BMJ Best Practice

Carotid artery stenosis

The right clinical information, right where it's needed

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Summary

- Stroke is the fifth leading cause of death, and the leading cause of disability in the UK and US. Carotid artery stenosis causes approximately 10% to 15% of all ischaemic strokes.
- Atherosclerotic plaque in the cervical carotid artery is the most common cause. Plaque disruption and atheroembolisation into the intracranial circulation is the most common mechanism for stroke.
- The majority of carotid artery stenoses are mild or moderate, and asymptomatic.
- Duplex ultrasonography is the preferred mode of diagnosis; CT or magnetic resonance angiography helps to define the anatomy if intervention is indicated.
- All patients with carotid artery stenosis should receive antiplatelet therapy, as well as risk factor modification.
- Carotid revascularisation of high-grade asymptomatic, and moderate or high-grade symptomatic, carotid artery stenosis prevents future stroke.

Definition

Carotid artery stenosis is a narrowing of the lumen of the carotid artery. Atherosclerotic plaque in the cervical carotid artery is the most common cause. The unique haemodynamics at the carotid bifurcation predisposes this area to atherosclerosis. The majority of patients have mild- or moderate-sized plaques, while some develop high-grade stenoses. A small percentage of plaques may rupture and embolise to occlude intracranial arteries (causing a transient ischaemic attack or stroke) or occlude retinal arteries (to cause amaurosis fugax or retinal strokes).

Epidemiology

Approximately 10% to 15% of all ischaemic strokes are associated with carotid artery stenosis. About one third of strokes are thromboembolic in aetiology, and atherosclerotic carotid stenosis is the most common single cause.[3]

For the northern Manhattan population, stroke attributable to carotid stenosis occurred in 17 per 100,000 (95% CI 8 to 26) black people, 9 per 100,000 (95% CI 5 to 13) Hispanic people, and 5 per 100,000 (95% CI 2 to 8) white people.[4] In a pooled study of stroke centres in Germany, carotid artery stenosis was the cause in 20.9% of stroke patients.[5] Asymptomatic carotid artery stenosis affects approximately 7% of women and 12% of men >70 years of age.[6]

Stroke is the fifth leading cause of death in the UK and US. There are approximately 152,000 strokes in the UK every year.[7] In the US, each year 610,000 patients have a new stroke, and 130,000 deaths per year are attributable to cerebrovascular disease. Stroke is also the leading cause of disability among older Americans. The Framingham study confirmed that increasing age, hypertension, diabetes mellitus, smoking, and cardiovascular diseases were risk factors for stroke.[8] [9] [10] Although there has been a 50% reduction in mortality over the past 2 decades, 21% of survivors will still have a second stroke, and 7% a third stroke.[11] At least 40% will require long-term nursing care.[12]

Aetiology

The most common cause of carotid artery stenosis is atherosclerotic plaque in the cervical carotid artery. The unique haemodynamics at the carotid bifurcation predisposes this area to atherosclerosis. A small percentage of plaques may rupture and embolise to occlude intracranial arteries (causing a transient ischaemic attack or stroke) or occlude retinal arteries (to cause amaurosis fugax or retinal strokes). Other less common causes include radiation arteritis, spontaneous or traumatic dissection, and fibromuscular dysplasia.

Pathophysiology

Histological evaluation of atherosclerotic plaques has demonstrated that they originate from fatty streaks that, over time, accumulate into a lipid core. The fatty streak becomes a fibroatheroma as fibrous tissue accumulates over the core and forms a fibrous cap. Through unknown mechanisms, some plaques become unstable resulting in an enlarging lipid core, intraplaque haemorrhage, plaque enlargement, fibrous cap rupture, ulceration, and luminal thrombosis.[13] These histomorphological features have been associated with the production of atheroemboli and neurological symptoms. Specifically, these features have frequently been observed in explanted plaque specimens obtained from symptomatic patients.

[Fig-1]

Conversely, small lipid cores located deep within the plaque with a thick fibrous cap have been observed in plaque specimens from patients with asymptomatic carotid stenosis.
[Fig-2]

Duplex ultrasound and recent advances in magnetic resonance imaging allow tissue characterisation of plaques. This has the potential for defining high-risk lesions in the future.

The unique haemodynamics at the carotid bifurcation predispose this area to atherosclerosis. Along the inner wall of the carotid bulb, blood flow remains laminar, with high velocity and high shear stress. Conversely, along the outer wall there are areas of flow separation, stasis, turbulent flow, and a complex oscillating shear stress pattern that predispose to atherosclerotic plaque deposition.[14]

Although rare neurological events have been attributed to progressive stenosis and decreased blood flow from enlarging atherosclerotic plaques, most such events are secondary to plaque rupture and atheroembolisation from the lesion. Disruption of the fibrous cap with exposure of atherosclerotic debris to the flow lumen appears to be responsible for these embolic complications. Additional factors such as adequacy of collateralisation, plaque ulceration or haemorrhage, hypotension, or a low cardiac output may also play a contributory role.

Classification

Based on symptomatic status[1] [2]

- Symptomatic: associated with atheroembolic focal neurological symptoms such as stroke, transient ischaemic attack, or amaurosis fugax
- Asymptomatic: not associated with focal neurological symptoms.

Based on aetiology[1] [2]

- Atherosclerosis
- Restenosis from neointimal hyperplasia after revascularisation
- Dissection
- Fibromuscular dysplasia.

Based on degree of stenosis[1] [2]

- Mild stenosis (<50% diameter reduction)
- Moderate stenosis (50%-69% diameter reduction)
- Haemodynamically significant or high-grade stenosis (70%-79% diameter reduction)
- Critical stenosis (80%-99% diameter reduction); a very tight and long stenosis (from the carotid bifurcation to the base of the skull) in the range of >95% is sometimes called a string sign
- Occlusion.

Primary prevention

Primary prevention of carotid atherosclerotic stenosis involves appropriate treatment of risk factors. There is good evidence to support the aggressive management of hypertension, hypercholesterolaemia, and smoking cessation to prevent carotid stenosis and stroke.[1]

Screening

Duplex ultrasonography is the preferred imaging modality for identifying patients with asymptomatic carotid stenosis when clinically indicated.[2] [19] The low prevalence of asymptomatic carotid stenosis in the general population means that indiscriminate screening of all adults does not reduce the risk of stroke, and is not recommended.[2] [20] However, patients with at least one high-risk factor should be considered for imaging. High-risk factors include patients with peripheral arterial occlusive disease, or patients ≥65 years of age with coronary artery occlusive disease, hypertension, hypercholesterolaemia, or smoking history.[2] [22]

The presence of a bruit is associated with carotid artery stenosis of any severity in 47% of patients;[18] however, a clinically high-grade stenosis (i.e., 70%-79% diameter reduction) is found in only <2% of individuals with a bruit. Therefore, indiscriminate imaging of all patients with a bruit has not generally been recommended by guidelines.[2] However, it is still considered an important clinical sign in an otherwise asymptomatic patient with risk factors for atherosclerosis, and imaging is recommended in patients with a bruit who have at least one high-risk factor.

Routine screening for coronary artery disease is not recommended preoperatively in people without symptomatic coronary artery disease.[1] A history and physical examination plus ECG (as for any preoperative workup) are needed. A history suggestive of coronary artery disease or an abnormal ECG should prompt further testing for coronary artery disease. This may involve a stress test or cardiac catheterisation.

Secondary prevention

Patients should be advised to maintain an active lifestyle with regular cardiovascular exercise.

Continued treatment of hypertension, hyperlipidaemia, and smoking cessation, as well as antiplatelet therapy, is recommended.

Case history

Case history #1

A 72-year-old man presents with sudden onset of left arm weakness and numbness. He is being treated for hypertension and diabetes, and smokes 20 cigarettes per day. He has undergone coronary artery stenting subsequent to an MI 2 years ago. He has a regular heart rhythm. Duplex ultrasonography is consistent with a >80% stenosis of the right internal carotid artery. Contrast-enhanced CT demonstrates a right frontoparietal infarction without evidence of intracranial haemorrhage.

Case history #2

A 62-year-old woman presents for a routine annual evaluation to her primary care physician. She is being treated for hypertension and diabetes. She smokes 20 cigarettes per day. She has undergone coronary artery bypass grafting subsequent to unstable angina 2 years ago. She does not recollect an episode of sensory or motor deficit or of monocular blindness. She has a regular heart rhythm with a loud systolic bruit audible over her right neck. She has no demonstrable motor or sensory deficits on physical examination. Duplex ultrasonography is consistent with a 50% stenosis of the right internal carotid artery.

