Interventional procedure overview of transfemoral carotid artery stent placement for asymptomatic extracranial carotid stenosis

Contents

Table 1 Abbreviations

Abbreviation	Definition
BMT	Best medical treatment
CEA	Carotid endarterectomy
CAS	Carotid artery stenting
CI	Confidence interval
HR	Hazard ratio
HRQOL	Health-related quality of life
IQR	Interquartile range
mRS	Modified Rankin Scale
MI	Myocardial infarction
OR	Odds ratio
RR	Rate ratio
TCAR	Transcervical carotid (or transcarotid) artery revascularisation
TIA	Transient ischaemic attack

Indications and current treatment

The main arteries in the neck (the carotid arteries) can become narrowed by fatty deposits (extracranial carotid stenosis). Blood clots can form on these fatty deposits. Fragments can then detach and lodge in thinner arteries that supply blood to parts of the brain. This can cause a stroke or TIA (sometimes called a 'mini stroke'). If the carotid stenosis is not causing any health problems it is asymptomatic. It may be identified incidentally during imaging and investigations for other conditions, or during health screening.

For people with asymptomatic extracranial carotid stenosis, management includes lifestyle modification (diet, exercise, and smoking cessation) and pharmacological therapy (antithrombotics, lipid-lowering agents, blood pressure

reduction, and glycaemic control). Some people with severe stenosis may be offered revascularisation and the conventional surgical approach used is CEA. This involves making an incision in the side of the neck to access the narrowed section of artery and remove the fatty deposits. A newer alternative approach is TCAR, which uses a transcarotid neuroprotection system. The common carotid artery is accessed directly, through a smaller incision than CEA. This procedure is not being considered in this overview. NICE's interventional procedures guidance on transcervical extracorporeal reverse flow neuroprotection for reducing the risk of stroke during carotid artery stenting was published in 2016.

Unmet need

Treatment for asymptomatic carotid stenosis aims to reduce the risk of stroke. For most people, this can be achieved by medical management. People who are at higher risk of stroke may be offered revascularisation. CEA is the standard technique and involves a cut on the side of the neck. CAS is an alternative when CEA is unsuitable.

What the procedure involves

CAS is usually done under local anaesthetic. It involves passing a guidewire into the carotid artery. The common femoral artery is the usual access point. The carotid stenosis is then usually predilated using a balloon catheter. A metal mesh (stent) is inserted, which keeps the artery open to maintain blood flow and prevent restenosis and embolism.

Embolic protection devices are often used during the procedure to reduce the risk of procedural cerebral emboli.

CAS is a less invasive percutaneous alternative to CEA. Potential advantages include the avoidance of general anaesthesia and the need for a neck incision

that may result in cranial and cutaneous nerve damage. The rate of surgical complications such as myocardial infarction may also be reduced.

Outcome measures

The main outcomes included perioperative and long-term incidence of stroke, death and myocardial infarction, and the incidence of restenosis.

Modified Rankin Scale

The mRS is the most widely used outcome measure in stroke clinical trials. It is an ordinal scale that ranges from 0 (no symptoms at all) to 6 (death). A good outcome following stroke is commonly defined as a score of 0 to 2 and a poor outcome is a score of 3 to 6.

Evidence summary

Population and studies description

This interventional procedures overview is based on over 300,000 patients from 9 key studies including 1 systematic review and network meta-analysis (Gasior 2023), 2 systematic reviews (Wang 2022 and Müller 2020), 2 randomised controlled trials (Halliday 2021 and Reiff 2022), 1 prospective cohort study (Yang 2021), 2 retrospective cohort studies (Cole 2020 and Jalbert 2015) and 1 retrospective international administrative dataset (Gaba 2021). This is a rapid review of the literature, and a flow chart of the complete selection process is shown in figure 1. This overview presents 9 studies as the key evidence in table 2 and table 3, and lists 154 other relevant studies in table 5.

Studies took place in Europe (including the UK), North America, Oceania, South America, Asia and Africa. There was a higher proportion of men and the mean or median age in the studies that reported it was above 60 years.

The 2 randomised controlled trials included only asymptomatic people with carotid artery stenosis, and both had 5-year follow up. One compared CAS against CEA and random allocation was done between 2008 and 2020, with a sample size of 3,625 (Halliday 2021). It included asymptomatic people with severe unilateral or bilateral carotid artery stenosis (generally 60% or higher on ultrasound). This trial was included in the systematic reviews by Gasior et al. (2023) and Wang et al. (2022). The other trial was initially designed to have 3 arms comparing CAS, CEA and BMT. But, it was amended because of slow recruitment to 2 substudies, each with 2 arms, comparing CEA plus BMT with BMT alone and CAS plus BMT with BMT alone. It included asymptomatic people who had at least 70% (using European Carotid Surgery Trial criteria) stenosis and were 50 to 85 years old. Recruitment and survey took place between 2009 and 2019. The original planned sample size was 3,640, but the study was prematurely terminated because of low recruitment and the final sample size was 513 (Reiff 2022). The 1-year results from this trial were included in the systematic reviews by Gasior et al. (2023) and Wang et al. (2022).

The systematic review and network meta-analysis included data on asymptomatic people with carotid artery stenosis from 13 randomised controlled trials. The trials were published before November 2021 with follow-up data up to 5 years. It was designed to compare perioperative and long-term stroke and mortality risk between CEA, CAS and BMT (before and after 2000; Gasior 2023).

The systematic review by Wang et al. (2022) included data on people with asymptomatic carotid artery stenosis who had CAS or CEA. The data was from 7 randomised controlled trials published before November 2021, with follow-up data up to 10 years. It described the overall risk of bias among the included trials as low. The systematic review by Müller et al. (2020) included 22 randomised controlled trials comparing CAS with CEA, 7 of which had data on asymptomatic people. The trials were published before August 2018. It described the evidence

as high quality in general but noted that more studies are needed on the asymptomatic population.

The retrospective cohort study by Cole et al. (2020) included data on 435,627 people who had CAS or CEA for asymptomatic (70%) or symptomatic carotid artery stenosis between 2010 and 2015. People were matched based on demographics, comorbidities and severity of illness. Data on periprocedural outcomes and readmissions within 90 days was analysed.

The study by Gaba et al. (2021) included data from an international administrative dataset on 16,079 people with asymptomatic and 2,918 people with symptomatic carotid artery stenosis, who had CAS or CEA. The primary outcome was in-hospital death within 7 days.

The study by Yang et al. (2021) was a prospective cohort study of CEA or CAS in China. It included people with both asymptomatic and symptomatic carotid stenosis. Outcomes were presented separately for each group. The primary outcome was stroke, myocardial infarction or death within 1 month of the procedure.

The study by Jalbert et al. (2015) was a retrospective cohort study of Medicare beneficiaries aged at least 66 years in the US who had CAS. Approximately half were asymptomatic, 91% were at high surgical risk, and 97% had carotid stenosis of at least 70%. There was a high prevalence of ischaemic heart disease, heart failure, diabetes mellitus and peripheral artery disease in the study population. A high proportion of participants had had coronary artery bypass surgery in the past year. The main outcomes were periprocedural (30-day) and long-term risks of mortality and stroke or TIA, as well as periprocedural myocardial infarction.

Table 2 presents study details.

