{383}\) High as these risks might seem, it is important to consider how occlusion and the patient’s neurological status influences stroke risk after CABG. CABG patients reporting a prior history of TIA/stroke and those with carotid occlusion incur a much higher risk of post-CABG stroke. D’Agostino observed that the rate of post-CABG stroke was 18% in patients with a previously symptomatic unilateral carotid stenosis, increasing to 26% in symptomatic patients with bilateral stenoses who then underwent isolated CABG.\(^{384}\) A systematic review suggested that CABG patients with carotid occlusion incurred an 11% risk of stroke after CABG.\(^{382}\)
After excluding patients with symptomatic carotid disease (who are definitely at higher risk of post-CABG stroke) and those with occlusion (who cannot undergo CEA), the risk of perioperative stroke in a recent systematic review fell to $\leq 2.0\%$ in CABG patients with unilateral (non-operated) asymptomatic 50–99\%, 70–99\%, and 80–99\% carotid stenoses.\textsuperscript{383} In the same systematic review, 6.5\% of patients with bilateral ACS suffered a perioperative stroke, while 9.1\% either died or had a stroke during CABG.\textsuperscript{383}

The aetiology and laterality of perioperative stroke in 4674 CABG patients screened preoperatively for carotid disease found that 86\% of strokes could not be attributed to carotid disease.\textsuperscript{382} In a pooled series of 23,557 patients undergoing CABG without prophylactic CEA/CAS, 95\% of 476 postoperative strokes could not be attributed to carotid disease.\textsuperscript{385–387} Accordingly, most of the available evidence suggests no causal relationship between a significant, asymptomatic unilateral stenosis and post-CABG stroke, that is other aetiologies may play a more important role, particularly aortic arch atheroembolism. As CABG patients increase in age, so too does the prevalence of severe carotid disease, severe aortic arch disease, and post-CABG stroke (Table 23).\textsuperscript{22,382,388}

Interestingly, the presence of a carotid bruit was the only significant predictor of severe aortic arch atherosclerotic disease,\textsuperscript{389} while a $>70\%$ carotid stenosis on DUS was an independent predictor of severe aortic arch disease.\textsuperscript{390} In a 2015 systematic review of predictors associated with stroke after CABG, Mao found seven variables associated with an increased risk of post-CABG stroke including increasing age, prior stroke/TIA, carotid stenosis, history of PAD, unstable angina, prolonged cardiopulmonary bypass, and postoperative atrial fibrillation.\textsuperscript{391}

### 2.7.2. What is the value of screening patients undergoing cardiac surgery?

Given the low prevalence of stroke after CABG, routine screening for ACS before CABG cannot be supported. Clinical/imaging factors associated with an increased likelihood of finding a severe carotid stenosis in CABG patients include increasing age, carotid bruit, history of prior stroke/TIA, and left main stem disease.\textsuperscript{382,392}

### 2.7.3. Are carotid interventions indicated in cardiac surgery patients?

The many different causes of stroke during CABG and the lack of a clear causal association with ACS mean that routine prophylactic carotid revascularization is unlikely to reduce the prevalence of post-CABG stroke. However, some CABG patients will benefit from a staged/synchronous carotid intervention. The literature supports staged or synchronous carotid interventions in CABG patients with a history of stroke/TIA,\textsuperscript{384} but is less supportive of prophylactic CEA/CAS in CABG patients with unilateral 70–99\% asymptomatic stenoses, where the stroke risk may only be about 2\%.\textsuperscript{383,395} The evidence would, however, support prophylactic CEA (or CAS) in patients with bilateral asymptomatic 70–99\% stenoses or a 70–99\% stenosis with contralateral occlusion.\textsuperscript{383}

However, a RCT has challenged this interpretation of the literature.\textsuperscript{394} Illuminati randomised 185 CABG patients with unilateral, asymptomatic 70–99\% carotid stenoses to staged/synchronous CEA prior to CABG or isolated CABG followed by CEA at a later date (deferred CEA). Thirty-day mortality was 1\% in each group, while 30-day death/stroke rate was 4\% (deferred CEA) and 1\% (staged/synchronous CEA) ($p = ns$). Interestingly, the 90-day death/stroke rate was 9\% with deferred CEA versus 1\% for staged/synchronous CEA. The authors concluded that prophylactic CEA was potentially beneficial in CABG patients with unilateral asymptomatic 70–99\% carotid stenoses to reduce the 90-day risk of ipsilateral stroke, rather than perioperative stroke.\textsuperscript{304}

### 2.7.4. What carotid surgical/endovascular options are available?

Interventional strategies include: (1) staged CEA followed by CABG; (2) staged CABG followed by CEA; (3) synchronous CEA and CABG; (4) staged CAS followed by CABG; and (5) “same day” CAS + CABG. Table 24 summarises the findings of several meta-analyses published over the last two decades. The majority of patients ($>80\%$) would have been neurologically asymptomatic with unilateral ICA stenoses and the majority reported 30-day death/stroke rates of 7–8\%.

Table 25 presents similar data, this time from administrative dataset registries, which are more likely to reflect “real world” practice. Thirty-day death/stroke ranged from 6\% to 10\% in predominantly asymptomatic patients, with the highest procedural risks being observed in patients with a history of stroke/TIA who underwent either staged/synchronous CEA + CABG (14\%) or CAS — CABG (44\%).\textsuperscript{404}

One systematic review\textsuperscript{400} suggested that performing CABG off-pump was associated with the lowest rates of post-CABG stroke, attributed to no cannulation of a diseased aortic arch. However, Gopaldas\textsuperscript{406} found no evidence to support this in patients undergoing either staged or synchronous carotid interventions (Table 25).

CAS might be an alternative to CEA. In an updated meta-analysis (Table 24), which included 2727 patients who underwent staged or “same day” CAS-CABG, the overall 30-day death/stroke rate was 7.9\%.\textsuperscript{401} The majority (80\%) were neurologically asymptomatic with a unilateral carotid stenosis, in whom the 30-day death/stroke rate was 6.7\% after CAS + CABG with a death/stroke/MI rate of 8.5\%. Given the low rates of stroke in asymptomatic patients with unilateral stenoses undergoing isolated CABG, it is unlikely that CAS + CABG (or CEA + CABG) will benefit the

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### Table 23. Prevalence of post-CABG stroke and its association with age and prevalence of carotid and aortic arch disease.

<table>
<thead>
<tr>
<th>Age</th>
<th>Prevalence of post-CABG stroke</th>
<th>Prevalence of carotid stenosis $&gt;70%$ on screening</th>
<th>Prevalence of aortic arch disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>50–59</td>
<td>1–2%</td>
<td>0.2% M:0.1% F</td>
<td>9%</td>
</tr>
<tr>
<td>60–69</td>
<td>2–3%</td>
<td>0.8% M:0.2% F</td>
<td>18%</td>
</tr>
<tr>
<td>70–79</td>
<td>4–7%</td>
<td>2.1% M:1.0% F</td>
<td>22%</td>
</tr>
<tr>
<td>$\geq 80$</td>
<td>8–9%</td>
<td>3.1% M:0.9% F</td>
<td>33%</td>
</tr>
</tbody>
</table>

M = males; F = females.