Other presentations

Typically, eye symptoms from carotid atheroembolisation include amaurosis fugax (temporary loss of vision in the ipsilateral eye, typically described as a curtain or shade falling over the eye). Atypical eye symptoms include: homonymous haemianopia (resulting from emboli to optic radiation), intermittent retinal blindness (loss of vision on exposure to bright light), neovascularisation of iris (resulting from ophthalmic artery ischaemia), and, rarely, complete blindness (resulting from ischaemic optic neuropathy). Typical transient ischaemic attacks (TIAs) of temporary loss of sensory, motor, or visual function last for <15 minutes and always return to baseline within 24 hours. Alternatively, patients may have recurring attacks of TIA without an interval allowing complete recovery. The deficit is often the same with each attack and there is no deterioration in function. These symptoms are associated with a worse outcome and are referred to as crescendo TIAs. Finally, patients may also present with recurring attacks of focal neurological deficits with progressive deterioration in neurological function. This is termed a stroke in evolution and generally lasts >24 hours.

Step-by-step diagnostic approach

Carotid artery stenosis is the most common preventable cause of stroke. Because one of the major goals of management is the prevention of stroke, the identification of individuals with asymptomatic stenosis is an important objective. In the presence of neurological symptoms, the focus is on preventing a recurrent stroke or transient ischaemic attack (TIA). In view of its low cost, ready availability, and relative accuracy, carotid duplex ultrasonography has become the mainstay of screening, initial imaging, and, in some instances, is the only imaging modality utilised for the workup of carotid stenosis. Other important considerations in the diagnosis include determining the degree of stenosis and assessing the presence of ischaemic injury to the brain.

History and physical examination

Most people with carotid artery stenosis are asymptomatic. The most frequent reason for suspecting the diagnosis is the presence of atherosclerotic high-risk factors. However, even though a cervical bruit is not a sensitive or specific sign (it is associated with carotid artery stenosis of any severity in 47% of patients),[18] its presence often prompts evaluation for the condition.

High-risk factors include:[2]

- peripheral arterial occlusive disease
- age ≥65 years with coronary artery occlusive disease
- age ≥65 years with hypertension
- age ≥65 years with hypercholesterolaemia
- age ≥65 years with history of smoking.

The patient should be assessed for the presence of focal neurological deficits. The presence of deficits (e.g., sudden onset of visual loss or visual field deficit, weakness, aphasia, altered sensation, or dysarthria) lasting >24 hours indicates ischaemic stroke. Stereotypical and temporary loss of sensory, motor, or visual function that lasts for <24 hours indicates a TIA.

Patients may present with a variety of visual symptoms, such as amaurosis fugax (temporary loss of vision in the ipsilateral eye), homonymous haemianopia (decrease in visual field from emboli to the optic radiation), intermittent retinal blindness (loss of vision on exposure to bright light), neovascularisation of iris (resulting from ophthalmic artery ischaemia), and, rarely, complete blindness (resulting from ischaemic optic neuropathy).

Screening of the asymptomatic patient

Duplex ultrasonography is the preferred imaging modality for identifying patients with asymptomatic carotid stenosis.[2] [19]
[Fig-3]

The low prevalence of asymptomatic carotid stenosis in the general population means that indiscriminate screening of all adults does not reduce the risk of stroke, and it is therefore not recommended.[2] [20] However, patients with at least one high-risk factor should be considered for imaging.

The presence of a bruit is associated with carotid artery stenosis of any severity in 47% of patients;[18] however, a clinically high-grade stenosis (i.e., 70%-79% diameter reduction) is found in only <2% of individuals with a bruit.[21] Therefore, indiscriminate imaging of all patients with a bruit has not generally been recommended by guidelines.[2] However, it is still considered an important clinical sign in an otherwise asymptomatic patient with risk factors for atherosclerosis, and imaging is recommended in patients with a bruit who have at least one high-risk factor.

Investigations

Duplex ultrasonography should be ordered when carotid artery stenosis is suspected in either an asymptomatic or symptomatic patient. The most frequent reason for suspecting the diagnosis in an asymptomatic patient is the presence of atherosclerotic high-risk factors.[2] [22] Duplex ultrasonography will identify a ≥70% degree of stenosis with a sensitivity of 99%, specificity of 86%, and an overall accuracy of 95%.[23]

Once it has been established that a stenosis is present in the cervical carotid artery, the next focus is to determine the degree of stenosis. The majority of carotid stenoses are either mild (<50% diameter reduction) or moderate (50%-69% diameter reduction). Lesion severity has an important role in determination of the type of potential therapy for the patient and prognosis. Quantification is generally performed using the North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria, whereby the diameter of the arterial lumen at the tightest region of stenosis is compared with the region of the distal internal carotid artery that is free of disease and has non-tapering walls.[24] These criteria have become accepted worldwide and other criteria (e.g., the European Carotid Surgery Trial [ECST] criteria) are rarely used.

The formula used to calculate the degree of stenosis is:

Percentage stenosis = [1 - (minimum diameter/distal diameter)]×100

Ultrasonography also identifies the anatomy, status of the contralateral carotid, collateral flow, and possible differential diagnoses.[25]

In the past, the definitive test for determination of the degree of stenosis has been cervical carotid angiography;
[Fig-4]

however, non-invasive alternatives (primarily duplex ultrasonography) have largely replaced this as the preferred diagnostic test.[2] This is because catheterisation of the aortic arch and carotid artery is required, which increases the risk of atheroembolic stroke. It is generally only ordered when non-invasive tests show a suspicion of a string sign (i.e., a very tight and long stenosis, from the carotid bifurcation to the base of the skull, in the range of >95%).

When duplex ultrasonography is non-diagnostic, or more information is required on the vessels proximal or distal to the cervical carotid artery, computed tomography angiography (CTA) or magnetic resonance angiography (MRA) are appropriate alternatives.[2] These tests should be ordered when the results of duplex ultrasonography are equivocal, or fall in the moderate (50%-69% diameter reduction) stenosis range, which is at the threshold where carotid artery revascularisation may be necessary. They should also be ordered when there is a need to evaluate the arterial anatomy proximal and distal to the cervical carotid artery, or to view the aortic arch before carotid stenting. CTA is performed more commonly compared with MRA, but MRA is preferred in some institutions with specialised capability. CTA is the best modality to determine the degree of stenosis. This is important when determining whether the patient is a candidate for carotid artery stenting or carotid endarterectomy. MRA has a tendency to overestimate stenosis severity.

In symptomatic patients, appropriate assessment of ischaemic brain injury is best accomplished with MRI and/or CT.

Risk factors

Strong

older age

- Age is the single most important risk factor for stroke and also increases the risk for carotid artery stenosis.[2] For each successive 10 years after the age of 55 years, the stroke rate doubles.[15]

- Asymptomatic carotid artery stenosis affects approximately 7% of women and 12% of men >70 years of age.[6]

smoking

- Smoking is an independent predictor of carotid artery stenosis.[2] [16]
- Smokers may have a 50% increased risk for atheroembolic stroke compared with non-smokers.[8]

hx of cardiovascular disease

- The prevalence of high-grade carotid artery stenosis among patients with symptomatic peripheral vascular disease or significant coronary artery disease warranting an intervention is approximately 20%, regardless of the patient's age.[2] [17]

Weak

hx of hypertension

- High systolic blood pressure is an independent predictor of carotid artery stenosis.[2] [16]
- The age-adjusted relative risk of stroke among hypertensive patients (i.e., blood pressure >160/95 mmHg) compared with normotensive people (i.e., blood pressure <140/90 mmHg) is 3.0 in men and 2.9 in women.[9]

hx of hypercholesterolaemia

- Hypercholesterolaemia is a high-risk factor for carotid artery stenosis in patients 65 years of age or older.[2]

History & examination factors

Key diagnostic factors

asymptomatic (common)

- Many people with carotid stenosis have no signs or symptoms.
- The most frequent reason for suspecting the diagnosis is the presence of atherosclerotic high-risk factors (i.e., patients with peripheral arterial occlusive disease, or patients 65 years of age or older with coronary artery occlusive disease, hypertension, hypercholesterolaemia, or smoking history).[2] [22]

cervical bruit (uncommon)

- Not a sensitive or specific sign; however, its presence often prompts evaluation for the condition.
- Although the presence of a bruit is associated with a carotid stenosis of any severity in 47% of patients,[18] a clinically high-grade stenosis (i.e., 70%-79% diameter reduction) is found in only <2% of individuals with a bruit.[21]

focal neurological deficit lasting >24 hours (i.e., stroke) (uncommon)

- Ischaemic stroke most commonly presents with sudden onset of visual loss or visual field deficit, weakness, aphasia, altered sensation, or dysarthria.
- Carotid stenosis predisposes to watershed strokes (in border zones where cerebral blood supply is decreased).[25]

focal neurological deficit lasting <24 hours (i.e., transient ischaemic attack [TIA]) (uncommon)

- Stereotypical and temporary loss of sensory/motor/visual function. Return to baseline at the end of an attack. The deficit generally lasts for 10 to 15 minutes, but may last up to 24 hours. High-grade stenoses may also cause repetitive, very brief TIAs lasting <1 minute.[25]
- In people who have had a stroke attributable to carotid disease, a history of TIA can be elicited in at least half.[25]

Other diagnostic factors

transient visual symptoms (uncommon)

- Patients may present with a variety of visual symptoms, such as amaurosis fugax (temporary loss of vision in the ipsilateral eye), homonymous haemianopia (decrease in visual field from emboli to the optic radiation), intermittent retinal blindness (loss of vision on exposure to bright light), neovascularisation of iris (resulting from ophthalmic artery ischaemia), and, rarely, complete blindness (resulting from ischaemic optic neuropathy).