There were also a number of case reports of adverse events identified in the literature, which have been included in table 5.

Figure 1 Flow chart of study selection

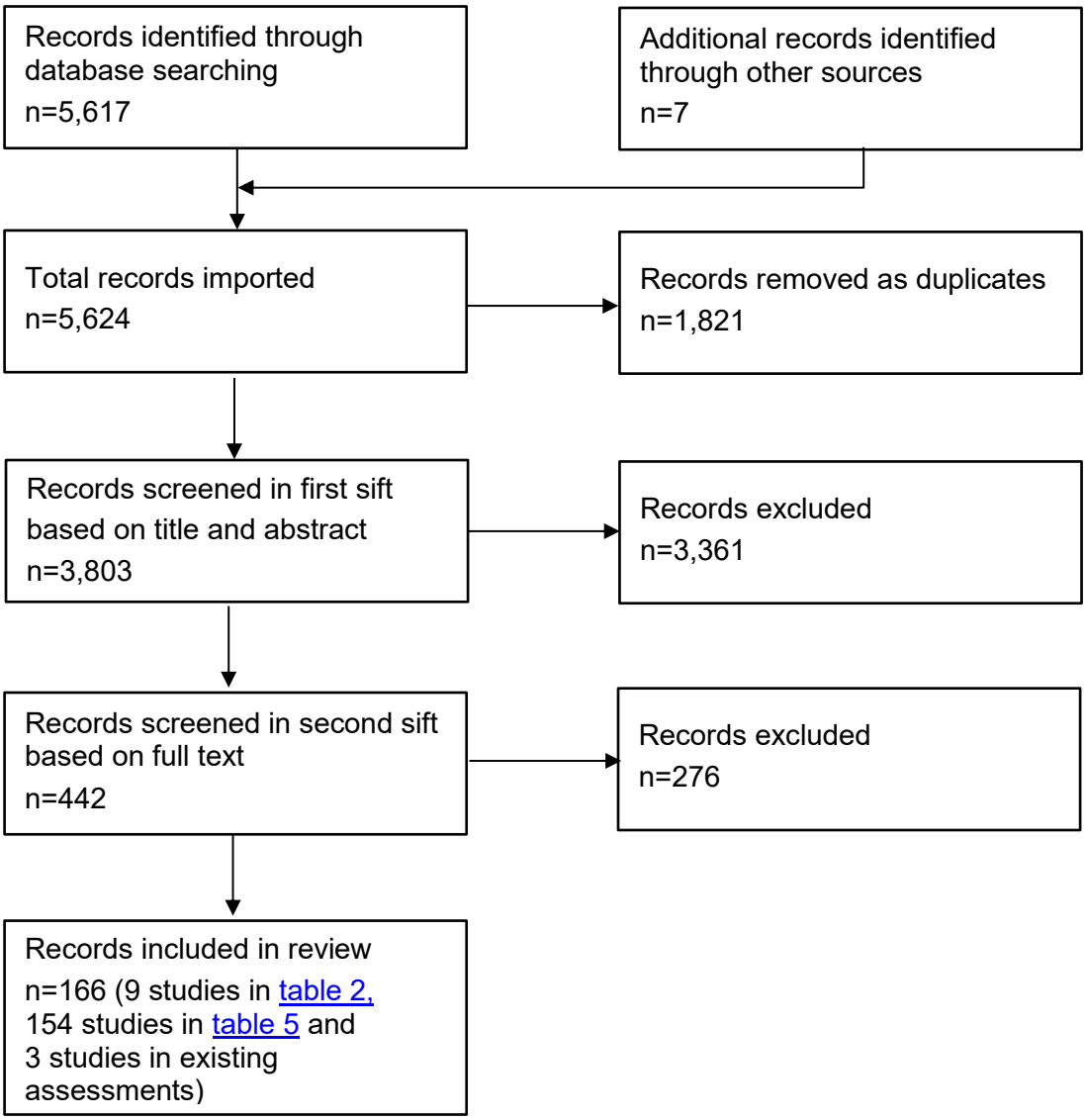

Table 2 Study details

Study no.	First author, date country	Patients (male: female)	Age	Study design	Inclusion criteria	Intervention	Follow up
1	Gasior 2023 Austria, Germany, Switzerland, US, Canada, Israel, Germany, Russia and 2 studies included 30 or more countries.	n=14,310 'The majority of patients in all reports were men'	Pooled mean 67.9 years (range 40 to 91)	Systematic review and network meta-analysis Search date: November 2021 13 randomised controlled trials (17 records)	Published randomised controlled trials comparing at least 2 modalities of intervention (CEA, CAS, and BMT alone) were included. Asymptomatic lesions were defined as image confirmed carotid stenosis 50% or more in the absence of preceding neurological symptoms, indicating a cerebrovascular event in the 6 months before study enrolment.	• CAS • CEA • BMT (traditional, which was used with recruitment dates before 2000 or modern, used for trials with recruitment dates after 2000)	Up to 5 years

Study no.	First author, date country	Patients (male: female)	Age	Study design	Inclusion criteria	Intervention	Follow up
2	Wang J, 2022 Country not reported for individual studies	n=7,117 Proportion of women was between 30% and 43%	Mean ranged from 66.6 to 70.0 years	Systematic review and meta-analysis Search date: November 2021 7 randomised controlled trials (16 articles) were included.	Only randomised controlled trials evaluating participants having CAS versus CEA in asymptomatic carotid artery stenosis patients, published in English, were included. Outcome events included any stroke (whether disabling, severe, non-disabling, or minor), death, or myocardial infarction.	• CAS (n=3,919) • CEA (n=3,198) (Note: there is some discrepancy in the total number of patients described throughout the review. The numbers cited here have been taken from the table rather than the text).	Up to 10 years
3	Müller MD, 2020 Studies were based in UK, Europe, Australia, Canada, US, China, France, Germany, Austria, Switzerland, New Zealand, Czech Republic	n=3,378 with asymptomatic carotid stenosis (5,396 people with symptomatic carotid stenosis were also included)	Overall mean not reported	Systematic review and meta-analysis (Cochrane review) Search date: August 2018 22 randomised controlled trials were identified, 7 of which	Randomised controlled trials comparing CAS with CEA for symptomatic or asymptomatic atherosclerotic carotid stenosis. In addition, randomised controlled trials	• CAS (n=2,058) • CEA (n=1,320) Any acceptable technique for CEA (such as use of a shunt or not, patching or not, local or general anaesthesia) and any acceptable endovascular	Up to 5 years

Study no.	First author, date country	Patients (male: female)	Age	Study design	Inclusion criteria	Intervention	Follow up
				included data on asymptomatic people.	comparing CAS with medical therapy alone were included. Of the 7 trials, 5 included people with asymptomatic carotid stenosis only.	technique for treatment of carotid artery stenosis (such as simple balloon angioplasty, use of a stent or not, any type of cerebral protection device) were included.	
4	Halliday A, 2021 33 countries, from Europe (including UK), North America, South America, Asia and Africa	n=3,625 (2,545:1,080)	1,802 (50%) were below 70 and 1,823 (50%) were 70 or older.	Randomised controlled trial (ACST-2; international, multicentre) Random allocation was done between 2008 and 2020.	Severe unilateral or bilateral carotid artery stenosis (generally 60% or higher on ultrasound); no relevant neurological symptoms in the preceding 6 months; CT or MRI confirmation of suitability for CAS and for CEA. Exclusion criteria included previous ipsilateral intervention, unsuitability for CAS	• CAS (n=1,811) Any CE-approved devices were allowed, and procedural double antiplatelet therapy was usual. • CEA (n=1,814) Shunting and patching were optional. Long-term medical care was to be similar in both groups and generally involved antithrombotic, antihypertensive,	Mean 4.9 years (range 0 to 12)