* Prevalence of carotid stenosis based on population screening, not screening in CABG patients.
asymptomatic patient with unilateral stenoses. Another important finding from the systematic review was that performing staged or same-day CAS+CABG in patients with a prior history of TIA/stroke was associated with a 15% 30-day risk of death/stroke.401

Using propensity scoring, Shishehbor evaluated three approaches to carotid revascularisation in CABG patients with predominantly asymptomatic carotid disease, staged CEA-CABG (n = 45), staged CAS-CABG (n = 110), and combined CEA-CABG (n = 195). Staged CAS-CABG and combined CEA-CABG were associated with similar rates of death, stroke, and MI in the short term, with both being better than staged CEA-CABG.407 Mortality was comparable across all treatment strategies in the early period, whereas higher stroke rates were observed in the combined CEA-CABG group and higher MI rates in the staged CEA-CABG
The requirement for DAPT after CAS can be a problem for the staged CAS-CABG approach, as it increases the risk of MI between the two procedures, as well as increasing the risk of perioperative bleeding during urgent or emergency CABG. However, evidence suggests that CAS can be performed on the same day as CABG using aspirin/heparin cover, with thienopyridine antiplatelet agents being started 6–12 hours after CABG.401,408,409

### 2.7.5. Managing patients with unstable coronary artery disease

The Carotid Artery Revascularization and Endarterectomy (CARE) registry involved 255 patients who underwent CAS and 196 who underwent CEA prior to urgent cardiac surgery. The 30-day rate of death/stroke and MI was 15% after CAS and 22% after CEA,410 which is considerably higher than reported in Tables 24 and 25. CARE did not, however, separate staged CEA-CABG and combined CEA + CABG and significant regional variations existed in practice, with 60% of carotid interventions being undertaken in asymptomatic patients.

### 2.8. Carotid disease and major non-cardiac surgery

Vascular surgeons are often asked to advise on how to manage a patient undergoing major non-cardiac surgery who has a concurrent severe ACS. Should prophylactic CEA or CAS be considered to reduce the risk of perioperative stroke?

#### 2.8.1. Prevalence of stroke after major non-cardiac surgery

The prevalence of perioperative stroke depends on the nature and complexity of the surgical procedure, the presence of risk factors and (most particularly) the timing of major surgery after a recent TIA or stroke (Table 26).
The prevalence of perioperative stroke was <1% in all but two cohorts undergoing major (non-cardiac operations) in Table 26, suggesting that (for the vast majority of patients) perioperative stroke during major non-cardiac surgery is rarely a major problem.

**2.8.2. Prediction of stroke after major non-cardiac surgery.**

Table 27 summarises features associated with an increased risk of perioperative stroke after non-cardiac surgical procedures. The most consistent were increasing age and a history of previous stroke.

**2.8.3. Timing of major surgery after recent stroke.** One of the main findings from Table 27 was how the timing of major non-cardiac operations after a recent stroke impacted on perioperative stroke. In a large Danish national study of adult patients undergoing 481,183 elective, non-cardiac operations, 7137 (1.5%) were undertaken in patients with a prior history of stroke. In the latter cohort, the risk of perioperative stroke was 11.9% when elective non-cardiac operations were performed within 3 months of stroke onset, declining to 4.5% where 3–6 months had elapsed and 1.8% where 6–12 months had elapsed. This compares with 0.1% in patients who had no history of prior stroke.413

**2.8.4. Is there a role for prophylactic carotid endarterectomy or stenting?** Patients undergoing non-cardiac, non-vascular major surgery with three or four cardiovascular risk factors (age, coronary disease, renal failure, hypertension, diabetes, smoking, body mass index >35 kg/m², chronic obstructive pulmonary disease, previous TIA) incurred a 0.7% incidence of perioperative stroke. With five or more risk factors, the incidence of perioperative stroke increased to 1.9%.419,420 It is therefore important to review the overall cardiovascular risk profile in patients undergoing major non-cardiac, non-vascular surgical procedures as part of the consent process.418,421 Most perioperative strokes are ischaemic and secondary to cardiac embolism. The perioperative period also involves complex haemodynamic stresses involving hypercoagulable and systemic inflammatory responses, all of which increase the risk of perioperative stroke, especially if anticoagulation or antiplatelet therapies need to be withdrawn.

The role of prophylactic carotid revascularisation in patients with ACS undergoing major non-cardiac, non-vascular surgical procedures has been evaluated in one RCT and one non-randomised study. Ballotta randomised 79 patients with severe ACS to prophylactic CEA within 1 wk of the major surgical procedure (n = 40), versus a deferred CEA after the major surgical procedure (n = 39). There were no perioperative deaths or strokes in either group. Two deferred patients (5%) suffered a minor stroke 65 and 78 days after their major surgical procedure, while awaiting CEA.422

Sonny performed a retrospective study to determine whether the presence of ACS predisposed patients who were undergoing non-cardiac, non-carotid surgery to a heightened risk of perioperative stroke. During a 5-year period, 2110 patients had carotid DUS performed within 6 months before or 1 month after their operation. Thirty-seven per cent of patients had at least one ACS >50%, while 13% had >70% stenoses. Of the 2110 patients included, 112 (5%) died within 30 days and 54 (3%) suffered a postoperative stroke. Neither of the stenosis thresholds (>50%, >70%) was associated with an increased risk of perioperative stroke.414 Where possible, statin and antiplatelet therapy should not be stopped prior to major non-vascular surgical procedures in patients with asymptomatic 50—99% carotid stenoses.423 The decision to temporarily withdraw anticoagulant therapy should be made on an individual patient basis following a review of whether the bleeding risk exceeds the risk of thromboembolic stroke.
2.9. Occlusive disease of proximal common carotid and innominate arteries

2.9.1. Introduction. The incidence of significant stenosis or occlusion affecting the origins of aortic arch branch vessels is 0.5–6.4%, with a relatively higher frequency affecting the innominate or left subclavian arteries, as opposed to the left CCA. Total CCA occlusion is relatively rare, affecting 2–4% of patients undergoing angiography for symptomatic cerebrovascular disease. Patients with a symptomatic arch origin stenosis have a 2.3% annual risk of developing a stenosis affecting another arch branch vessel, while tandem occlusive disease affecting the carotid bifurcation may be present in up to 17% of patients.

2.9.2. Clinical presentation. Left CCA lesions give rise to left hemispheric and left retinal symptoms. Left subclavian lesions give rise to vertebrobasilar and/or left upper extremity symptoms, while innominate lesions can involve three territories (right carotid, vertebrobasilar, and right upper extremity). Occlusive lesions involving branches of the aortic arch are generally atherosclerotic, but arteritis (Takayasu’s, radiation) and dissection should be considered in younger patients.