Diagnostic tests

1st test to order

Test	Result
duplex ultrasonography • Should be ordered when carotid stenosis is suspected in an asymptomatic or symptomatic patient. [Fig-3] • The most frequent reason for suspecting the diagnosis in an asymptomatic patient is the presence of atherosclerotic high-risk factors (i.e., patients with peripheral arterial occlusive disease, or patients 65 years of age or older with coronary artery occlusive disease, hypertension, hypercholesterolaemia, or smoking history).[2] [22] • Duplex ultrasonography will identify ≥70% stenosis with a sensitivity of 99%, specificity of 86%, and an overall accuracy of 95%.[23] • Quantification is generally performed using the North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria, whereby the diameter of the arterial lumen at the tightest region of stenosis is compared with the region of the distal internal carotid artery that is free of disease and has non-tapering walls.[24] These criteria have become accepted worldwide and other criteria are rarely used. • The formula used to calculate the degree of stenosis is: • Percentage stenosis = [1 - (minimum diameter/distal diameter)] ×100 • Ultrasonography also identifies the anatomy, status of the contralateral carotid, collateral flow, and possible differential diagnoses.[25]	**elevated blood flow velocities along with visualisation of details of the plaque within the carotid arteries; the velocities are translated into ranges of stenosis, generally categorised as mild (<50%), moderate (50%-69%), high-grade (70%-79%), and critical (80%-99%); a very tight and long stenosis (from the carotid bifurcation to the base of the skull) in the range of >95% is sometimes called a string sign**

Other tests to consider

Test	Result
computed tomography angiography (CTA) of head, neck, and chest • CT angiography should be ordered when results of duplex ultrasonography are equivocal, or fall in the 50%-69% stenosis range which is at the threshold where carotid artery revascularisation may be necessary. • CT angiography should also be ordered when there is a need to evaluate the arterial anatomy proximal and distal to the cervical carotid artery, or to view the aortic arch before carotid stenting. • CT angiography is non-invasive, less susceptible than magnetic resonance angiography (MRA) to overestimate the stenosis, faster and less expensive than MRA. • It requires exposure to ionising radiation, and the iodinated contrast is a hazard in patients with renal insufficiency. • The sensitivity and specificity for the diagnosis of a ≥70% stenosis is 85% and 93% respectively.[26]	**visualisation of the narrowed carotid artery lumen; expressed as a specific percent stenosis; may also visualise the atherosclerotic plaque within the arterial wall; will demonstrate the arterial anatomy proximal and distal to the cervical carotid artery**
magnetic resonance angiography (MRA) of head, neck, and chest • Less commonly performed than CTA, but preferred in some institutions with specialised capability for MRA. • Should be ordered when results of duplex ultrasonography are equivocal, or fall in the moderate (50%-69% diameter reduction) stenosis range, which is at the threshold where carotid artery revascularisation may be necessary. • Should also be ordered when there is a need to evaluate the arterial anatomy proximal and distal to the cervical carotid artery, or to view the aortic arch before carotid stenting. • Non-invasive and does not require ionising radiation. • Cannot be used in patients with ferromagnetic implants. Gadolinium-based contrast agents may not be used in renal insufficiency. • MRA has a tendency to overestimate stenosis severity. T2-weighted protocol will visualise and differentiate calcification (seen as black). • The sensitivity and specificity for the diagnosis of a ≥70% stenosis are 88% and 84%, respectively.[22]	**visualisation of the narrowed carotid artery lumen; expressed as a specific percent stenosis; will also visualise details of the atherosclerotic plaque within the arterial wall; will demonstrate the arterial anatomy proximal and distal to the cervical carotid artery**
cervical angiography • The definitive test for identifying and quantifying the degree of stenosis in the carotid artery; however, it is infrequently ordered as it is invasive (requiring catheterisation of the aortic arch and carotid artery) and carries a risk of atheroembolic stroke. [Fig-4] • Generally ordered when non-invasive tests show a suspicion of a string sign (i.e., ≥95% stenosis).	**definitively identifies and quantifies degree of stenosis**
CT brain • In symptomatic patients, appropriate assessment of ischaemic brain injury with CT is recommended. All patients with transient ischaemic attack or possible ischaemic stroke should initially undergo a CT scan of the brain to rule out intracranial haemorrhage. It is the most important test to differentiate haemorrhagic from ischaemic stroke.	**hypoattenuation (darkness) of the brain parenchyma; loss of grey matter-white matter differentiation, and sulcal effacement**

Test	Result
MRI brain • In symptomatic patients, appropriate assessment of ischaemic brain injury with MRI is recommended. It provides more accurate information about the stroke lesion compared with CT. In patients with recent stroke, special protocols can visualise changes as early as a few hours after the event.	**acute ischaemic infarct appears bright on diffusion-weighted imaging; at later stages, T2 images may also show increased signal in the ischaemic territory**

Differential diagnosis

Condition	Differentiating signs / symptoms	Differentiating tests
Carotid dissection or subintimal haematoma	• Younger age group <50 years. • Neck pain. • Associated with vigorous exercise or event that sustains severe neck movement (e.g., roller coaster ride, motor vehicle accident). • May have Horner's syndrome or history of genetic collagen abnormality.[25]	• Duplex ultrasound, computed tomography angiography (CTA), and magnetic resonance angiography may show the intimal flap and intramural thrombus. [Fig-5] [Fig-6]
Thrombotic occlusion of the carotid artery resulting from plaque rupture	• No differentiating symptoms/ signs.	• Duplex ultrasonography will show an occluded carotid artery filled with thrombus.
Fibromuscular dysplasia	• Asian ancestry. • Younger age group <50 years. • Female sex. • Evidence of additional arch vessel occlusive disease (e.g., absent radial pulses as a result of subclavian artery stenosis).	• Duplex ultrasound may show homogenous intramural lesion without calcification. • CTA may show additional occlusive lesions in the arch vessels.

Diagnostic criteria

Duplex ultrasound velocity criteria for the diagnosis and grading of stenosis severity

The test allows stratification of the degree of carotid artery stenosis on the basis of greyscale and Doppler velocity results into the following strata: normal (no stenosis), <50% stenosis, 50% to 69% stenosis, 70% to 79% stenosis, 80% to 99% stenosis, near occlusion (string sign), and total occlusion.[22] [23]

While velocity criteria have been published for additional categories of stenosis, the key purpose of defining patients with >50% stenosis is to identify symptomatic patients that may benefit from revascularisation.

North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria[24]

The diameter of the arterial lumen at the tightest region of stenosis is compared with the region of the distal internal carotid artery that is free of disease and has non-tapering walls. These criteria have become accepted worldwide and other criteria are rarely used. The formula used to calculate the degree of stenosis is:

Percentage stenosis = [1 - (minimum diameter/distal diameter)] ×100.

European Carotid Surgery Trial (ECST) criteria[27]

The diameter of the arterial lumen at the tightest region of stenosis is compared with the estimated normal lumen diameter at the site of the lesion, based on a visual impression of where the normal arterial wall was before development of the stenosis. The formula used to calculate the degree of stenosis is:

Percentage stenosis = [1 - (minimum diameter/estimated normal diameter)] ×100.

Relationship between NASCET and ECST criteria

It is critical that physicians treating carotid disease must specify which methodology was used to arrive at the estimation of stenosis. The degree of stenosis is now usually calculated according to the NASCET criteria, although the ECST criteria may also be used.[28]

The NASCET and ECST estimates of stenosis have a high degree of correlation, but are not numerically similar.[29] A 70% stenosis calculated according to the NASCET criteria corresponds to an 82% stenosis according to the ECST criteria. The NASCET method routinely provides a lower percent stenosis than the ECST method, a relationship that is best defined by the following equation:

ECST % stenosis = 0.6 (NASCET % stenosis) + 40%

Step-by-step treatment approach

Carotid artery stenosis is the most common disorder affecting the extracranial carotid artery. Management of the stenosis is a cornerstone of stroke prevention. It is one of the most intensively studied vascular diseases and debated by multiple medical specialists since the introduction of carotid endarterectomy as a therapeutic option more than half a century ago. In the last two decades, carotid artery stenting was introduced as an endovascular alternative to carotid endarterectomy, and pharmacological therapy for stroke prevention has also evolved. Several randomised controlled trials performed within the past 2 decades form the basis for current treatment recommendations involving the 3 components of therapy (pharmacological, carotid endarterectomy, and carotid artery stenting).