Study no.	First author, date country	Patients (male: female)	Age	Study design	Inclusion criteria	Intervention	Follow up
					or CEA, high procedural risk, high risk of cardiac emboli, or any major life-threatening condition. Patients likely to need other surgery could not enter the trial until at least 1 month after it.	and lipid-lowering therapy.	
5	Reiff T, 2022 Austria, Germany, Switzerland	n=513 (381:132)	Median 70 years	Randomised controlled trial (SPACE-2; multicentre) Recruitment started in 2009 and was terminated early in 2014 because of continued low recruitment.	People aged 50 to 85 years with asymptomatic carotid artery stenosis of the distal common carotid artery or the extracranial internal carotid artery of at least 70% according to European Carotid Surgery Trial criteria, or equivalent to at least 50% to 99% according to North American	• CAS plus BMT (n=197) • CEA plus BMT (n=203) • BMT alone (n=113) CAS was usually done under local anaesthetic. Routine access route was the femoral artery. Before stenting, dual antiplatelet treatment was offered for at least 3 days, and statins (if	Median 59.9 months

Study no.	First author, date country	Patients (male: female)	Age	Study design	Inclusion criteria	Intervention	Follow up
					Symptomatic Carotid Endarterectomy Trial criteria, using ultrasound criteria.	not already being taken). Dual antiplatelet therapy was continued for 4 to 6 weeks. CEA was done under either general or local anaesthetic with optional shunt use, and neurological and cardiopulmonary monitoring. Statins were started 1 week preoperatively, and antiplatelet therapy was offered for at least 3 days preoperatively. BMT comprised medication recommended by current treatment guidelines and modification of lifestyle factors.	
6	Cole T, 2020 US	n=435,627	Mean 71 years	Retrospective cohort study (matched)	Patients who had CEA or CAS for asymptomatic and	• CAS (n=57,273)	90 days

Study no.	First author, date country	Patients (male: female)	Age	Study design	Inclusion criteria	Intervention	Follow up
		70% asymptomatic 61% male			symptomatic carotid stenosis between 2010 and 2015.	• CEA (n=378,354)	
7	Gaba K, 2021 Australia, Belgium, Denmark, Finland, England, the Netherlands, and US	n=16,079 asymptomatic (2,918 symptomatic) 35% female	Median 69 years (CAS), 71 years (CEA)	International administrative dataset (retrospective)	All people who had CEA or CAS between 2011 and 2015. They were defined as symptomatic if they had had a stroke, TIA, or amaurosis fugax in the 6 months before CEA or CAS. If they had not, they were deemed asymptomatic.	• CAS (n=2,777 asymptomatic and symptomatic) • CEA (n=16,220 asymptomatic and symptomatic)	7 days
8	Yang B, 2021 China	n=1,645 asymptomatic 83% male	Mean 65.9 years (CAS), 64.3 (CEA), p<0.001	Prospective multicentre cohort study 2013 to 2016	Age 18 years or over, symptomatic or asymptomatic internal carotid artery stenosis with degree of stenosis 50% or more (moderate to severe stenosis) as assessed by CT angiography or	• CAS (n=887) • CEA (n=758) The choice of embolic protection devices and stents, dilation strategy and balloon size were left to the discretion of the physician.	1 month

Study no.	First author, date country	Patients (male: female)	Age	Study design	Inclusion criteria	Intervention	Follow up
					digital subtraction angiography. Patients with a TIA or stroke within 6 months were defined as symptomatic.		
9	Jalbert J, 2015 US	n=22,516 (11,839 asymptomatic) 61% male	Mean 76 years	Cohort study	Fee-for-service Medicare beneficiaries at least 66 years old undergoing CAS with embolic protection and continuously enrolled in Medicare for at least 1 year. 97% of participants had at least 70% carotid artery stenosis.	• CAS	Mean 747 days (for mortality)

Table 3 Study outcomes (results are for asymptomatic people unless otherwise stated)

First author, date	Efficacy outcomes	Safety outcomes
Gasior S, 2023	**Long-term stroke (13 trials, n=11,693)** When compared with combined BMT, both CEA (OR 0.35, 95% CI 0.21 to 0.59) and CAS	**Perioperative stroke (6 trials, n=6,855)**

First author, date	Efficacy outcomes	Safety outcomes
	(OR 0.51, 95% CI 0.26 to 0.98) significantly reduced the odds of a minor stroke occurring up to 5 years. GRADE assessment established a high degree of certainty that CEA resulted in 20 fewer minor stroke events per 1,000 patients (95% CI -0.03 to -0.01) than modern BMT. CAS resulted in 10 fewer minor stroke events per 1,000 patients (95% CI -0.02 to 0.0) than modern BMT. CEA (OR 0.27, 95% CI 0.19 to 0.39) and CAS (OR 0.37, 95% CI 0.22 to 0.62) also reduced the odds of an ipsilateral stroke occurring up to 5 years versus combined BMT alone, a finding consistent with the use of BMT before and after 2000. **Long-term mortality (9 trials, n=11,101)** With a moderate level of certainty, the results demonstrated that no treatment was significantly superior in reducing the odds of mortality from 30 days to 5 years.	CEA reduced the odds of all stroke events occurring within 30 days perioperatively compared with CAS (OR 1.6, 95% CI 1.1 to 2.2). CEA specifically reduced the odds of a minor perioperative stroke (OR 1.7, 95% CI 1.1 to 2.6) but did not affect the odds of a major stroke event occurring (OR 0.89, 95% CI 0.33 to 2.3.) Neither intervention reduced the odds of contralateral perioperative stroke or ipsilateral stroke event (OR 1.7, 95% CI 0.96 to 3.1) GRADE assessment=moderate degree of confidence **Perioperative mortality (6 trials, n=6,855)** Neither procedure was favoured to reduce the odds of 30 day perioperative mortality. **Perioperative myocardial infarction (6 trials, n=855)** There was moderate certainty that CAS reduced the odds of perioperative myocardial infarction compared with CEA (OR 0.49, 95% CI 0.26 to 0.91). However, the risk difference was 0 fewer cases per 1,000 (95% CI 0 to -0.01). **Cranial nerve injury (5 trials, n=5,360)** CAS reduced the odds of cranial nerve injury compared with CEA (OR 0.07, 95% CI 0.01 to 0.42). There was moderate certainty that the risk difference was 40 fewer per 1,000 (95% CI 0 to -0.07). Only 1 randomised controlled trial reported a cranial nerve injury following CAS.