2.9.3. Indications for revascularisation. Indications for revascularising arch branch origin lesions are similar to those for performing CEA. The natural history of isolated CCA or innominate stenoses is unknown. In patients with neurological sequelae or upper extremity ischaemia, the indication for revascularisation is relatively straightforward. There is no evidence supporting open or endovascular interventions in asymptomatic patients.

2.9.4. Endovascular versus open surgical reconstruction. There is controversy regarding the optimal intervention for patients with innominate artery disease, as there is often

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<td>III</td>
<td>B</td>
<td>414,422</td>
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</table>
multivessel involvement. Until 30 years ago, supra-aortic occlusive disease could only be treated by open surgery. Transposition of the CCA on to the subclavian artery provides direct autogenous revascularisation, but this may not always be feasible. Open CCA endarterectomy can be performed via an open or retrograde semi-closed endarterectomy. However, with recent advances in hybrid interventions, most innominate or proximal CCA stenoses/occlusions are now treated by open retrograde angioplasty and stenting.424 In the largest published series of primary stenting for 145 aortic side branch origin lesions in 114 patients, the technical success rate was 97% and there were no strokes or deaths at 30 days. During a mean follow-up of 52 months (range 2–163), restenosis-free survival was 96% and 83% at 12 and 60 months, respectively.424

2.9.5. Open revascularisation: cervical versus transthoracic reconstruction. Techniques for reconstructing arch vessels include bypass via a transthoracic or extra-thoracic (cervical) approach. The transthoracic approach involves a median sternotomy or the less invasive “trap-door” technique. Cervical reconstructions are less invasive and are associated with fewer procedural risks. Patients with an isolated subclavian or CCA lesion (with a patent ipsilateral carotid or subclavian artery) should undergo transposition or bypass via a cervical approach. Saphenous vein was previously the first-choice conduit, but it is often small in calibre and more prone to kinking/angulation than prosthetic grafts, which otherwise offer durable patency and low morbidity.426 At the other end of the spectrum is the patient with involvement of all three arch branches, where graft outflow must arise from the aorta via a median sternotomy. Transthoracic reconstructions can be performed with acceptably low morbidity/mortality. Moreover, the transthoracic approach is associated with significantly better long-term patency.427

2.9.6. Tandem proximal inflow and internal carotid artery disease. “Tandem disease” involves lesions affecting the innominate artery or proximal CCA, in addition to significant disease within the ipsilateral ICA. Historically, most were treated by total open procedures, but most now undergo a hybrid approach where open retrograde angioplasty/stenting of the innominate or proximal CCA is followed by CEA.428

<table>
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<td>Each 1 y increase in age</td>
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<td></td>
<td></td>
<td>Cardiac history</td>
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<td>Females</td>
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<td></td>
<td>Acute/chronic renal failure</td>
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<td>BMI</td>
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<td>Coronary disease</td>
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<td>Prior stroke</td>
<td>1.6 (1.3–2.1)</td>
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<tr>
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<td></td>
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<td>Diabetes</td>
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<td>Hypertension</td>
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<td>COPD</td>
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<td>Smoking</td>
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<td></td>
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<td>History of stroke</td>
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<td>Stroke 3–6 months</td>
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<td>Stroke 6–12 months</td>
<td>10.4 (6.2–17.4)</td>
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</table>

BMI = body mass index.
2.10. Unresolved issues relating to managing carotid artery disease

The Writing Group identified key issues relating to the investigation and management of carotid artery disease that need to be addressed to better inform future guidelines. These include:

- Should the “accepted” risk thresholds for performing CEA or CAS be reduced from 6% in symptomatic patients and 3% in asymptomatic patients?
- Should the time threshold for a patient being defined as “recently symptomatic” (currently 6 months) be reduced?
- The need to develop a validated algorithm for identifying “high-risk for stroke” asymptomatic patients in whom to target CEA and CAS.
- To determine whether asymptomatic carotid disease contributes towards cognitive decline and whether CEA/CAS can reverse or prevent this?
- Whether measurement of plasma biomarkers to evaluate excessive endothelial and coagulation system activation has any potential for guiding risk stratification in patients with asymptomatic carotid disease.
- Should all recently symptomatic patients be started on dual antiplatelet therapy once parenchymal haemorrhage is excluded on CT/MRI and then be continued through the perioperative period?
- Relevance of new DW-MRI lesions after CEA and CAS. Do these contribute towards a higher rate of recurrent stroke or cognitive decline?
- In patients undergoing emergency stent retrieval thrombectomy for acute ischaemic stroke because of an ICA or MCA (M1/M2) occlusion, is it safe to perform CAS to treat concurrent extracranial ICA stenoses during the same procedure?
- Which recently symptomatic patients with 0–49% ICA stenoses might benefit from urgent CEA or CAS?
- What is the optimal timing for performing CEA or CAS after intravenous thrombolysis?
- How should the presence of a tandem distal ICA severe stenosis influence management decisions in recently symptomatic patients with 50–99% ICA stenoses?

Can we accurately define patients who really are “high-risk for CEA” in whom one should preferentially perform CAS?

Can we accurately define patients who really are “high-risk for CAS” in whom one should preferentially perform CEA?

What is the optimal method for protecting the brain during CAS: none, distal filter, proximal protection, transcarotid approach?

Is it safe to perform CEA under locoregional anaesthesia if the patient is taking dual antiplatelet therapy?

Does intravenous heparin therapy confer any additional benefit over mono or dual antiplatelet therapy in patients who present with crescendo TIAs?

Is CEA under locoregional anaesthesia safer than CAS in “high-risk for CEA” patients with significant cardiac or chronic pulmonary disease?

Is there any role for testing antiplatelet resistance prior to CEA or CAS?

3. MANAGEMENT OF VERTEBRAL ARTERY DISEASE

3.1. Introduction

3.1.1. Burden of vertebrobasilar stroke. One-fifth of ischaemic strokes affect the vertebrobasilar territory, otherwise termed the posterior circulation. Vertebrobasilar events receive much less attention than those affecting the carotid territory, but data suggest they are associated with a similarly high risk of early recurrent stroke.