There are new ongoing randomised trials in the US [ClinicalTrials.gov: carotid revascularization for primary prevention of stroke (CREST-2)] and Europe [Asymptomatic Carotid Surgery Trial 2] [European Carotid Surgery Trial 2 (ECST-2)] that may update these recommendations in the coming decade, and there is ongoing research that compares medical management with revascularisation.

The treatment approach is broadly based on the clinical presentation (asymptomatic versus symptomatic) and may be further modified based on uncommon presentations or aetiologies of stenosis.

The North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria have become accepted worldwide to calculate the degree of stenosis and other criteria are rarely used. The NASCET criteria are used to define the degree of stenosis in this section.

Asymptomatic carotid artery stenosis

Pharmacotherapy is generally considered to be the first-line therapy in asymptomatic patients with <70% stenosis; however, physicians in some countries may also consider medical management in patients with ≥70% stenosis.[1] [2] [30] [31] [32] 1[B]Evidence The selection of asymptomatic patients for carotid revascularisation should be guided by the severity of stenosis, and an assessment of the patient's comorbid conditions, life expectancy, and surgeon-specific outcomes.

If medical management is selected, aspirin is the preferred antiplatelet agent. In the presence of a contraindication to aspirin, either clopidogrel or ticlopidine are reasonable alternatives. Patients on anticoagulation (e.g., warfarin) for an unrelated indication may continue on that medication with the additional goal of preventing atheroembolic stroke.[1] [28] [32] Risk factors such as cigarette smoking, hypercholesterolaemia, and hypertension must be managed according to appropriate guidelines.[1] Lifestyle modifications include increased physical activity and exercise as appropriate.[1]

If surgery is selected, antiplatelet therapy should be started preoperatively to reduce the risk of complications such as stroke and myocardial infarction. It should be initiated at diagnosis and continued indefinitely after the procedure.

As plaques within the carotid bulb enlarge and the overlying fibrin cap is eroded, ulcerations may appear over the surface. This becomes a source of atheroemboli to the retina and cerebral cortex. The majority of large ulcerations occur in association with high-grade stenoses and will warrant carotid endarterectomy on the basis of the degree of stenosis.

Asymptomatic patients with large ulcers in the presence of <50% stenosis form a therapeutic dilemma. The majority are best treated with non-operative management. Recurrent atheroembolic episodes in the

absence of any other explanation may warrant carotid endarterectomy, but the recommendation is based on weak evidence.[33] [34]

In the US, carotid artery stenting is recommended when revascularisation is indicated in patients with neck anatomy unfavourable for arterial surgery (e.g., very high lesion close to the base of the skull, radiation-induced stenosis, tracheostomy, or restenosis after a prior carotid endarterectomy).[1] [2] This approach differs in other countries. For example, in the UK stenting in asymptomatic patients is only recommended within randomised controlled trials.[35] Dual antiplatelet therapy (e.g., aspirin plus either clopidogrel or ticlopidine) is preferred in patients with stents and is used for the first 1 to 3 months, followed by aspirin alone.[25]

Symptomatic carotid artery stenosis

Symptomatic patients include those with transient ischaemic attack (TIA), stroke, and amaurosis fugax.

These patients should undergo carotid endarterectomy if the ipsilateral carotid stenosis is ≥50%.[1] [2] Rapid referral to a specialist as soon as the neurological event occurs is recommended, with early revascularisation (i.e., within 2 weeks) in patients whose neurological symptoms have stabilised.

It is reasonable to perform carotid artery stenting when revascularisation is indicated in patients with neck anatomy unfavourable for arterial surgery (e.g., very high lesion close to the base of the skull, radiation-induced stenosis, tracheostomy, or restenosis after a prior carotid endarterectomy).[1] [2]

Antiplatelet therapy should be started preoperatively to reduce the risk of complications such as stroke and myocardial infarction. It should be initiated at diagnosis and continued indefinitely after the procedure. Aspirin alone,2[B]Evidence clopidogrel alone, or the combination of aspirin plus extended-release dipyridamole 3[B]Evidence are preferred antiplatelet agents in symptomatic patients.[1] 4[A]Evidence Dual antiplatelet therapy (e.g., aspirin plus either clopidogrel or ticlopidine) is preferred in patients with stents and is used for the first 1 to 3 months, followed by aspirin alone.[25]

Risk factors such as cigarette smoking, hypercholesterolaemia,5[B]Evidence and hypertension 6[A]Evidence must be managed according to appropriate guidelines.[1] Lifestyle modifications include increased physical activity and exercise as appropriate.[1]

Concurrent carotid and coronary artery stenosis

The combination of carotid endarterectomy and coronary bypass is associated with a perioperative stroke, MI, and death rate of 9% to 12%.[36] Therefore, the combined procedure is usually recommended for patients with symptomatic carotid stenosis and critically symptomatic coronary artery disease.[37]

Asymptomatic carotid stenosis may be addressed after coronary revascularisation. Conversely, patients with symptomatic carotid stenosis and stable coronary disease may have carotid endarterectomy performed 1 to 4 weeks before coronary bypass.[1]

Routine screening for coronary artery disease is not recommended preoperatively in people without symptomatic coronary artery disease.[1] A history and physical examination plus ECG (as for any preoperative workup) are needed. Per American Heart Association recommendations, a history suggestive of coronary artery disease or an abnormal ECG should prompt further testing for coronary artery disease. This may involve a stress test or cardiac catheterisation.

Bilateral carotid artery stenosis

In asymptomatic people found to have bilateral carotid stenoses ≥70%, the higher-grade stenosis is generally addressed surgically first. In the case of equal degrees of stenosis, handedness is considered. For example, the left carotid may be surgically treated first in a right-handed person.

In symptomatic people found to have asymptomatic carotid stenosis in a contralateral carotid artery, the asymptomatic carotid stenosis is treated based on the merits of that stenosis. Generally if surgery is indicated, it might be undertaken electively 2 to 4 weeks after treatment related to the acute neurological episode. This is to allow resolution of and observation of neurological symptoms.

Relationship to any existing coronary artery disease may also need to be considered.

Antiplatelet therapy should be started preoperatively to reduce the risk of complications such as stroke and myocardial infarction. It should be initiated at diagnosis and continued indefinitely after the procedure. If the patient undergoes endarterectomy, the choice of therapy will depend on whether the patient is asymptomatic (aspirin, clopidogrel, or ticlopidine monotherapy) or symptomatic (aspirin or clopidogrel monotherapy, or aspirin plus dipyridamole). Dual antiplatelet therapy (e.g., aspirin plus either clopidogrel or ticlopidine) is recommended in patients with stents and is used for the first 1 to 3 months, followed by aspirin alone.[25]

Risk factors such as cigarette smoking, hypercholesterolaemia,5[B]Evidence and hypertension 6[A]Evidence must be managed according to appropriate guidelines.[1] Lifestyle modifications include increased physical activity and exercise as appropriate.[1]

Carotid restenosis

Recurrent high-grade stenosis after a prior carotid endarterectomy or stenting occurs infrequently (approximately 6% over 2 years).[38] Restenosis is generally a consequence of neointimal hyperplasia when it occurs within the first 2 years after surgery; and commonly due to new atherosclerotic plaque when it occurs beyond 2 years after surgery. Residual stenosis is a stenosis found within 30 days of the carotid intervention.

There is ongoing controversy regarding the optimal treatment approach for this relatively rare occurrence.[38] In many countries, medical management (i.e., aspirin, clopidogrel, or ticlopidine monotherapy) is recommended in asymptomatic patients owing to the low risk of embolic stroke associated with neointimal hyperplasia. Revascularisation is reserved for symptomatic patients. The method of revascularisation is not protocol driven and choice depends on the treating physician.