First author, date	Efficacy outcomes	Safety outcomes
Wang J, 2022	**Long-term outcomes of composite outcome among any perioperative stroke, death, or myocardial infarction and long-term stroke, death, or myocardial infarction** • CAS=9.8% (309/3,141) • CEA=10.9% (264/2,423) OR=1.18 (95% CI 0.94 to 1.48), p=0.14, I^2=0% (4 studies)	**30 days outcome of composite endpoint including stroke, death and myocardial infarction** • CAS=3.5% (137/3,920) • CEA=3.2% (102/3,198) OR=1.13 (95% CI 0.87 to 1.47), p=0.37, I^2=0% (7 studies) **30 days outcome of any stroke** • CAS=3.0% (112/3,735) • CEA=1.9% (58/3,010) OR=1.62 (95% CI 1.17 to 2.25), p=0.004, I^2=0% (5 studies) **30 days outcome of non-disabling strokes** • CAS=2.5% (88/3,562) • CEA=1.4% (40/2,833) OR=1.81 (95% CI 1.23 to 2.65), p=0.003, I^2=0% (4 studies) **30 days outcome of disabling strokes and death** • CAS=0.7% (24/3,494) • CEA=0.8% (22/2,765) OR=0.91 (95% CI 0.50 to 1.65), p=0.76, I^2=0% (3 studies)

First author, date	Efficacy outcomes	Safety outcomes
Müller MD, 2020	**Death or any stroke between randomisation and 30 days after treatment or ipsilateral stroke until end of follow up** • CAS=45 per 1,000 (95% CI 31 to 63) • CEA=36 per 1,000 OR=1.27 (95% CI 0.87 to 1.84); n=3,315, 6 studies, p=0.22, I^2=0%; moderate-certainty evidence **Severe (70% or more) restenosis during follow up (in people with asymptomatic or symptomatic carotid artery stenosis)** • CAS=67 per 1,000 (95% CI 43 to 103) • CEA=56 per 1,000 OR=1.21 (95% CI 0.76 to 1.93); n=5,744, 9 studies, p=0.42, I^2=61.4%; low-certainty evidence **Moderate or severe (50% or more) restenosis during follow up (in people with asymptomatic or symptomatic carotid artery stenosis)** • CAS=30.3% (309/1,019) • CEA=21.1% (231/1,096) OR=2.00 (95% CI 1.12 to 3.6); n=2,115, 4 studies, p=0.02, I^2=43.6%	**Death or any stroke between randomisation and 30 days after treatment** • CAS=25 per 1,000 (95% CI 14 to 42) • CEA=14 per 1,000 OR=1.72 (95% CI 1.00 to 2.97); n=3,378, 7 studies, p=0.05, I^2=0%; moderate-certainty evidence **Death or major or disabling stroke between randomisation and 30 days after treatment** • CAS=5 per 1,000 (95% CI 1 to 19) • CEA=3 per 1,000 OR=1.54 (95% CI 0.39 to 6.11); n=2,601, 2 studies, p=0.54, I^2=0%; moderate-certainty evidence **Myocardial infarction between randomisation and 30 days after treatment** • CAS=0.65% (12/1,844) • CEA=1.45% (16/1,102) OR=0.53 (95% CI 0.24 to 1.15); n=2,601, 6 studies, p=0.11, I^2=0% **Death or any stroke or myocardial infarction between randomisation and 30 days after treatment** • CAS=32 per 1,000 (95% CI 20 to 50) • CEA=28 per 1,000 OR=1.16 (95% CI 0.73 to 1.85); n=2,978, 6 studies, p=0.8, I^2=0%; moderate-certainty evidence

First author, date	Efficacy outcomes	Safety outcomes
		Cranial nerve palsy • CAS=0.1% (2/1,823) • CEA=3.3% (36/1,092) OR=0.09 (95% CI 0.03 to 0.27); n=2,915, 5 studies, p<0.0001, I^2=0% **Access site haematoma (needing surgery, blood transfusion, or prolonging hospital stay, where severity was defined)** • CAS=0.2% (3/1,726) • CEA=1.5% (15/993) OR=0.14 (95% CI 0.02 to 0.9); n=2,719, 3 studies, p=0.04, I^2=34.7%
Halliday A, 2021	**Any non-procedural stroke during follow up** • CAS=5.2% (91/1,748) • CEA=4.5% (79/1,767) RR 1.16 (95% CI 0.86 to 1.57), p=0.33 **Fatal non-procedural stroke (mRS score 6) during follow up** • CAS=0.9% (16/1,748) • CEA=1.1% (20/1,767) **Disabling non-procedural stroke (mRS score 3 to 5) during follow up**	**Myocardial infarction within 30 days of procedure** • CAS=0.3% (5/1,705; none were fatal) • CEA=0.7% (12/1,736; 4 were fatal), p=0.15 **Any stroke within 30 days of procedure** • CAS=3.6% (61/1,705) • CEA=2.4% (41/1,736), p=0.06 **Fatal stroke within 30 days of procedure** • CAS=0.4% (7/1,705) • CEA=0.3% (5/1,736), p=0.77

First author, date	Efficacy outcomes	Safety outcomes
	• CAS=1.6% (28/1,748) • CEA=1.4% (25/1,767) **Non-disabling non-procedural stroke (mRS score 0 to 2) during follow up** • CAS=2.7% (47/1,748) • CEA=1.9% (34/1,767)	**Non-disabling stroke (mRS score 0 to 2) within 30 days of procedure** • CAS=2.7% (48/1,705) • CEA=1.6% (29/1,736), p=0.03 **Death or disabling stroke within 30 days of procedure** • CAS=0.9% (15/1,705) • CEA=1.0% (18/1,736), p=0.77 **Death, myocardial infarction or any stroke within 30 days of procedure** • CAS=3.9% (67/1,705) • CEA=3.2% (55/1,736), p=0.26 **Cranial nerve palsy within 30 days of procedure** • CAS=0% (0/1,653) • CEA=5.4% (96/1,788)
Reiff T, 2022	**Cumulative incidence of any stroke or death from any cause within 30 days or any ipsilateral ischaemic stroke within 5 years (primary endpoint):** • CAS plus BMT=4.4% (95% CI 2.2 to 8.6) • CEA plus BMT=2.5% (95% CI 1.0 to 5.8) • BMT alone=3.1% (95% CI 1.0 to 9.4)	**Stroke within 30 days of procedure** • CAS=2.5% (5/197; all ipsilateral, 1 was disabling) • CEA=2.5% (5/203; 4 ipsilateral, 1 contralateral and disabling) There were no deaths within 30 days of the procedure.

First author, date	Efficacy outcomes	Safety outcomes

	The difference between treatment groups was not statistically significant (p=0.62).
	
	There were 3 strokes in the CAS group after 30 days (all ipsilateral) and none in the CEA group.
	