3.1.2. Aetiology of vertebrobasilar stroke. The causes of vertebrobasilar stroke/TIA are similar to those affecting the anterior circulation, including cardioembolism, large artery thromboembolism, and small artery disease. Atherosclerosis of the vertebral or basilar arteries accounts for 20–25% of strokes. Stenoses mostly occur at the VA origins, but they can affect the distal VA and basilar arteries. Intracranial stenoses are more common in individuals with a sub-Saharan African or East Asian ethnic origin, compared with Caucasians. Thromboembolism appears to be the main cause of ischaemia in patients with VA stenoses. This is supported by the detection of circulating emboli on TCD distal to the stenosis and by the temporal risk profile in patients with symptomatic stenoses, which shows a high early risk of recurrent stroke followed by a much lower risk, despite the continued presence of a stenosis.
Haemodynamic compromise was previously thought to be the main cause of vertebrobasilar symptoms. However, studies suggest that this is less common than previously thought. In the New England posterior circulation registry, only 13/407 patients (3%) had symptoms secondary to haemodynamic ischaemia and this was most commonly seen in patients with bilateral intracranial VA disease.\textsuperscript{431} Cardiac embolism, usually from atrial fibrillation, accounted for a quarter of posterior circulation strokes/TIAs. An additional quarter resulted from disease of the small penetrating arteries, resulting in lacunar stroke. These penetrating arteries arise from the intracranial vertebral, basilar, and posterior cerebral arteries.\textsuperscript{431}

3.1.3. Symptoms attributable to vertebral artery disease. The vertebrobasilar system supplies the brainstem, cerebellum, occipital lobes, and (in most patients) the inferior temporal lobes and most of the thalami. Accordingly, ischaemia can give rise to a wide range of symptoms, including vertigo, ataxia, eye movement disorders, bilateral limb weakness, complete visual loss (cortical blindness), and hemianopia.\textsuperscript{430} However, vertebrobasilar events can also include symptoms that are classically attributable to presumed anterior circulation ischaemia, including unilateral weakness or numbness. In a consecutive series of 407 patients with posterior circulation stroke in a tertiary referral centre, the most common symptoms were dizziness (47%), unilateral limb weakness (41%), dysarthria (31%), headache (28%), and nausea/vomiting (27%). The most common signs were unilateral limb weakness (38%), gait ataxia (31%), unilateral limb ataxia (30%), dysarthria (28%), and nystagmus (24%).\textsuperscript{432}

3.1.4. Imaging strategies in vertebral artery disease. MRI is more sensitive than CT for imaging posterior circulation ischaemia/infarcts, particularly in the brainstem.\textsuperscript{433} This reflects the higher resolution of MRI over CT for identifying infarcts, especially small ones in the brainstem or cerebellum, because MRI is less prone to artefact than CT. DWI is the most sensitive MRI technique for detecting acute ischaemia or infarction. DW-MRI may be positive for up to 2 wks after onset of ischaemia, although it can occasionally be negative, particularly with very small brainstem infarcts.\textsuperscript{434}

DUS is less sensitive at detecting VA stenoses than carotid stenoses.\textsuperscript{435} The VA can often, but not always, be visualised on DUS, but the more distal VA segments cannot be imaged directly and the presence of a stenosis is often only inferred from waveform abnormalities. If waveform abnormalities are present, however, they have a high specificity.\textsuperscript{436} DUS provides direct/indirect evidence of abnormal VA flow, including lesions located proximally or distally.\textsuperscript{437} DUS can estimate VA size and direction of flow and can differentiate between hypoplasia, stenosis, occlusion, and aplasia of the VA. However, it has low sensitivity, especially for the deeply located proximal VA segment.\textsuperscript{436,438} DUS can also indirectly suggest the presence of subclavian steal syndrome with pre-steal (transient mid-systolic flow deceleration), partial steal (flow reversal during systole), and complete subclavian steal (retrograde flow persisting throughout the cardiac cycle).

In the presence of VA origin occlusion, flow through collaterals may be seen, while stenoses may be visualised as turbulent flow or waveform dampening. An intra-stenotic post-stenotic PSV\textsubscript{VA} ratio $\geq$2.2 has been validated as the optimal criterion for diagnosing a proximal VA stenosis $\geq$50%, with a sensitivity and specificity of 96% and 89%, respectively.\textsuperscript{439} Beyond stenosis grading, VA diameters that differ by $>25\%$ are considered non-symmetrical.\textsuperscript{440} Hypoplasia in the V2 segment is defined as a diameter $\leq2.5$ mm and a significant decrease in flow velocities as compared with the contralateral side and an increase in ipsilateral flow resistance index $>0.85$.\textsuperscript{441}

Historically, intra-arterial angiography was the “gold standard” for diagnosing atherosclerotic VA disease. However, because of angiography-related stroke, it has been replaced by non-invasive imaging, especially CEMRA and CTA. Both allow visualisation of the entire vertebrobasilar system, thereby enabling simultaneous detection of extra- and intracranial VA and basilar stenoses. CEMRA provides better visualisation of the vertebrobasilar system, particularly the proximal VA, than non-contrast MRA techniques, such as time of flight imaging.\textsuperscript{435} In a study comparing CTA, CEMRA, and DUS, against the “gold standard” of intra-arterial digital subtraction angiography, CEMRA and CTA were found to have high sensitivity and specificity and were better than DUS for evaluating the VAs.\textsuperscript{439}

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<th>Recommendation 95</th>
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<tbody>
<tr>
<td>Colour Duplex ultrasound is recommended as the first-line imaging strategy in patients with suspected vertebrobasilar ischaemia, but must be followed by either contrast-enhanced magnetic resonance angiography or computed tomography angiography before any decisions on intervention are made</td>
<td>I</td>
<td>B</td>
<td>438,439</td>
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</table>

3.2. Secondary prevention in asymptomatic patients

3.2.1. Optimal medical therapy

3.2.1.1. Risk factor control. There have been no specific RCTs evaluating the effect of risk factor control in patients with asymptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for ACS (Section 2.2.1.1).
### 3.2.1.2. Antiplatelet therapy.

There have been no specific RCTs evaluating the effect of antiplatelet therapy in patients with asymptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for ACS (Section 2.2.1.2).

### 3.2.1.3. Lipid-lowering therapy.

There have been no specific RCTs evaluating the effect of statin therapy in patients with asymptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for ACS (Section 2.2.1.3).

### 3.2.1.4. Treatment of hypertension.

There have been no specific RCTs evaluating the effect of antihypertensive therapy in patients with asymptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for ACS (Section 2.2.1.4).

### 3.2.1.5. Treatment in diabetic patients.

There have been no specific RCTs evaluating the effect of therapy for diabetes in patients with asymptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for ACS (Section 2.2.1.5).

### 3.2.2. Screening for asymptomatic vertebral artery disease.

There have been no specific RCTs evaluating the effect of screening in patients with asymptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for ACS (Section 2.2.2).

### 3.2.3. Interventions for asymptomatic vertebral artery disease.

The risk of stroke in patients with asymptomatic VA stenoses is much lower than for symptomatic VA stenoses. In a hospital-based study of 3717 patients with atherosclerotic carotid disease, 7.6% had asymptomatic VA stenoses of >50% on DUS. The annual stroke risk was 0.2% in patients with isolated asymptomatic VA stenoses and 0.8% for those with VA and carotid artery stenoses.