In contrast to this, in the US, the general recommendation is to perform carotid artery stenting when the stenosis reaches ≥70% (in asymptomatic patients) and ≥50% (in symptomatic patients).[2] Dual antiplatelet therapy (e.g., aspirin plus either clopidogrel or ticlopidine) is used for the first 1 to 3 months, followed by aspirin alone taken indefinitely in patients undergoing stenting.[25]

Risk factors such as cigarette smoking, hypercholesterolaemia,5[B]Evidence and hypertension 6[A]Evidence must be managed according to appropriate guidelines.[1] Lifestyle modifications include increased physical activity and exercise as appropriate.[1]

Treatment details overview

Consult your local pharmaceutical database for comprehensive drug information including contraindications, drug interactions, and alternative dosing. (see Disclaimer)

Acute (summary)

Patient group	Tx line	Treatment
asymptomatic carotid stenosis <70%	1st	antiplatelet therapy and cardiovascular risk reduction
asymptomatic carotid stenosis ≥70%	1st	antiplatelet therapy and cardiovascular risk reduction
	adjunct	carotid endarterectomy or stenting
symptomatic	1st	
▪ ipsilateral carotid stenosis ≥50%	1st	carotid endarterectomy
▪ ipsilateral carotid stenosis ≥50%	plus	antiplatelet therapy and cardiovascular risk reduction
▪ ipsilateral carotid stenosis <50%	1st	antiplatelet therapy and cardiovascular risk reduction

Ongoing (summary)

Patient group	Tx line	Treatment
bilateral carotid stenosis	1st	carotid endarterectomy or stenting based on merits of each carotid artery
	plus	antiplatelet therapy and cardiovascular risk reduction
carotid restenosis	1st	antiplatelet therapy ± revascularisation

TREATMENT

Treatment options

Acute

Patient group	Tx line	Treatment
asymptomatic carotid stenosis <70%	**1st**	**antiplatelet therapy and cardiovascular risk reduction** » Pharmacotherapy is generally considered first-line therapy in asymptomatic patients with <70% (North American Symptomatic Carotid Endarterectomy Trial [NASCET] criteria) stenosis. » In asymptomatic patients, aspirin is the preferred medication. In the presence of a contraindication to aspirin, either clopidogrel or ticlopidine are reasonable alternatives. Antiplatelet therapy is initiated at diagnosis and continued indefinitely. » Patients on anticoagulation (e.g., warfarin) for an unrelated indication may continue on that medication with the additional goal of preventing atheroembolic stroke.[1] [28] [32] » Risk factors such as cigarette smoking, hypercholesterolaemia, and hypertension must be managed according to appropriate guidelines.[1] » Lifestyle modifications include increased physical activity and exercise as appropriate.[1] » Asymptomatic patients with large ulcers in the presence of <50% (NASCET criteria) stenosis form a therapeutic dilemma. The majority are best treated with non-operative management; however recurrent atheroembolic episodes in the absence of any other explanation may warrant carotid endarterectomy, even though the recommendation is based on weak evidence.[33] [34] **Primary options** » aspirin: 75-325 mg orally once daily **OR** **Secondary options** » clopidogrel: 75 mg orally once daily **OR** **Secondary options**

Acute

Patient group	Tx line	Treatment
		» ticlopidine: 250 mg orally twice daily
asymptomatic carotid stenosis ≥70%	**1st**	**antiplatelet therapy and cardiovascular risk reduction** » There is ongoing debate about the benefits of carotid revascularisation in asymptomatic patients; therefore, physicians in some countries will consider medical management in patients with ≥70% (NASCET criteria) stenosis. » Studies demonstrate that aggressive medical management with antiplatelet therapy and cardiovascular risk reduction strategies significantly reduce the risk of atheroembolic stroke from carotid artery stenosis,[31] and an international poll of specialists conducted across several continents found that almost half of the specialists recommended medical management, while the rest recommended revascularisation.[30] » In asymptomatic patients, aspirin is the preferred medication. In the presence of a contraindication to aspirin, either clopidogrel or ticlopidine are reasonable alternatives. Antiplatelet therapy is initiated at diagnosis and continued indefinitely. » Patients on anticoagulation (e.g., warfarin) for an unrelated indication may continue on that medication with the additional goal of preventing atheroembolic stroke.[1] [28] [32] » Risk factors such as cigarette smoking, hypercholesterolaemia, and hypertension must be managed according to appropriate guidelines.[1] » Lifestyle modifications include increased physical activity and exercise as appropriate.[1] **Primary options** » aspirin: 75-325 mg orally once daily **OR** **Secondary options** » clopidogrel: 75 mg orally once daily **OR** **Secondary options**

TREATMENT

Acute

Patient group	Tx line	Treatment
		» ticlopidine: 250 mg orally twice daily
	adjunct	**carotid endarterectomy or stenting**
		» There is ongoing debate about the benefits of carotid revascularisation in asymptomatic patients. Studies demonstrate that aggressive medical management with antiplatelet therapy and cardiovascular risk reduction strategies significantly reduce the risk of atheroembolic stroke from carotid artery stenosis,[31] and an international poll of specialists conducted across several continents found that almost half of the specialists recommended medical management, while the rest recommended revascularisation.[30]
		» This equal divide in opinion is reflected in the variations seen in the approach to treatment, ranging from selective revascularisation in very healthy patients with an ulcerated or otherwise high-risk stenosis,[31] to the more liberal revascularisation performed in all patients with asymptomatic carotid stenosis ≥70% (NASCET criteria) if the risk of perioperative stroke, MI, and death is low. [1] [2] [32] 1[B]Evidence
		» If revascularisation is performed, antiplatelet therapy should be started preoperatively to reduce the risk of complications such as stroke and myocardial infarction. It should be initiated at diagnosis and continued indefinitely after the procedure. Intraoperative anticoagulation with heparin is used to help to prevent stroke as a complication.
		» Asymptomatic carotid stenosis may be addressed after coronary revascularisation. Conversely, patients with symptomatic carotid stenosis and stable coronary disease may have carotid endarterectomy performed 1 to 4 weeks before coronary bypass.[1]
		» Carotid artery stenting is recommended when revascularisation is indicated in patients with neck anatomy unfavourable for arterial surgery (e.g., very high lesion close to the base of the skull, radiation-induced stenosis, tracheostomy, or restenosis after a prior carotid endarterectomy) in the US.[1] [2] However, this approach differs in other countries. For example, in the UK stenting in asymptomatic patients is only recommended within randomised controlled trials.[35]

Acute

Patient group	Tx line	Treatment
symptomatic	**1st**	
ipsilateral carotid stenosis ≥50%	**1st**	**carotid endarterectomy** » Symptomatic patients include those with TIA, stroke, and amaurosis fugax. » Symptomatic patients should undergo carotid endarterectomy if the carotid stenosis is ≥50% (NASCET criteria).[1] [2] Rapid referral to a specialist as soon as the neurological event occurs is recommended, with early revascularisation (i.e., within 2 weeks) in patients whose neurological symptoms have stabilised. » Concomitant coronary artery disease should be considered. Patients with symptomatic carotid stenosis and stable coronary disease may have carotid endarterectomy performed 1 to 4 weeks before coronary bypass.[1] The combination of carotid endarterectomy and coronary bypass is associated with a perioperative stroke, MI, and death rate of 9% to 12%.[36] Therefore, the combined procedure is only recommended for the rare patient with concurrent symptomatic carotid stenosis and critically symptomatic coronary artery disease.[37]
ipsilateral carotid stenosis ≥50%	**plus**	**antiplatelet therapy and cardiovascular risk reduction** » Antiplatelet therapy should be started preoperatively to reduce the risk of complications such as stroke and myocardial infarction. It should be initiated at diagnosis and continued indefinitely after the procedure. Aspirin alone,2[B]Evidence clopidogrel alone, or the combination of aspirin plus extended-release dipyridamole 3[B]Evidence are the preferred medications in symptomatic patients.[1] 4[A]Evidence Antiplatelet therapy is initiated at diagnosis and continued indefinitely after carotid endarterectomy. » Risk factors such as cigarette smoking, hypercholesterolaemia,5[B]Evidence and hypertension 6[A]Evidence must be managed according to appropriate guidelines.[1] » Lifestyle modifications include increased physical activity and exercise as appropriate.[1] **Primary options** » aspirin: 75-325 mg orally once daily

TREATMENT

Acute

Patient group	Tx line	Treatment
		OR **Primary options** » clopidogrel: 75 mg orally once daily **OR** **Primary options** » aspirin/dipyridamole: 25/200 mg orally twice daily
ipsilateral carotid stenosis <50%	**1st**	**antiplatelet therapy and cardiovascular risk reduction** » Pharmacotherapy is the treatment of choice in patients with <50% (NASCET criteria) stenosis. » Aspirin alone,2[B]Evidence clopidogrel alone, or the combination of aspirin plus extended-release dipyridamole 3[B]Evidence are the preferred medications in symptomatic patients.[1] 4[A]Evidence » Risk factors such as cigarette smoking, hypercholesterolaemia,5[B]Evidence and hypertension 6[A]Evidence must be managed according to appropriate guidelines.[1] » Lifestyle modifications include increased physical activity and exercise as appropriate.[1] **Primary options** » aspirin: 75-325 mg orally once daily **OR** **Primary options** » clopidogrel: 75 mg orally once daily **OR** **Primary options** » aspirin/dipyridamole: 25/200 mg orally twice daily

Ongoing

Patient group	Tx line	Treatment
bilateral carotid stenosis	**1st**	**carotid endarterectomy or stenting based on merits of each carotid artery**