	The first primary endpoint event in the BMT group was on day 153 after randomisation (ipsilateral, disabling stroke), with another 2 ipsilateral events (1 disabling) in the 5-year follow-up period.
	Cox proportional-hazard testing
	• CAS plus BMT versus BMT alone: HR 1.55, 95% CI 0.41 to 5.85, p=0.52
	• CEA plus BMT versus BMT alone: HR 0.93, 95% CI 0.22 to 3.91, p=0.93
	• CAS versus CEA: HR 1.66, 95% CI 0.54 to 5.08, p=0.37
	
	5-year cumulative incidence of ipsilateral ischaemic stroke
	• CAS plus BMT=4.4% (95% CI 2.2 to 8.6)
	• CEA plus BMT=2.0% (95% CI 0.7 to 5.2)
	• BMT alone=3.1% (95% CI 1.0 to 9.4)
	Cox proportional-hazard testing
	• CAS plus BMT versus BMT alone: HR 1.55, 95% CI 0.41 to 5.85, p=0.52
		Serious adverse events reported over the 5-year follow-up period
		• CAS, n=289; CEA, n=243; BMT, n=151
		
		Type of serious event (proportion of total events in each treatment group)
		• Cardiovascular events
		  ○ CAS=42% (120/289)
		  ○ CEA=44% (106/243)
		  ○ BMT=50% (75/151)
		• Nervous system and sensory events
		  ○ CAS=17% (49/289)
		  ○ CEA=10% (25/243)
		  ○ BMT=15% (23/151)
		• Musculoskeletal events
		  ○ CAS=11% (32/289)
		  ○ CEA=7% (18/243)
		  ○ BMT=9% (14/151)
		• Urogenital events
		  ○ CAS=6% (17/289)
		  ○ CEA=10% (24/243)
		  ○ BMT=6% (9/151)
		• Digestive events
		  ○ CAS=5% (15/289)
		  ○ CEA=8% (20/243)
		  ○ BMT=7% (10/151)

First author, date	Efficacy outcomes	Safety outcomes

	• CEA plus BMT versus BMT alone: HR 0.74, 95% CI 0.17 to 3.32, p=0.70
	• CAS versus CEA: HR 2.09, 95% CI 0.63 to 6.92, p=0.23
	
	5-year cumulative incidence of any ischaemic or haemorrhagic stroke
	• CAS plus BMT=9.8% (95% CI 6.2 to 15.3)
	• CEA plus BMT=5.3% (95% CI 2.9 to 9.6)
	• BMT alone=6.5% (95% CI 2.9 to 13.9)
	Cox proportional-hazard testing
	• CAS plus BMT versus BMT alone: HR 1.66, 95% CI 0.65 to 4.20, p=0.29
	• CEA plus BMT versus BMT alone: HR 0.93, 95% CI 0.34 to 2.57, p=0.89
	• CAS versus CEA: HR 1.78, 95% CI 0.81 to 3.88, p=0.15
	5-year cumulative all-cause mortality
	• CAS plus BMT=9.3% (95% CI 5.7 to 15.0)
	• CEA plus BMT=7.6% (95% CI 4.5 to 12.8)
	• BMT alone=8.0% (95% CI 4.1 to 15.4)
	Cox proportional-hazard testing
	• CAS plus BMT versus BMT alone: HR 1.05, 95% CI 0.45 to 2.48, p=0.91
	• CEA plus BMT versus BMT alone: HR 0.87, 95% CI 0.36 to 2.11, p=0.76
		• Respiratory events
		  ○ CAS=6% (16/289)
		  ○ CEA=5% (13/243)
		  ○ BMT=6% (9/151)
		• Endocrinopathies, nutritional events, and metabolic events
		  ○ CAS=3% (8/289)
		  ○ CEA=1% (3/243)
		  ○ BMT=2% (3/151)
		• Haematological events
		  ○ CAS=1% (4/289)
		  ○ CEA=4% (9/243)
		  ○ BMT=1% (1/151)
		• Skin events
		  ○ CAS=2% (7/289)
		  ○ CEA=2% (4/243)
		  ○ BMT=1% (1/151)
		• Psychiatric events
		  ○ CAS<1% (1/289)
		  ○ CEA=2% (4/243)
		  ○ BMT=0% (0/151)
		• Allergic events
		  ○ CAS=0% (0/289)
		  ○ CEA<1% (1/243)
		  ○ BMT=0% (0/151)
		• Other events

First author, date	Efficacy outcomes	Safety outcomes
	• CAS versus CEA: HR 1.21, 95% CI 0.57 to 2.53, p=0.62 **Restenosis of at least 70%** • CAS=10.2% (95% CI 6.6 to 15.8) • CEA=3.2% (95% CI 1.5 to 7.1) HR 3.19, 95% CI 1.27 to 8.04, p=0.0138	○ CAS=7% (20/289) ○ CEA=7% (16/243) ○ BMT=4% (6/151) Two intracranial haemorrhages were reported, 1 in the CAS plus BMT group (431 days after randomisation) and a fatal event in the BMT alone group that happened 402 days after randomisation. Three hyperperfusion syndromes were reported in the CAS plus BMT group, 1 with cerebral infarction, but none of these led to permanent disability.
Cole T, 2020	**Length of hospital stay (midnights)** • CAS=1.9 • CEA=2.3, p<0.001 **Transfer to a skilled nursing or intermediate care facility** • CAS=2.9% • CEA=2.6%, p<0.001 **Discharge with home health care** • CAS=8.1% • CEA=4.8%, p<0.001	**Periprocedural stroke** • CAS=0.2% • CEA=0.3%, p=0.113 **Periprocedural myocardial infarction** • CAS=0.8% • CEA=1.2%, OR 1.58 (95% CI 1.27 to 1.97) **In-hospital mortality** There was no difference between the groups regarding in-hospital mortality difference, in asymptomatic patients. **Readmission within 30 days** On multivariate analysis, female sex (OR 1.18, 95% CI 1.10 to 1.26, p<0.001) and symptomatic status (OR 1.21, 95% CI 1.11 to 1.33, p<0.001) were associated with a higher risk of readmission within 30 days.
Gaba K, 2021	No efficacy data was reported.	**7-day in-hospital mortality**

First author, date	Efficacy outcomes	Safety outcomes
		• CAS=0.7% (18/2,470), 95% CI 0.4 to 1.1 • CEA=0.1% (21/14,102), 95% CI 0.1 to 0.2 **Length of stay more than 2 days** • CAS=27.5% (601/2,187), 95% CI 25.6 to 29.4 • CEA=28.5% (2,864/10,039), 95% CI 27.7 to 29.4 **Head CT within 2 days of procedure** • CAS=3.2% (71/2,187), 95% CI 2.5 to 4.0 • CEA=2.1% (207/10,039), 95% CI 1.8 to 2.3
Yang B, 2021	No efficacy data was reported.	**Stroke, myocardial infarction, or death within 1 month of procedure (primary outcome):** • CAS=4.7% (42/887), 95% CI 3.5 to 6.3 • CEA=4.9% (37/758), 95% CI 3.5 to 6.6, p=0.890 **Stroke within 1 month of procedure:** • CAS=4.1% (36/887), 95% CI 2.9 to 5.5 • CEA=3.3% (25/758), 95% CI 2.2 to 4.8, p=0.416 **Ischaemic stroke within 1 month of procedure:** • CAS=2.9% (26/887), 95% CI 2.0 to 4.2 • CEA=2.0% (15/758), 95% CI 1.2 to 3.2, p=0.217 **Haemorrhagic stroke within 1 month of procedure:**