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<tr>
<td>A healthy diet, smoking cessation, and physical activity are recommended for all patients with asymptomatic vertebral artery disease</td>
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<td>Low-dose aspirin (75–325 mg daily) or clopidogrel (75 mg daily) if aspirin-intolerant, is recommended in asymptomatic patients with vertebral stenoses for the prevention of myocardial infarction and other vascular events</td>
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<td>Statin therapy is recommended for the prevention of late stroke, myocardial infarction, and other cardiovascular events in patients with asymptomatic vertebral artery stenoses</td>
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<td>Antihypertensive treatment is recommended for patients with hypertension and asymptomatic extracranial vertebral artery stenoses to maintain long-term blood pressure &lt;140/90 mmHg</td>
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<td>In diabetic patients with asymptomatic vertebral artery stenoses, strict glycaemic control is recommended</td>
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<td>In diabetic patients with asymptomatic vertebral artery stenoses, the target blood pressure should be &lt;140/85 mmHg</td>
<td>I</td>
<td>B</td>
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with symptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for symptomatic carotid stenoses (Section 2.3.2.1).

3.3.1.2. Antiplatelet therapy. There have been no specific RCTs evaluating the effect of antiplatelet therapy in patients with symptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for symptomatic carotid stenoses (Section 2.3.2.2).

3.3.1.3. Lipid-lowering therapy. There have been no specific RCTs evaluating the effect of risk factor control in patients with symptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for symptomatic carotid stenoses (Section 2.3.2.3).

3.3.1.4. Treatment of hypertension. There have been no specific RCTs evaluating the effect of antihypertensive therapy in patients with symptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for symptomatic carotid stenoses (Section 2.3.2.4).

<table>
<thead>
<tr>
<th>Recommendation 102</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population screening for asymptomatic vertebral artery stenoses is not recommended</td>
<td>III</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 103</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asymptomatic vertebral artery atherosclerotic lesions should not be treated by open or endovascular interventions</td>
<td>III</td>
<td>C</td>
<td>442</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 104</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>A healthy diet, smoking cessation, and physical activity are recommended for all patients with symptomatic vertebral artery disease</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 105</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antiplatelet therapy is recommended in symptomatic patients with 50–99% stenoses not undergoing vertebral interventions. First-choice therapy is clopidogrel 75 mg daily or aspirin 75 mg daily plus modified release dipyridamole 200 mg twice daily. If intolerant of dipyridamole or clopidogrel, aspirin monotherapy (75–325 mg) should be used. If aspirin- and clopidogrel-intolerant, use modified release dipyridamole 200 mg twice daily</td>
<td>I</td>
<td>A</td>
<td>121–124,126</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 106</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that patients undergoing vertebral artery stenting should receive dual antiplatelet therapy with aspirin (75–325 mg daily) and clopidogrel (75 mg daily). Clopidogrel should be started at least 3 days prior to stenting or as a single 300 mg loading dose in urgent cases followed by 75 mg daily. Aspirin and clopidogrel should be continued for at least 4 wks after stenting and then optimal long-term secondary preventive antiplatelet therapy should be continued indefinitely</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 107</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term aspirin plus clopidogrel therapy is not recommended in symptomatic patients undergoing open surgery or stenting of vertebral artery stenoses unless indicated for cardiac reasons</td>
<td>III</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 108</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrent gastro-protection therapy or proton pump inhibition with pantoprazole should be considered in patients prescribed clopidogrel who have one or more factors that increase the patient’s risk of gastrointestinal bleeding (prior history of gastrointestinal bleeding, older age, Helicobacter pylori infection, concomitant use of aspirin, or other non-steroidal anti-inflammatory agents, anticoagulants, selective serotonin re-uptake inhibitors and steroids)</td>
<td>IIa</td>
<td>B</td>
<td>148–151</td>
</tr>
</tbody>
</table>
3.3.1.5. Treatment in diabetic patients. There have been no specific RCTs evaluating the effect of therapy for diabetes in patients with symptomatic VA stenoses. Accordingly, it is reasonable to adopt the same strategy that has been recommended for symptomatic carotid stenoses (Section 2.3.2.4).

3.3.2. Interventions in recently symptomatic patients. It was previously thought that vertebrobasilar events had a more benign prognosis than carotid events. Consequently, patients were less rigorously investigated and did not always receive intensive secondary prevention. Recent evidence, however, suggests that VA stenoses are associated with higher rates of early recurrent stroke, with a risk profile similar to (or worse) than that for carotid disease. Evidence suggests that the 90-day risk of recurrent stroke is 7% in patients with no VA stenoses, 16% in patients with extracranial VA stenoses, and 33% in those with intracranial VA or basilar artery stenoses. This is not, however, reflected in several RCTs. In CAVATAS, the mean interval between symptom onset and randomisation was 92 days (range 5–376), while the mean interval between randomisation and endovascular treatment was 45 days (range 7–148 days). In the Stenting of Symptomatic Atherosclerotic Lesions in the Vertebral or Intracranial Arteries (SSYLVIA) study, the mean delay between qualifying event and stenting was 73 days (median 29, range 1–959 days). In the Vertebral Artery Stenting Trial (VAST), the median interval between last symptom and randomisation was 25 days (IQR 11–50), while the delay between randomisation and stenting was 7 days (0–12).

3.3.2.1. Role of vertebral revascularisation in “positional vertigo.” It is not unusual for a diagnosis of “positional vertigo” to be made in patients presenting with dizziness or vertigo during lateral neck rotation or extension. Historically, these symptoms have been attributed to VA “nipping” in the bony foramina of the transverse processes of the cervical vertebrae. However, while occasional diagnoses have been corroborated using CTA/MRA/DSA, most are probably made without any further investigation. As a consequence, patients may then be turned down for major surgery on the mistaken belief that they might be at high risk for perioperative stroke because of a misdiagnosis of vertebrobasilar ischaemia. A systematic review of the literature observed that out of 20 published studies, seven reported no changes in VA or posterior cerebral artery (PCA) blood flow, while 13 described varying changes (reversal, complete occlusion, reduced flow). In a series of 46 patients with an accessible window for TCD and who presented with dizziness/vertigo on head movement, none exhibited any change in extracranial VA flow during head turning/extension and none had reversal of VA flow. There were also no changes in PCA flow characteristics (directionality/flow velocities) during head turning. In this series, 74% were referred to a balance clinic, where 94% noted an improvement following entry into a vestibular rehabilitation programme, presumably because of successful treatment for benign positional vertigo.

3.3.3. Open surgical management. Access to the VA is less easy than for the ICA. This is the main reason why surgery is less commonly undertaken to treat symptomatic stenoses. Surgical approaches to lesions at the VA origin include transposition to the ipsilateral CCA, VA re-implantation, vein bypass grafting from the subclavian artery. Reconstruction of the distal VA can treat stenoses or occlusions within the V2/V3 segments, but worldwide experience is limited.
A variety of techniques have been reported for reconstructing the distal VA V3 segment (from C2 to where the VA perforates the dura). These include transposition (suitable only for C1–C2 reconstructions) and bypass grafting. Transposition procedures using the ECA or occipital artery rely on the size and patency of the donor artery and are indicated if there is no suitable graft available. Graft conduits include reversed saphenous vein, prosthetic, and other autologous grafts (e.g. radial artery). The only available data available are from non-controlled studies, which are vulnerable to publication bias and selective reporting of favourable results. These have reported early complication rates of 2.5–25% for VA reconstructions, with perioperative mortality rates of 0–4% and mortality rates of 2–8% for distal artery reconstruction.