Ongoing

Patient group	Tx line	Treatment
		» In asymptomatic people found to have bilateral carotid stenoses ≥70% (NASCET criteria), the higher-grade stenosis is generally addressed surgically first. In the case of equal degrees of stenosis, handedness is considered. For example, the left carotid would usually be surgically treated first in a right-handed person. » In symptomatic people (i.e., TIA, amaurosis fugax, or stroke) found to have carotid stenosis in a contralateral carotid artery, the asymptomatic carotid stenosis is treated based on the merits of that stenosis. Generally if surgery is indicated, it might be undertaken electively 2 to 4 weeks after treatment related to the acute neurological episode. This is to allow resolution of and observation of neurological symptoms. » In the case where bilateral carotid endarterectomy is required, the evaluation of cranial nerve function (IX, X, XII) may be indicated prior to the second surgery. » Relationship to any existing coronary artery disease may also need to be considered.
	plus	**antiplatelet therapy and cardiovascular risk reduction** » Antiplatelet therapy should be started preoperatively to reduce the risk of complications such as stroke and myocardial infarction. It should be initiated at diagnosis and continued indefinitely after the procedure. If the patient undergoes endarterectomy, the choice of therapy will depend on whether the patient is asymptomatic (aspirin, clopidogrel, or ticlopidine monotherapy) or symptomatic (aspirin or clopidogrel monotherapy, or aspirin plus dipyridamole). Dual antiplatelet therapy (e.g., aspirin plus either clopidogrel or ticlopidine) is recommended in patients with stents and is used for the first 1 to 3 months, followed by aspirin alone.[25] » Risk factors such as cigarette smoking, hypercholesterolaemia,5[B]Evidence and hypertension 6[A]Evidence must be managed according to appropriate guidelines.[1] » Lifestyle modifications include increased physical activity and exercise as appropriate.[1]

Ongoing

Patient group	Tx line	Treatment
carotid restenosis	**1st**	**antiplatelet therapy ± revascularisation**

» Recurrent high-grade stenosis after a prior carotid endarterectomy or stenting occurs infrequently (approximately 6% over 2 years).[38] Restenosis is generally a consequence of neointimal hyperplasia when it occurs within the first 2 years after surgery; and commonly due to new atherosclerotic plaque when it occurs beyond 2 years after surgery. Residual stenosis is a stenosis found within 30 days of the carotid intervention.

» There is ongoing controversy regarding the optimal treatment approach for this relatively rare occurrence.[38] In many countries, medical management (i.e., aspirin, clopidogrel, or ticlopidine monotherapy) is recommended in asymptomatic patients owing to the low risk of embolic stroke associated with neointimal hyperplasia. Revascularisaton is generally reserved for symptomatic patients. The method of revascularisation is not protocol driven and choice depends on the treating physician.

» However, in the US, the general recommendation is to perform carotid artery re-stenting when the stenosis reaches ≥70% (NASCET criteria) in asymptomatic patients and ≥50% (in symptomatic patients).[2]

» Dual antiplatelet therapy (e.g., aspirin plus either clopidogrel or ticlopidine) is used for the first 1 to 3 months in patients who undergo stenting, followed by aspirin alone taken indefinitely in patients undergoing stenting.[25]

Emerging

Carotid stenosis risk prediction tool

There are several tools available that can be used to predict the risk of stroke in patients and stratify patients for specific therapies; however, none of them are prospectively validated or recommended by guidelines. One example is the carotid stenosis risk prediction tool. It is a model used for predicting the risk of ipsilateral ischaemic stroke in patients with recently symptomatic carotid bifurcation stenosis. This tool is currently considered to be a research tool. [Carotid stenosis risk prediction tool]

Recommendations

Monitoring

Patients may be followed up annually after the postoperative visits associated with revascularisation. In some countries, annual surveillance is not recommended. Clinical evaluation must include a neurological examination for development of new stroke-like symptoms. Testing must include non-invasive duplex ultrasound examination to identify potential recurrent stenosis or the development of stenosis in the contralateral carotid artery. Patients placed on pharmacological management and who have not had revascularisation should also be followed annually for possible disease progression in the form of increasing degrees of stenosis. A neurological assessment combined with duplex ultrasound is also considered appropriate.

Patient instructions

Patients should be made aware of the need for aggressive management of atherosclerosis risk factors, including hypertension, hypercholesterolaemia, and smoking cessation.

Patients should be instructed to take aspirin for the rest of their lives.

Complications

Complications	Timeframe	Likelihood
stroke after carotid endarterectomy	**short term**	**low**
The risk of stroke is generally highest within the first week of surgery and occurs in 2.3% of patients.[40] This is generally caused by thrombosis of the endarterectomy site with intracranial embolism; or by embolisation of atheromatous debris from the endarterectomised arterial surface. Intraoperative anticoagulation with heparin is the best form of prevention. If a neurological deficit is observed in the immediate postoperative period, this may be secondary to technical error. In this event, patients should be returned immediately to the operating room for re-exploration. Perioperative thromboembolic or atheroembolic strokes may prompt endovascular rescue attempts in the form of thrombectomy or thrombolysis.		
stroke after carotid artery stenting	**short term**	**low**
The risk of stroke is generally highest within the first week of surgery and occurs in 4.1% of patients.[40] This is generally caused by thrombosis of the stent with intracranial embolism; or by embolisation of atheromatous debris generated during delivery or deployment of the stent. Preoperative dual antiplatelet therapy with aspirin and clopidogrel once daily along with intraoperative anticoagulation with heparin to maintain activated clotting times of 250 to 300 milliseconds is the best form of prevention. Dual antiplatelet therapy is used for 1 to 3 months following stenting, followed by aspirin alone.[25]		

FOLLOW UP

Complications	Timeframe	Likelihood
myocardial infarction after carotid endarterectomy or stenting	**short term**	**low**
The risk of MI is 2.3% after carotid endarterectomy and 1.1% after carotid artery stenting, and is concentrated within the first few days of the procedure.[40] Preoperative antiplatelet therapy: aspirin before carotid endarterectomy, and aspirin plus clopidogrel before carotid artery stenting are the optimal methods of prevention.		
haematomas and access site bleeding	**short term**	**low**
Incisional haematomas (carotid endarterectomy) or puncture site haematomas (carotid artery stenting) are infrequent and best managed expectantly. Rarely, expansile haematomas from continued active bleeding require operative intervention and blood transfusions.		
cranial nerve injuries after carotid endarterectomy	**short term**	**low**
Injuries to the hypoglossal, vagus, and glossopharyngeal nerves have been reported after surgery. They are most commonly a result of traction; rarely from a complete transection. Most deficits will recover within 6 months of the surgery. The risk of postoperative cerebral haemorrhage and cerebral hyperperfusion syndrome is highest in the first 72 hours after revascularisation.		
cerebral hyperperfusion syndrome	**short term**	**low**
Neurological symptoms (e.g., unilateral headache, stroke, seizure) occurring within hours, or sometimes days, after carotid artery revascularisation. This is a rare complication. It is more frequently associated with revascularisation of an extremely tight stenosis and with a concomitant occlusion or tight stenosis in the opposite (contralateral) carotid artery. It is believed to occur slightly more frequently after carotid artery stenting compared with carotid endarterectomy because of the more aggressive intraprocedural anticoagulation used during carotid artery stenting. Patients often present with non-specific headaches and difficult to control hypertension postoperatively. Other symptoms include unilateral headaches, strokes, or seizures. Brain imaging may reveal cerebral oedema with or without frank haemorrhage. Severe instances may be associated with a midline shift. Management is essentially supportive and includes control of blood pressure, reduction of anticoagulation (if any is being used), head elevation, and surgical decompression in the worst instances.		
postoperative cerebral haemorrhage	**short term**	**low**

Complications	Timeframe	Likelihood
This is a rare complication of carotid artery stenting and is generally associated with the aggressive anticoagulation and antiplatelet therapy utilised during the procedure. Symptoms include unilateral headaches, seizures, or strokes. Treatment is guided by the severity of the complication and is generally supportive. It may include management of blood pressure, head elevation, and surgical decompression in severe cases.		
ischaemic stroke	**variable**	**medium**
The risk for stroke in patients with asymptomatic carotid stenosis is approximately 2% per year.[39] The risk rises if a prior transient ischaemic attack or stroke has already occurred and approaches 10% per year.[24] The aetiology is usually atherosclerotic plaque disruption and embolisation with ischaemic brain infarction. For asymptomatic stenoses <70%, optimal pharmacological therapy is the mainstay of stroke prevention, while revascularisation is reserved for high-grade stenoses ≥70%.		

Prognosis

Prognosis is related to the degree of carotid stenosis.[25] Patients with asymptomatic carotid stenosis ≤70% managed with pharmacological therapy demonstrate progression to high-grade stenosis at a generally modest rate of no more than 5% per year. Carotid artery revascularisation is effective in preventing stroke, and <1% of patients per year have a stroke after carotid endarterectomy.[39] Both carotid endarterectomy and stenting are anatomically durable procedures, and restenosis occurs in approximately 6% of patients over 2 years after either procedure.[38] Patients may be followed clinically and with a non-invasive duplex ultrasound examination on an annual basis. In some other countries, annual surveillance is not recommended.