First author, date	Efficacy outcomes	Safety outcomes
		• CAS=1.1% (10/887), 95% CI 0.6 to 2.0 • CEA=1.3% (10/758), 95% CI 0.7 to 2.3, p=0.723 **Death within 1 month of procedure:** • CAS=0.7% (6/887), 95% CI 0.3 to 1.4 • CEA=0.5% (4/758), 95% CI 0.5 to 1.2, p=0.699 **Myocardial infarction within 1 month of procedure:** • CAS=0.5% (4/887), 95% CI 0.2 to 1.1 • CEA=1.3% (10/758), 95% CI 0.7 to 2.3, p=0.056 **Other complications within 1 month of procedure (including cranial nerve injury, incision haematoma, and pulmonary infection):** • CAS=2.6% (23/887), 95% CI 1.7 to 3.8 • CEA=3.6% (27/758), 95% CI 2.4 to 5.1, p=0.254
Jalbert J, 2015	**All asymptomatic participants (n=11,839)** • Unadjusted risk of mortality after periprocedural period=27.7% (95% CI 26.4 to 28.9) • Unadjusted risk of stroke or TIA after periprocedural period=7.2% (95% CI 6.5 to 7.9) **National Coverage Determination Indication of asymptomatic carotid stenosis 80% or above (n=9,851)**	**All asymptomatic participants (n=11,839)** • Unadjusted risk of mortality during periprocedural period=1.0% (95% CI (0.9 to 1.2) • Unadjusted risk of stroke or TIA during periprocedural period=2.3% (95% CI 2.1 to 2.6) • Unadjusted risk of myocardial infarction during periprocedural period=2.2% (95% 2.0 to 2.5) **National Coverage Determination Indication of asymptomatic carotid stenosis 80% or above (n=9,851)**

First author, date	Efficacy outcomes	Safety outcomes
	• Unadjusted risk of mortality after periprocedural period=29.4% (95% CI 27.9 to 30.9) • Unadjusted risk of stroke or TIA after periprocedural period=7.3% (95% CI 6.5 to 8.2)	• Unadjusted risk of mortality during periprocedural period=1.2% (95% CI 0.9 to 1.4) • Unadjusted risk of stroke or TIA during periprocedural period=2.3% (95% CI 2.0 to 2.6) • Unadjusted risk of myocardial infarction during periprocedural period=2.4% (95% 2.1 to 2.7)

Procedure technique

Most studies did not describe the CAS procedure in detail. There are different stents and different cerebral protection devices available, and table 5 includes a number of studies that investigate different aspects of the technique. These include proximal balloon occlusion compared with distal filter protection, closed-cell stents compared with open-cell stents, and dual-layer stents compared with conventional stents.

Efficacy

Non-procedural stroke

Stroke during follow up beyond 30 days was reported as an outcome in 3 studies. In the network meta-analysis of 14,310 people, there was a statistically significant lower odds of a minor stroke occurring up to 5 years after the procedure when CAS was compared with BMT (OR 0.51, 95% CI 0.26 to 0.98; n=11,693, 13 trials). The odds of an ipsilateral stroke were also reduced (OR 0.37, 95% 0.22 to 0.62; Gasior 2023). In the randomised controlled trial of 3,625 people comparing CAS with CEA, the rate of non-procedural stroke during follow up was the same in both groups (5% [91/1,748 and 79/1,767]; RR 1.16, 95% CI 0.86 to 1.57, p=0.33). The rate of fatal non-procedural stroke (mRS score 6) was 1% in both groups (16/1,748 for CAS and 20/1,767 for CEA). The rate of disabling non-procedural stroke (mRS 3 to 5) was 1.6% (28/1,748) for those who had CAS and 1.4% (25/1,767) for those who had CEA. For non-disabling non-procedural stroke (mRS 0 to 2) the rate was 2.7% (47/1,748) in the CAS group and 1.9% (34/1,767) in the CEA group (p value not reported; Halliday 2021).

Mortality

Mortality during follow up beyond 30 days was reported as an outcome in 3 studies. In the network meta-analysis of 14,310 people, comparing CAS, CEA

and BMT, no treatment was statistically significantly superior in reducing the odds of mortality from 30 days to 5 years (n=11,101; 9 trials; Gasior 2023). In the randomised controlled trial of 513 people, 5-year cumulative all-cause mortality was 9% in those who had CAS plus BMT (95% CI 6% to 15%), 8% in those who had CEA plus BMT (95% CI 5% to 13%) and 8% in those who had BMT alone (95% CI 4% to 15%; Reiff 2022). In the cohort study of 22,516 people (11,839 asymptomatic), the risk of mortality after the periprocedural period was 28% (95% CI 26% to 29%; Jalbert 2015).

Composite outcomes of stroke, death and myocardial infarction

Composite outcomes were reported in 3 studies, all of which showed similar rates for CAS and CEA within the studies. In the systematic review of 7,117 people, long-term outcomes of any perioperative stroke, death or myocardial infarction and long-term stroke, death or myocardial infarction was 10% for CAS (309/3,141) and 11% for CEA (264/2,423), OR 1.18 (95% CI 0.94 to 1.48, p=0.14, I^2=0%, 4 studies; Wang 2022). In the systematic review of 3,378 people with asymptomatic carotid artery stenosis, the rate of death or any stroke between randomisation and 30 days after treatment or ipsilateral stroke until the end of follow up was 45 per 1,000 in those who had CAS and 36 per 1,000 in those who had CEA (OR 1.27, 95% CI 0.87 to 1.84, p=0.22, I^2=0%, n=3,315, 6 studies, moderate-certainty evidence).

In the randomised controlled trial of 513 people, the cumulative incidence of any stroke or death from any cause within 30 days or any ipsilateral stroke within 5 years was 4% for CAS plus BMT (95% CI 2 to 9), 3% for CEA plus BMT (95% CI 1 to 6) and 3% for BMT alone (95% CI 1 to 9), p=0.62 (Reiff 2022).

Restenosis

Restenosis was reported as an outcome in 2 studies. In the systematic review by Müller et al. (2020), severe restenosis (70% or more) during follow up in people

with asymptomatic or symptomatic carotid artery stenosis was 67 per 1,000 (95% CI 43 to 103) for CAS and 56 per 1,000 for CEA (OR 1.21, 95% CI 0.76 to 1.93; n=5,744, 9 studies, p=0.42, I^2=61%, low-certainty evidence). The rates of moderate or severe restenosis (50% or more) were 30% (309/1,019) for CAS and 21% (231/1,096) for CEA (OR 2.00, 95% CI 1.12 to 3.6, n=2,115, 4 studies, p=0.02, I^2=44%). In the randomised controlled trial of 513 people by Reiff et al. (2022), restenosis of at least 70% within 5 years was 10% in the group who had CAS (95% CI 7 to 16) and 3% in the group who had CEA (95% CI 2 to 7), HR=3.2 (95% CI 1.3 to 8.0, p=0.014).

Safety

Stroke within 30 days of procedure

Periprocedural stroke was reported as an outcome in 7 studies. Several studies showed a statistically significant increased risk in periprocedural non-disabling stroke associated with CAS when compared with CEA. In the network meta-analysis by Gasior et al. (2023), CEA reduced the odds of all stroke events within 30 days of the procedure compared with CAS (OR 1.6, 95% CI 1.1 to 2.2). It specifically reduced the odds of a minor perioperative stroke (OR 1.7, 95% CI 1.1 to 2.6) but did not affect the odds of a major stroke event (OR 0.89, 95% CI 0.3 to 2.3).