3.3.4. Endovascular treatment

3.3.4.1. Stenting vs. medical therapy. Few data are available regarding extracranial VA stenting in the early time period after onset of symptoms. A review of 600 cases of symptomatic VA stenoses (symptoms within 6 months) treated with angioplasty ± stenting stratified the stenoses according to whether they were proximally or distally located. Stenting of the proximal VA was technically successful in 99%, with a mortality of 0.3% and a periprocedural stroke rate of 1.3%. Following stenting, there was a low rate of annual recurrent stroke (0.6%), although there was a 25% restenosis rate. By contrast, stenting or angioplasty of the distal VA was associated with higher morbidity (10.6% for stenting, 7.1% for angioplasty), with mortality rates of 3.2% and 3.7%, respectively.

A systematic review, involving 1000 patients undergoing extracranial VA stenting, reported a periprocedural stroke risk of 1.1%. However, high restenosis rates (25–30%) complicated VA origin stenting. The systematic review observed that the use of drug eluting stents (DES) was associated with lower rates of restenosis compared with bare metal stents (BMS) (11% vs. 30%) after a mean follow-up of 24 months, although not all case series have shown this association. The available data suggest that interventions involving intracranial VA stenoses were associated with higher procedural risks than for extracranial lesions. However, this has to be balanced against the much higher risk of recurrent stroke for patients with intracranial VA stenoses.

There are few RCT data to guide practice. CAVATAS randomised 16 patients with symptomatic VA stenoses to angioplasty or BMT. None developed recurrent symptoms, but many patients were recruited months after their last TIA/stroke, that is well beyond the high-risk period for recurrent stroke.

The VAST study randomised 115 symptomatic patients with >50% intra- or extracranial VA stenoses. Fifty-seven were randomised to stenting and 58 to BMT. Three stented patients suffered a stroke, MI, or vascular death within 30 days of treatment, versus one in the BMT group. During a median 3-year follow-up, seven stented patients (12%) and four (7%) in the BMT group experienced a stroke in the territory of the symptomatic VA. During follow-up, there were eight “any” strokes in the stented group and seven in the BMT group. VAST was stopped prematurely because of regulatory issues and was underpowered to show any significant difference between stenting and BMT. There was no evidence of any benefit favouring stenting. It did, however, suggest that the risk of stenting for patients with intracranial VA stenoses was relatively high. This is very similar to data from the Stenting and Aggressive Medical Management for Preventing Recurrent Stroke and Intracranial Stenosis Trial (SAMMPRIS). SAMMPRIS compared stenting (Wingspan stent) against BMT in 450 patients with symptomatic intracranial stenoses, of whom 60 (13%) had stenoses of the VA or basilar arteries. Basilar artery stenoses were associated with particularly high rates of periprocedural ischaemic stroke following stenting (21% vs. 7% for other arteries).

A systematic review, involving 672 symptomatic patients in four RCTs and six non-randomised studies between 2007 and 2015, and which compared outcomes between percutaneous transluminal angioplasty (PTA) plus BMT versus BMT alone, observed no significant benefit from PTA + BMT over BMT alone (Table 28).

Not included in Feng’s meta-analysis was the Vertebral Artery Ischaemia Stenting Trial (VIST), which presented its results at the European Stroke Organisation Conference in 2016. VIST randomised 182 patients with symptomatic intra- and extracranial VA stenoses between BMT versus angioplasty with or without stenting. Almost all, however, underwent stenting. It had been hoped to recruit 540 patients, but funding was stopped because of slow recruitment. Of the 91 patients randomised to stenting, the procedure was not performed in 30 (33%). The main reason in 23 patients (77%) was the finding of a stenosis <50% on DSA at the time of the planned stenting. Selection prior to randomisation had been on the basis of CTA or MRA. Of the 61 patients in the stent group, the stenosis was extracranial in 48 (79%) and intracranial in 13 (21%). Mean follow-up was 3.5 years. The primary endpoint was any stroke during follow-up and on “intention to treat”

Table 28. 30-day and long-term outcomes in a meta-analysis of PTA + BMT versus BMT in patients with symptomatic vertebral artery stenoses.a

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>PTA + BMT</th>
<th>BMT</th>
<th>PTA + BMT</th>
<th>PTA + BMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior circulation TIA</td>
<td>16.7%</td>
<td>0.0%</td>
<td>p = .09</td>
<td>10%</td>
</tr>
<tr>
<td>Posterior circulation infarction</td>
<td>1.8%</td>
<td>1.7%</td>
<td>p = .99</td>
<td>6%</td>
</tr>
</tbody>
</table>

Data derived from Feng et al.459
analyses, this occurred in five patients (including one fatal stroke) in the stent group and in 12 patients (including two fatal strokes) in the medical group (HR 0.40, 95% CI 0.14–1.13, p = .08), which trended in favour of stenting. However, after adjusting for time from last symptom to randomisation, which was significantly shorter in the stented arm, the results became significant with a HR of 0.34 (95% CI 0.12–0.98, p = .04). As the majority of patients in VIST had extracranial stenoses, drawing firm conclusions on the benefit of stenting intracranial stenoses was not possible, but the risk of peri-procedural stroke appeared to be higher for intracranial stenoses (zero for stenting of extracranial stenoses, 2/13 [15%] following stenting of intracranial stenoses). Higher stroke risks associated with stenting of intracranial stenoses was also observed in the SAMMPRIS study.457

The fact that VIST (like VAST before it) stopped early, means that the study was inevitably underpowered to make definitive conclusions. However, while awaiting corroboration in larger RCTs, the VIST findings suggest that stenting of recently symptomatic extracranial VA stenoses may be appropriate in selected patients, especially those with recurrent symptoms, despite risk factor modification and optimal BMT.460,462

<table>
<thead>
<tr>
<th>Recommendation 113</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients with recurrent vertebrobasilar territory symptoms (despite best medical therapy) and who have a 50–99% extracranial vertebral artery stenosis may be considered for revascularisation</td>
<td>IIb</td>
<td>B</td>
<td>446,449,451,460,461</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendation 114</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>No one should have a diagnosis of “positional vertigo” attributed to nipping of the vertebral arteries on head movements, unless corroborated by computed tomodigraphic, magnetic resonance or digital subtraction angiography</td>
<td>III</td>
<td>C</td>
<td>447,448</td>
</tr>
</tbody>
</table>

3.3.4.2. Adjuvant medical therapy. Protocols regarding dual antiplatelet therapy, statins and intravenous heparin are the same as for CAS (Sections 2.3.2.2.3 and 2.3.2.3.3).