Carotid stenosis is also a marker for atherosclerosis elsewhere in the vascular tree. Appropriate and aggressive identification and management of hypertension, hypercholesterolaemia, and smoking cessation must continue lifelong after treatment for carotid stenosis.

Diagnostic guidelines

Europe

Guidelines on the diagnosis and treatment of peripheral artery diseases

Published by: European Society of Cardiology **Last published:** 2011

Summary: Covers the diagnosis of atherosclerotic disease of extracranial carotid and vertebral, mesenteric, renal, and upper and lower extremity arteries.

North America

Screening for asymptomatic carotid artery stenosis

Published by: US Preventive Services Task Force **Last published:** 2014

Summary: This guideline provides recommendations for screening for asymptomatic carotid stenosis.

Management of extracranial carotid disease

Published by: Society for Vascular Surgery **Last published:** 2011

Summary: This guideline details major areas of emphasis including imaging of carotid stenosis and risk stratification to select patients for revascularisation.

Management of patients with extracranial carotid and vertebral artery disease

Published by: American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines; American Stroke Association; American Association of Neuroscience Nurses; American Association of Neurological Surgeons; American College of Radiology; American Society of Neuroradiology; Congress of Neurological Surgeons; Society of Atherosclerosis Imaging and Prevention; Society for Cardiovascular Angiography and Interventions; Society of Interventional Radiology; Society of NeuroInterventional Surgery; Society for Vascular Medicine; Society for Vascular Surgery **Last published:** 2011

Summary: This guideline details recommendations for the diagnosis of extracranial carotid artery stenosis.

Treatment guidelines

Europe

Guidelines on the diagnosis and treatment of peripheral artery diseases

Published by: European Society of Cardiology **Last published:** 2011

Summary: Covers the treatment of atherosclerotic disease of extracranial carotid and vertebral, mesenteric, renal, and upper and lower extremity arteries.

Europe

Invasive treatment for carotid stenosis: indications, techniques

Published by: European Society for Vascular Surgery **Last published:** 2009

Summary: Recommendations for the invasive treatment of carotid artery stenosis.

North America

Guidelines for the prevention of stroke in patients with stroke and transient ischemic attack

Published by: American Heart Association; American Stroke Association **Last published:** 2014

Summary: Evidence-based recommendations on the prevention of future stroke among survivors of ischaemic stroke or transient ischaemic attack.

Management of extracranial carotid disease

Published by: Society for Vascular Surgery **Last published:** 2011

Summary: This guideline details major areas of emphasis including medical therapy, technical standards for revascularisation, the relative roles of surgical and endovascular revascularisation, and management of unusual conditions associated with extracranial carotid pathology.

Management of patients with extracranial carotid and vertebral artery disease

Published by: American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines; American Stroke Association; American Association of Neuroscience Nurses; American Association of Neurological Surgeons; American College of Radiology; American Society of Neuroradiology; Congress of Neurological Surgeons; Society of Atherosclerosis Imaging and Prevention; Society for Cardiovascular Angiography and Interventions; Society of Interventional Radiology; Society of NeuroInterventional Surgery; Society for Vascular Medicine; Society for Vascular Surgery **Last published:** 2011

Summary: This guideline details recommendations for the management of extracranial carotid artery stenosis.

Online resources

1. ClinicalTrials.gov: carotid revascularization for primary prevention of stroke (CREST-2) *(external link)*
2. Asymptomatic Carotid Surgery Trial 2 *(external link)*
3. European Carotid Surgery Trial 2 (ECST-2) *(external link)*
4. Carotid stenosis risk prediction tool *(external link)*

Evidence scores

1. Reduction in cardiovascular events in people with asymptomatic but severe carotid artery stenosis: there is medium-quality evidence to suggest that, when compared with medical care, carotid endarterectomy may be more effective at reducing perioperative stroke, death, and subsequent ipsilateral stroke in people with asymptomatic but severe stenosis.
Evidence level B: Randomized controlled trials (RCTs) of <200 participants, methodologically flawed RCTs of >200 participants, methodologically flawed systematic reviews (SRs) or good quality observational (cohort) studies.

2. Reduction of cardiovascular events in people with a previous stroke or TIA: there is medium-quality evidence that, in comparing clopidogrel plus aspirin compared with aspirin alone, clopidogrel plus aspirin increases the rate of severe bleeding, and is no more effective at reducing the risk of a primary composite end point of MI, stroke, or cardiovascular death at 28 months in people with ischaemic stroke, TIA, clinically evident CVD, or multiple risk factors including previous stroke or TIA.
Evidence level B: Randomized controlled trials (RCTs) of <200 participants, methodologically flawed RCTs of >200 participants, methodologically flawed systematic reviews (SRs) or good quality observational (cohort) studies.

3. Reduction of cardiovascular events in people with a previous stroke or TIA: there is medium-quality evidence that, when comparing dipyridamole plus aspirin with aspirin alone, dipyridamole plus aspirin is more effective at reducing serious vascular events (stroke, MI, vascular death) in people with a previous ischaemic stroke or TIA; however, there is an increased risk of adverse effects associated with dipyridamole plus aspirin compared with aspirin alone.
Evidence level B: Randomized controlled trials (RCTs) of <200 participants, methodologically flawed RCTs of >200 participants, methodologically flawed systematic reviews (SRs) or good quality observational (cohort) studies.

4. Reduction of cardiovascular events in people with a previous stroke or TIA: there is good-quality evidence that, when compared with placebo or no antiplatelet treatment, antiplatelet treatment is more effective at reducing serious cardiovascular events (stroke, MI) in people with a previous stroke or TIA.
Evidence level A: Systematic reviews (SRs) or randomized controlled trials (RCTs) of >200 participants.

5. Reduction in cardiovascular events in people with a previous stroke: there is medium-quality evidence that, when compared with placebo, statins are more effective at reducing strokes at 4.3 to 5 years.
Evidence level B: Randomized controlled trials (RCTs) of <200 participants, methodologically flawed RCTs of >200 participants, methodologically flawed systematic reviews (SRs) or good quality observational (cohort) studies.

6. Reduction of cardiovascular events in people with a previous stroke or TIA: there is good-quality evidence that, when compared with placebo or no treatment, treatments to reduce blood pressure (i.e.,

beta-blockers, diuretics, ACE inhibitors) are more effective at 3 years at reducing stroke, MI, and total vascular events in people with a prior stroke or TIA.

Evidence level A: Systematic reviews (SRs) or randomized controlled trials (RCTs) of >200 participants.

Key articles

- Brott TG, Halperin JL, Abbara S, et al. 2011 ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS guideline on the management of patients with extracranial carotid and vertebral artery disease. Circulation. 2011;124:e54-e130. Full text Abstract
- Ricotta JJ, Aburahma A, Ascher E, et al. Updated Society for Vascular Surgery guidelines for management of extracranial carotid disease. J Vasc Surg. 2011;54:e1-e31. Full text Abstract
- North American Symptomatic Carotid Endarterectomy Trial Collaborators. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. N Engl J Med. 1991;325:445-453. Full text Abstract
- Grotta JC. Clinical practice. Carotid stenosis. N Engl J Med. 2013;369:1143-1150. Abstract

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Images

Figure 1: Ruptured plaque with intraplaque haemorrhage explanted from a patient with carotid stenosis and a recent atheroembolic stroke

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Figure 2: Stable plaque with a small deep-seated lipid core explanted from a patient with a high-grade carotid stenosis without neurological symptoms

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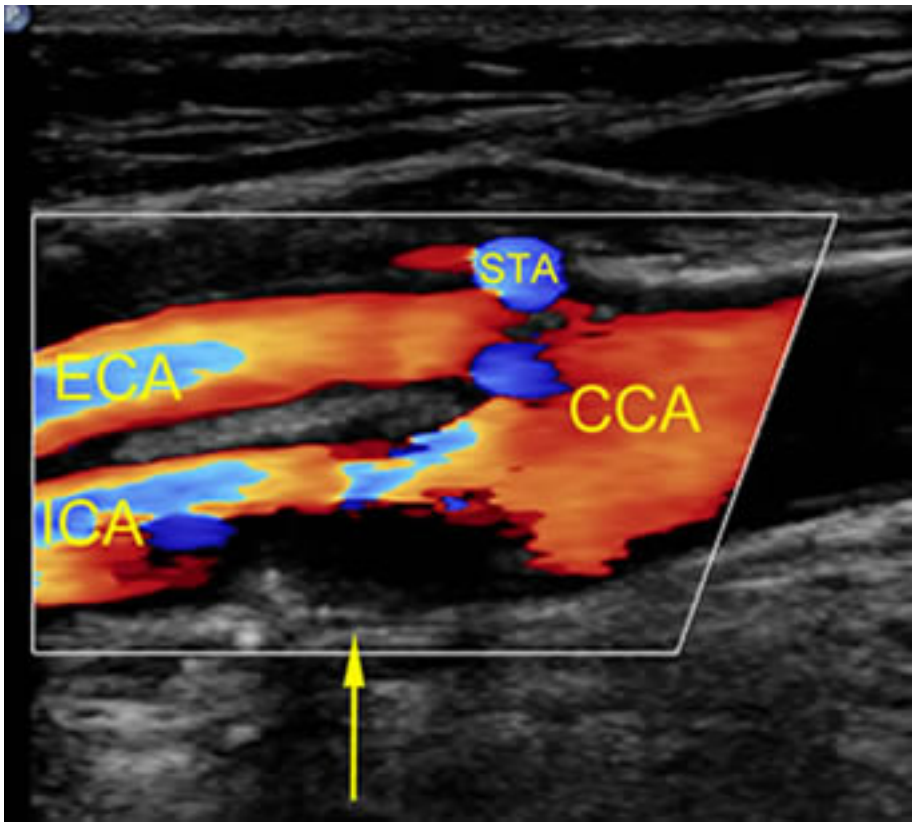