In the systematic review by Wang et al. (2022), the rate of any stroke within 30 days was 3% (112/3,735) for CAS and 2% (58/3,010) for CEA (OR 1.62, 95% CI 1.17 to 2.25, p=0.004, I^2=0%; 5 studies). For non-disabling stroke, the rate was 3% (88/3,562) for CAS and 1% (40/2,833) for CEA (OR 1.81, 95% CI 1.23 to 2.65, p=0.003, I^2=0%; 4 studies).

In the randomised controlled trial by Halliday et al. (2021), the rate of any stroke within 30 days was 4% (61/1,705) for CAS and 2% (41/1,736) for CEA, p=0.06.

The rate of fatal stroke was less than 1% in both groups (7/1,705 and 5/1,736, p=0.77). The rate of non-disabling stroke (mRS 0 to 2) was 3% (48/1,705) for CAS and 2% (29/1,736) for CEA, p=0.03. In the randomised controlled trial by Reiff et al. (2022), there was a similar rate of stroke within 30 days for CAS (3% [5/197]) and CEA (3% [5/203]).

In the retrospective cohort study by Cole et al. (2020), the rate of periprocedural stroke was similar for CAS (0.2%) and CEA (0.3%), p=0.113. In the prospective cohort study by Yang et al. (2021), the rates of stroke within 1 month of the procedure were also similar for CAS (4% [36/887]) and CEA (3% [25/758]), p=0.416. In the retrospective cohort study by Jalbert et al. (2015), the risk of stroke or TIA within the periprocedural period was 2% (95% CI 2 to 3).

Mortality within 30 days of procedure

Perioperative mortality was reported as an outcome in 6 studies. In the network meta-analysis by Gasior et al. (2023), neither procedure was favoured to reduce the odds of 30-day mortality (6 trials, n=6,855).

In the randomised controlled trial by Reiff et al. (2022), there were no deaths within 30 days of the procedure.

In the retrospective cohort study by Cole et al. (2020), there was no difference between CAS and CEA regarding in-hospital mortality. In the retrospective dataset by Gaba et al. (2021), 7-day in-hospital mortality was 1% (18/2,470) for CAS (95% CI 0.4 to 1) and less than 1% (21/14,102) for CEA (95% CI 0.1 to 0.2). In the prospective cohort study by Yang et al. (2021), mortality within 1 month of the procedure was 1% for both CAS (6/887) and CEA (4/758), p=0.699. In the retrospective cohort study by Jalbert et al. (2015), the risk of mortality after CAS during the periprocedural period was also 1% (95% CI 0.9 to 1.2).

Perioperative myocardial infarction

Perioperative myocardial infarction was reported as an outcome in 5 studies.

In the systematic review by Müller et al. (2020), the rate of myocardial infarction between randomisation and 30 days after treatment was 1% for CAS (12/1,844) and 2% for CEA (16/1,102), OR 0.53 (95% CI 0.24 to 1.15, n=2,601, 6 studies, p=0.11, I^2=0%).

In the randomised controlled trial by Halliday et al. (2021), the rates of myocardial infarction within 30 days of the procedure were less than 1% for CAS (5/1,705) and 1% for CEA (12/1,736), p=0.15.

In the retrospective cohort study by Cole et al. (2020), the rate of periprocedural myocardial infarction was 0.8% for CAS and 1.2% for CEA (OR 1.58, 95% CI 1.27 to 1.97). In the prospective cohort study by Yang et al. (2021), myocardial infarction within 1 month of the procedure was 0.5% for CAS (4/887) and 1% for CEA (10/758), p=0.056. In the retrospective cohort study by Jalbert et al. (2015), the risk of myocardial infarction after CAS during the periprocedural period was 2% (95% CI 2.0 to 2.5).

Composite outcome of periprocedural death, stroke and myocardial infarction

A composite outcome for periprocedural death, stroke and myocardial infarction was reported by 4 studies.

In the systematic review by Wang et al. (2022), the 30-day outcome for stroke, death and myocardial infarction was 4% (137/3,920) for CAS and 3% (102/3,198) for CEA (OR 1.13, 95% CI 0.87 to 1.47, p=0.37, I^2=0%; 7 studies). The 30-day outcome for disabling stroke and death was 1% in each group (24/3,494 for CAS and 22/2,765 for CEA), OR 0.91 (95% CI 0.50 to 1.65, p=0.76, I^2=0%; 3 studies).

In the systematic review by Müller et al. (2020), the rate of death or any stroke

between randomisation and 30 days after treatment was 25 per 1,000 for CAS and 14 per 1,000 for CEA (OR 1.72, 95% CI 1.00 to 2.97, p=0.05, I^2=0%, n=3,378; 7 studies; moderate-certainty evidence). The rate of death or major or disabling stroke between randomisation and 30 days after treatment was 5 per 1,000 for CAS and 3 per 1,000 for CEA (OR 1.54, 95% CI 0.39 to 6.11, p=0.54, I^2=0%, n=2,601; 2 studies; moderate-certainty evidence). The rate of death or any stroke or myocardial infarction between randomisation and 30 days after treatment was 32 per 1,000 for CAS and 28 per 1,000 for CEA (OR 1.16, 95% CI 0.73 to 1.85, p=0.8, I^2=0%, n=2,978; 6 studies; moderate-certainty evidence).

In the randomised controlled trial by Halliday et al. (2021), the rate of death or disabling stroke within 30 days of the procedure was 1% in both groups (p=0.77). The rate of death, myocardial infarction or any stroke was 4% (67/1,705) for CAS and 3% (55/1,736) for CEA (p=0.26).

In the prospective cohort study by Yang et al. (2021), stroke, myocardial infarction or death within 1 month of the procedure was 5% for both CAS (42/887) and CEA (37/758), p=0.89.

Cranial nerve injury

Cranial nerve injury was reported as an outcome in 3 studies, all of which showed a reduced risk associated with CAS compared with CEA.

In the network meta-analysis by Gasior et al. (2023), CAS reduced the odds of cranial nerve injury compared with CEA (OR 0.07, 95% CI 0.01 to 0.42). In the systematic review by Müller et al. (2020), the rate of cranial nerve injury was less than 1% (2/1,823) after CAS and 3% (36/1,092) after CEA (OR 0.09, 95% CI 0.03 to 0.27, p<0.0001, n=2,915, I^2=0%; 5 studies).

In the randomised controlled trial by Halliday et al. (2021), the rate of cranial nerve palsy within 30 days of the procedure was 0% (0/1,653) after CAS and 5% (96/1,788) after CEA (p value not reported).

Access site haematoma

Access site haematoma was reported as an outcome in 1 study. In the systematic review by Müller et al. (2020), the rate of access site haematoma (needing surgery, blood transfusion or prolonged hospital stay, where severity was determined) was less than 1% (3/1,726) after CAS and 2% (15/993) after CEA (OR 0.14, 95% CI 0.02 to 0.9, p=0.04, I^2=35%, n=2,719; 3 studies).

Intracranial haemorrhage

Intracranial haemorrhage was reported as an outcome in 1 study. In the randomised controlled trial by Reiff et al. (2022), there was 1 report of intracranial haemorrhage in the CAS plus BMT group that happened 431 days after randomisation.