3.3.4.3. Access. Most procedures are performed via a femoral approach (93%), although transbrachial (3%) and trans-radial access (5%) have been used.462 The procedure is usually performed under LA, thereby enabling continuous neurologic monitoring.

3.3.4.4. Choice of wires, access catheters, stent design. A 5F/6F guiding catheter or long-access sheath (when working via the CFA) is navigated to a stable position in the subclavian artery. The VA ostium is cannulated and the stenotic lesion crossed with 0.014- or 0.018-inch guide wires and treated using small coronary balloons and stents. Both monorail and over-the-wire systems are available, but the former has the advantage of using standard-length wires, making catheter exchange simpler. Despite high technical success rates, VA angioplasty (alone), especially when used for the treatment of disease at the VA origin, appears to have high rates of restenosis.463

Angioplasty with stent placement seems to aid durability. Specifically designed stents for the VA are not available and coronary balloon-expandable stents are typically used because they have a low crossing profile, limited foreshortening, and easy navigation through tortuous vessels. Although self-expanding stents are more difficult to deploy as precisely as balloon-expandable stents (especially in ostial lesions), they can be reserved for extracranial VA stenting in vessels with too large a diameter for using coronary stents (>4 mm). Late stent fracture with in-stent restenosis is a problem with endoluminal therapies at the VA origin. A recent meta-analysis of non-randomised studies suggested that there was no difference between DES and BMS regarding technical success, clinical success, and peri-procedural complications in the treatment of extracranial VA stenoses. However (compared with DES), BMS-treated patients had significantly higher rates of recurrent symptoms (2.8% vs. 11.3% (OR 3.3, p = .01) and restenoses (15.5% vs. 33.6%, OR 0.38, p = .001)462 (Section 3.4.2).

3.3.4.5. Cerebral protection devices. Procedures can be performed with or without CPDs, although VAs are sometimes too small to accommodate them. One large review found distal protection was only used in 2% of cases.462

3.4. Complications after vertebral interventions

3.4.1. Complications after surgical reconstructions. Relatively few surgeons have experience of performing significant numbers of open VA reconstructions. Accordingly, the results reported from large personal series by the small number who do, may not actually represent “real world” practice. Table 29 details 30-day rates of death, stroke (including laterality), and death/stroke after proximal and/or distal VA reconstructions in the contemporary literature.

Patency rates ranged from 84% to 100% at 30 days.449,451,465–467 with one series of 352 VA reconstructions reporting early occlusion rates of 7%.449 While 30-day death/stroke rates after proximal and/or distal VA reconstructions (Table 29) were relatively low
(2–7%), there was evidence of a trend across all published series that procedural risks were significantly higher when vertebral reconstructions were combined with carotid procedures (30-day death/stroke rate 8–11%). Paralysis of the spinal accessory nerve complicated 1e13% of procedures, averaging 7%, while Horner’s syndrome (temporary or permanent) complicated 2e21% of procedures.449,465,467

### 3.4.2. Procedural risks following vertebral artery stenting.

In a review of outcomes in 20 non-randomised studies involving 1767 undergoing VA stenting, only five strokes (0.3%) were reported as occurring in the perioperative period. The rate of procedural TIA was 9/1767 (0.5%), while access complications occurred in 13 patients (0.7%) and eight procedures (0.5%) were complicated by dissection.469

In this series, perioperative stroke was extremely rare. In the absence of specific studies on the treatment of stroke after VA stenting, no specific recommendations can be made other than advising they should probably be treated in the same way as after CAS (Section 2.6.1.2).

### 3.4.3. Restenosis after vertebral artery stenting.

Risk factors for in-stent restenosis (ISR) include tortuosity of the extracranial VA, diameter of the stent,470 diabetes mellitus, smoking, small VA diameters, and long stenoses (>10 mm).471 The SSYLVIA study enrolled 61 patients, where 18 had stenoses located within the extracranial VA. SSYLVIA observed that 43% of BMS that were placed in the extracranial VA had ISR after 6 months. The proportion with ISR was considerably higher in ostial VA lesions, compared with pre-posterior inferior cerebellar artery VA lesions and intracranial lesions (67%, 25%, and 32%, respectively).445

In meta-analyses, the prevalence of >50% ISR after VA stenting varied from 0 to 45%,454,471 reflecting heterogeneity regarding study duration, type of follow-up imaging, post-procedural medical therapy, and technical factors such as stent diameter. Table 30 summarises the findings from four systematic reviews on predominantly retrospective, single-centre case studies. Eberhardt combined data from over 300 endovascular interventions for symptomatic atherosclerotic disease of extracranial VAs and reported

### Table 29. Morbidity and mortality after vertebral artery reconstructions.

<table>
<thead>
<tr>
<th>Author</th>
<th>Operation</th>
<th>n =</th>
<th>% sympt</th>
<th>Death</th>
<th>Any stroke</th>
<th>Carotid stroke</th>
<th>VB stroke</th>
<th>Death/stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habozit 1991</td>
<td>All VA ops</td>
<td>109</td>
<td>100%</td>
<td>1.8%</td>
<td>2.8%</td>
<td>0.9%</td>
<td>1.8%</td>
<td>4.6%</td>
</tr>
<tr>
<td></td>
<td>VA ops only</td>
<td>73</td>
<td>0.0%</td>
<td>1.4%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VA + carotid</td>
<td>36</td>
<td>5.5%</td>
<td>5.5%</td>
<td></td>
<td></td>
<td></td>
<td>11%</td>
</tr>
<tr>
<td>Berguer 2000</td>
<td>All VA ops</td>
<td>369</td>
<td>94%</td>
<td>2.2%</td>
<td>3.2%</td>
<td>2.2%</td>
<td>1.1%</td>
<td>3.8%</td>
</tr>
<tr>
<td></td>
<td>Prox VA ops</td>
<td>252</td>
<td>1.6%</td>
<td>2.8%</td>
<td></td>
<td>2.8%</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distal VA ops</td>
<td>117</td>
<td>3.4%</td>
<td>4.3%</td>
<td></td>
<td>0.9%</td>
<td>3.4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VA ops only</td>
<td>286</td>
<td>2.4%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VA + carotid</td>
<td>83</td>
<td>6.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kieffer 2002</td>
<td>Distal VA</td>
<td>352</td>
<td>94%</td>
<td>2.0%</td>
<td>3.4%</td>
<td>2.0%</td>
<td>1.4%</td>
<td>3.4%</td>
</tr>
<tr>
<td></td>
<td>VA ops only</td>
<td>264</td>
<td>0.4%</td>
<td>2.3%</td>
<td></td>
<td>1.1%</td>
<td>1.1%</td>
<td>2.3%</td>
</tr>
<tr>
<td></td>
<td>VA + carotid</td>
<td>88</td>
<td>6.8%</td>
<td>6.8%</td>
<td></td>
<td>3.4%</td>
<td>3.4%</td>
<td>6.8%</td>
</tr>
<tr>
<td>Hanel 2009</td>
<td>Proximal VA</td>
<td>29</td>
<td>0.0%</td>
<td></td>
<td></td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Ramirez 2012</td>
<td>All VA ops</td>
<td>74</td>
<td>82%</td>
<td>4.1%</td>
<td>4.1%</td>
<td>2.6%</td>
<td>2.6%</td>
<td>6.8%</td>
</tr>
<tr>
<td></td>
<td>VA ops only</td>
<td>39</td>
<td>2.6%</td>
<td></td>
<td></td>
<td>0.0%</td>
<td></td>
<td>5.1%</td>
</tr>
<tr>
<td></td>
<td>VA + carotid</td>
<td>35</td>
<td>5.7%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.5%</td>
</tr>
<tr>
<td>Coleman 2013</td>
<td>Distal VA ops</td>
<td>41</td>
<td>91%</td>
<td>0.0%</td>
<td>2.4%</td>
<td></td>
<td>2.4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VA ops only</td>
<td>35</td>
<td>0.0%</td>
<td>0.0%</td>
<td></td>
<td></td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>VA + carotid</td>
<td>6</td>
<td>0.0%</td>
<td>33%</td>
<td></td>
<td></td>
<td>33%</td>
<td></td>
</tr>
</tbody>
</table>