Figure 3: Echolucent internal carotid artery atheroma (yellow arrow) causing 70% stenosis (North American Symptomatic Carotid Endarterectomy Trial criteria). CCA = common carotid artery, ECA = external carotid artery, ICA = internal carotid artery, STA = superficial temporal artery

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Figure 4: Angiogram demonstrating a high-grade stenosis of the internal carotid artery

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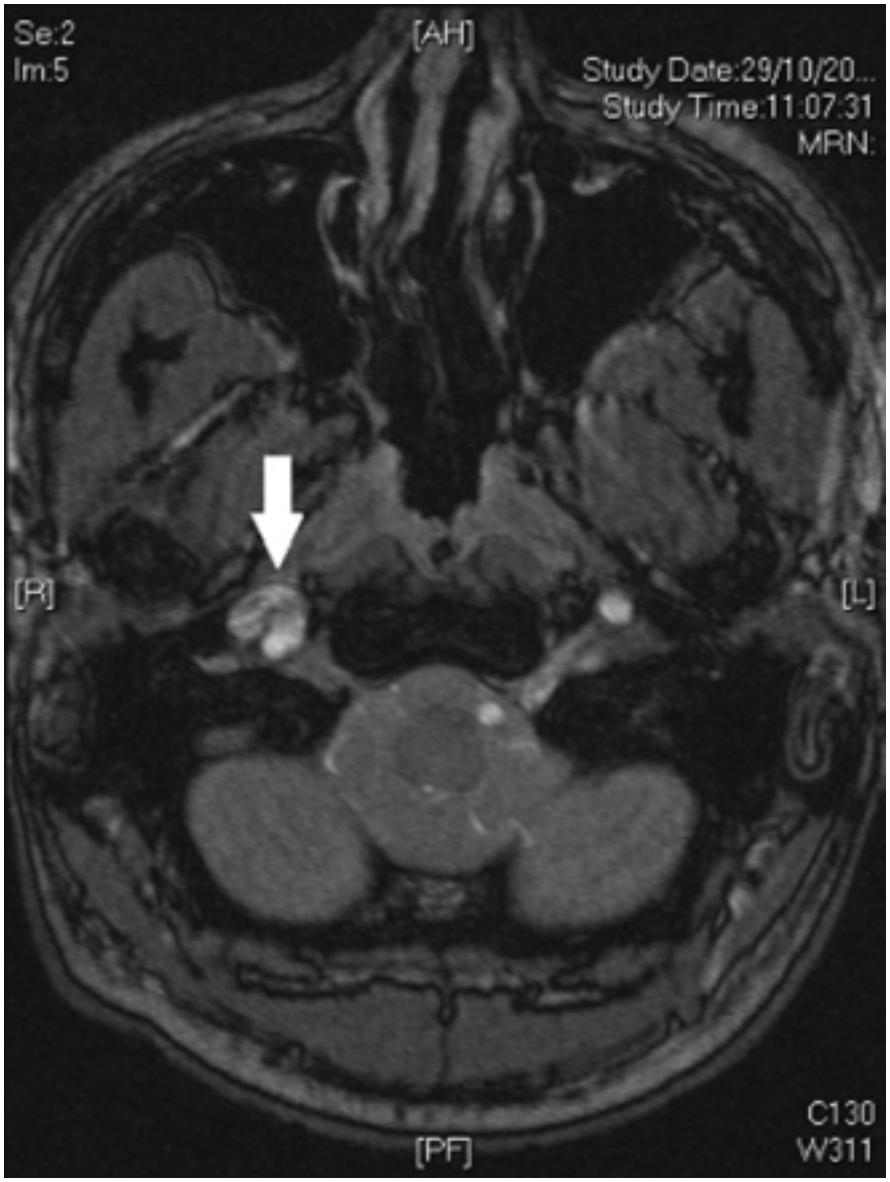

Figure 5: Magnetic resonance time of flight image of brain. The arrow shows the right carotid artery with a crescent-shaped appearance. This is consistent with intramural haematoma consequent upon dissection of the right carotid artery

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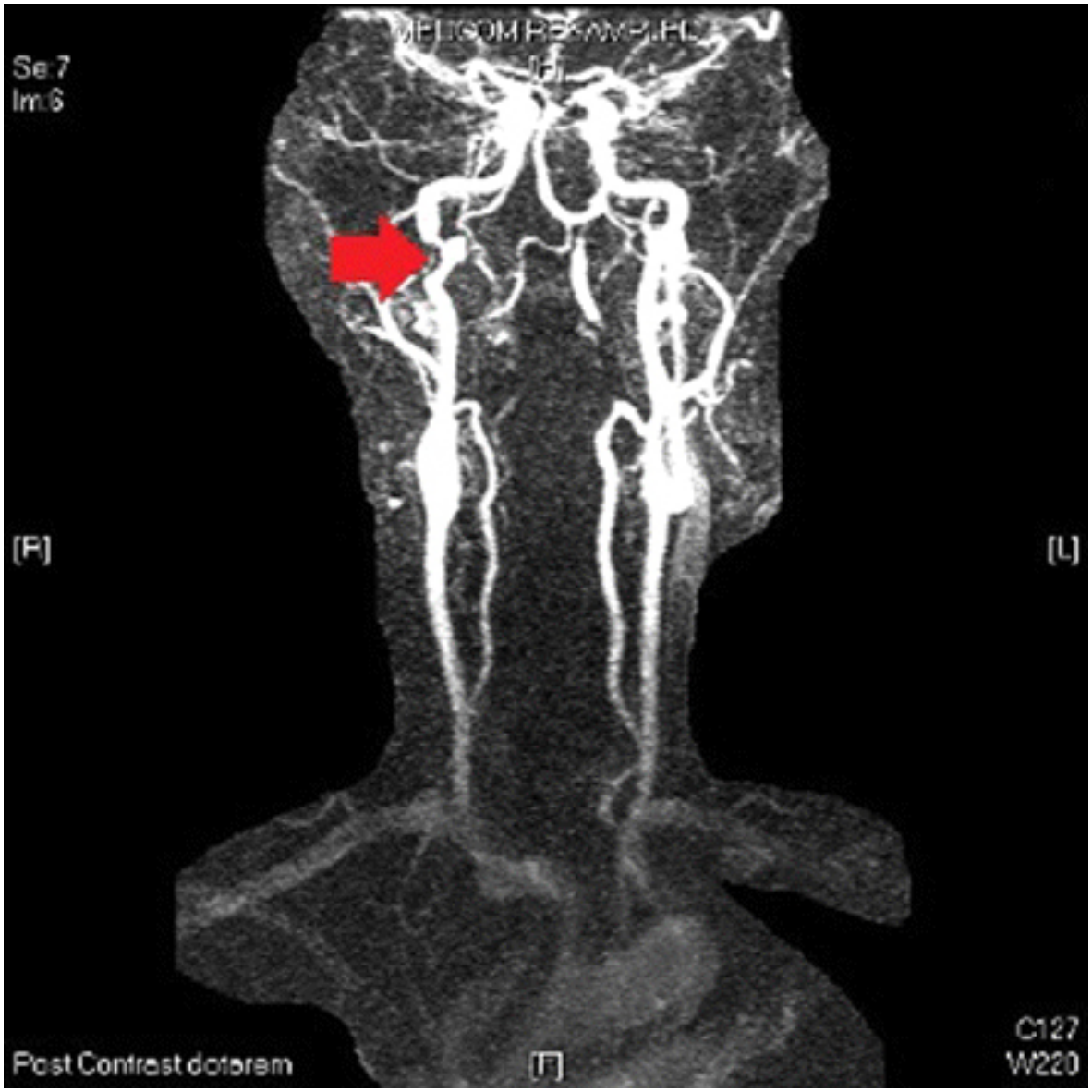

Figure 6: MRI of carotid artery. The arrow shows narrowing of the lumen of the carotid artery caused by intramural haematoma

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