### Table 30. Meta-analyses on rates of restenosis after VA stenting.

<table>
<thead>
<tr>
<th>Author</th>
<th>Years</th>
<th>n = BMS</th>
<th>n = DES</th>
<th>Mean follow-up</th>
<th>Mean ISR %</th>
<th>ISR BMS</th>
<th>ISR DES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eberhardt 2006</td>
<td>1966–2005</td>
<td>313</td>
<td>n/a</td>
<td>12 mo</td>
<td>25.7%</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Stayman 2011</td>
<td>na</td>
<td>980</td>
<td>340</td>
<td>196</td>
<td>30%</td>
<td>11.2%</td>
<td></td>
</tr>
<tr>
<td>Antoniou 2012</td>
<td>1981–2011</td>
<td>1010</td>
<td>801</td>
<td>209</td>
<td>na</td>
<td>23%</td>
<td>na</td>
</tr>
<tr>
<td>Langwieser 2014</td>
<td>Up to 2013</td>
<td>457</td>
<td>287</td>
<td>170</td>
<td>23.7%</td>
<td>8.2%</td>
<td></td>
</tr>
<tr>
<td>Tank 2016</td>
<td>2006–2012</td>
<td>304</td>
<td>148</td>
<td>156</td>
<td>24.4%</td>
<td>33.6%</td>
<td>15.5%</td>
</tr>
</tbody>
</table>

mo = months.
that 26% had significant ISR at 12 months. Stayman combined 27 studies (980 patients) and observed that restenosis rates were lower with DES than with BMS (11.2% vs. 30%). In a more recent systematic review of 42 studies published between 1981 and 2011 (1099 patients), ISR was 23%. However, among 151 patients treated with DES, only 12% developed a significant restenosis. Langwieser analysed nine studies comparing BMS and DES. DES were associated with significantly lower rates of restenosis (8.2%), compared with BMS (23.7%, \(p = .0001\)) and significantly lower rates of symptomatic restenosis (4.7%) compared with BMS (11.6%, \(p = .005\)). In a more recent systematic review of studies published between 2006 and 2012, when compared with DES, BMS had significantly higher rates of recurrent symptoms (2.8% vs. 11.3%, \(OR = 3.32, p = .011\)) and restenoses (\(OR = 2.63, p = .001\)).

### 3.5. Surveillance strategies after vertebrobasilar reconstructions

Open revascularisation procedures for proximal VA lesions are associated with high rates of symptomatic improvement and low rates of recurrent stenoses. Hanel reported late outcomes in 29 patients undergoing proximal VA reconstructions. Only two developed recurrent symptoms attributable to vertebrobasilar insufficiency, while only one of 14 patients in surveillance developed a recurrent VA stenosis. Kakino reported no cases of restenosis on follow-up angiography and no recurrent strokes during a mean follow-up of 54 months after VA to subclavian artery transposition. Restenosis rates after endovascular treatment are detailed in Table 30.

The relationship between VA restenoses and recurrent symptoms is unclear. After VA stenting, ISR affects 11–45% of patients, while stent fracture is not uncommon and has been associated with a higher prevalence of recurrent events. The pathophysiology of stent fracture and ISR is probably mechanical irritation from the fractured struts causing smooth muscle proliferation and impaired re-endothelialisation within the proximal VA. However, in another study, three out of 12 patients developed stent fractures and all remained asymptomatic.

Although DUS can identify proximal VA stenoses, the resolution of currently available ultrasound equipment is sub-optimal for the assessment of recurrent stenoses, especially within stented vessels. Hence, unlike with recurrent stenoses after CEA/CAS, surveillance imaging after VA endovascular interventions is challenging. While DSA remains the “gold standard,” its routine use cannot be justified, especially as recurrent events after VA interventions are very low. Accordingly, for those who advocate imaging surveillance after VA interventions, DUS may be performed after VA stenting of ostial or proximal VA segments at 6 and 12 months and yearly thereafter. Any suspected lesions should be corroborated by CTA or MRA before considering catheter angiography.

<table>
<thead>
<tr>
<th>Recommendation 116</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>When extracranial vertebral artery stenting is being considered, drug eluting stents should be considered in preference to bare metal stents</td>
<td>IIa</td>
<td>C</td>
<td>462,464,473</td>
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<table>
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<th>Recommendation 117</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>Digital angiography for serial surveillance after vertebral artery interventions is not recommended</td>
<td>III</td>
<td>B</td>
<td></td>
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<table>
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<tr>
<th>Recommendation 118</th>
<th>Class</th>
<th>Level</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial non-invasive imaging of the extracranial vertebral arteries may be considered in patients who have undergone open or endovascular interventions</td>
<td>IIb</td>
<td>C</td>
<td>454,462</td>
</tr>
</tbody>
</table>

### 3.6. Unresolved issues relating to vertebral artery disease

The Writing Group identified a number of key issues relating to the investigation and management of atherosclerotic VA disease that need to be addressed to better inform future guidelines. These include:

**Is there a role for early stenting in recently symptomatic patients with extracranial VA stenoses?**

**What is the optimal way to manage a recently symptomatic patient with an intracranial VA stenosis?**

**Should all recently symptomatic patients with vertebrobasilar TIA/stroke be started on dual antiplatelet therapy once parenchymal haemorrhage has been excluded?**

**Does the location of VA stenoses in symptomatic patients influence decisions regarding intervention or medical therapy?**

**What is the optimal method of detecting VA restenosis (CEMRA or CTA) after stenting with BMS or DES?**

**How best to manage patients with >70% asymptomatic restenoses after VA stenting?**
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