Hyperperfusion syndrome

Hyperperfusion syndrome was reported as an outcome in 1 study. In the randomised controlled trial by Reiff et al. (2022), there were 3 reports of hyperperfusion syndrome in the CAS plus BMT group, 1 with cerebral infarction. None of them led to permanent disability.

Other

A number of case reports describing adverse events associated with CAS are listed among the studies in table 5. These include acute hemifacial ischaemia, postoperative dislocation of stent, flushing, dyspnoea and palpitations, iliac artery injury, dislodged stent delivery sheath, stent shortening, retinal artery occlusion, massive non-aneurysmal subarachnoid haemorrhage, carotid free-floating thrombus, pseudoaneurysm, and late thrombosis.

Anecdotal and theoretical adverse events

Expert advice was sought from consultants who have been nominated or ratified by their professional society or royal college. They were asked if they knew of any other adverse events for this procedure that they had heard about (anecdotal), which were not reported in the literature. They were also asked if they thought there were other adverse events that might possibly occur, even if they had never happened (theoretical).

They listed the following adverse events that were not categorised as anecdotal or theoretical:

- access complications (bleeding, limb ischaemia)
- coronary complications, including bradycardia
- vascular injury
- occlusion of the carotid artery
- in-stent stenosis
- reperfusion bleed
- contrast reaction
- hypotension caused by vasovagal stimulation
- vasospasm
- protection device complications
- increased risk of new white matter lesions on brain DW MRI, of uncertain clinical consequence
- issues with stent deployment, filter wire insertion and removal.

Six professional expert questionnaires for this procedure were submitted. Find full details of what the professional experts said about the procedure in the specialist advice questionnaires for this procedure.

Validity and generalisability

- There is a large body of evidence, including data from the UK.
- There were 2 recent randomised controlled trials identified that focused on people with asymptomatic carotid artery stenosis.
- One randomised controlled trial that was designed to compare CAS and CEA against BMT was stopped prematurely because of low recruitment and funding restrictions. This led to a much smaller sample size than planned, which limits the validity of the results. The authors noted that the study design was complex and that structural reasons may have contributed to the low recruitment.
- The patient population of the randomised controlled trials is likely to differ from real-life clinical practice and BMT is likely to be implemented more consistently. The expertise of the centre and strict patient selection criteria may lead to lower complication rates than would be expected outside a trial.
- Mortality was considerably lower in the randomised controlled trial by Reiff et al. (2022) than the cohort study by Jalbert et al. (2015). The authors noted that some of this could be attributed to sufficient implementation of BMT targets, a lower proportion of high-risk patients and the selection of participants with a life expectancy of at least 5 years.
- The systematic reviews include follow-up data up to 10 years.
- There is a lot of variation in procedure technique for CAS, including different kinds of stent and different embolic protection devices.
- There may be variations in the definition of asymptomatic between studies.
- BMT has improved over time, which has reduced the risk of stroke in this population. Older trials are therefore less generalisable than those that recruited people more recently. Some of the trials included in the systematic reviews enrolled participants in the early 2000s. It is likely that technical

developments in CEA and CAS have also led to improvements, lowering the periprocedural risks.

- Trials included in the systematic reviews differed in assessment and definitions of myocardial infarction. Definition of stroke may also differ between studies.
- Of the 9 studies included in the key evidence, 5 declared no conflicts of interest. Cole et al. (2020) declared that 1 author was a consultant for several companies and had stock in GT Medical Technologies, none of which were related to the topic. Wang et al. (2022) declared that 1 author was a consultant for Medtronic, MicroVention Inc, and Penumbra Inc. Jalbert et al. (2015) declared that 1 author was a non-compensated adviser to Abbott Vascular, Boston Scientific, Cordis Corporation, Covidien Vascular, and Medtronic Vascular; and was a board member at VIVA Physicians, a not-for-profit education and research consortium; 1 author was a paid consultant to Optum Insight Epidemiology and World Health Information Science Consultants, LLC; 1 author was being supported by the pharmacoepidemiology program at the Harvard School of Public Health, funded by Pfizer and Asisa; 1 author was being supported by a midcareer development award grant from the Agency for Healthcare Research and Quality, US Department of Health and Human Services and was also receiving research support from Johnson & Johnson and personal income for consulting from Sanofi; and 1 author had made available online a detailed listing of financial disclosures (http://www.dcri.duke.edu/about-us/conflict-of-interest/).
- Ongoing studies
  - NCT04900844: Safety and Efficacy of the CGuard™ Carotid Stent System in Carotid Artery Stenting (C-Guardians); single-arm pivotal study; US; n=315; estimated study completion date Oct 2025

- NCT03121209: Carotid Revascularization and Medical Management for Asymptomatic Carotid Stenosis Trial - Hemodynamics (CREST-H); prospective observational study; US & Canada; n=500; estimated study completion date March 2027

- NCT02089217: Carotid Revascularization and Medical Management for Asymptomatic Carotid Stenosis Trial (CREST-2); 2 parallel multi-center randomized controlled trials; US, Canada, Australia, Israel & Spain; n=2,480; estimated study completion date February 2026

- NCT04271033: MicroNet-covered Stent System for Stroke Prevention in All Comer Carotid Revascularization (PARADIGM-EXT); single-arm registry; Poland; n=550; estimated study completion date June 2026

Existing assessments of this procedure

The US Society for Vascular Surgery published an implementation document for the management of extracranial cerebrovascular disease in 2022 (AbuRahma et al.). This included the following recommendations:

- 'For neurologically symptomatic patients with stenosis less than 50% or asymptomatic patients with stenosis less than 60% diameter reduction, optimal medical therapy is indicated. There are no data to support transfemoral CAS, TCAR, or CEA in this patient group.

- Neurologically asymptomatic patients with a 70% or greater diameter stenosis should be considered for CEA, TCAR, or transfemoral CAS for reduction of long-term risk of stroke, provided the patient has a 3- to 5-year life expectancy and perioperative stroke/death rates can be 3% or less. Perhaps future models to help estimate life expectancy based on calculating various physiologic comorbidities such as cardiac, pulmonary,

renal, malignancy, will be available in the future. The determination for which technique to use should be based on the presence or absence of high risk criteria for CEA, TCAR, or transfemoral CAS.

- Neurologically asymptomatic patients deemed high risk for CEA, TCAR, and transfemoral CAS should be considered for primary medical management. Intervention can be considered in these patients only with evidence that perioperative morbidity and mortality is less than 3%. CAS should not be performed in these patients except as part of an ongoing clinical trial.

- There are insufficient data to recommend transfemoral CAS as primary therapy for neurologically asymptomatic patients with 70% to 99% diameter stenosis. Data from CREST, ACT, and the VQI suggest that in properly selected asymptomatic patients, CAS may be equivalent to CEA in the hands of experienced interventionalists. Operators and institutions performing CAS must exhibit expertise sufficient to meet the previously established AHA [American Heart Association] guidelines for treatment of patients with asymptomatic carotid stenosis. Specifically, the combined stroke and death rate must be less than 3% to ensure benefit for the patient.'

The European Society for Vascular Surgery published clinical practice guidelines on the management of atherosclerotic carotid and vertebral artery disease in 2023 (Naylor et al.). It included the following recommendations relevant to CAS for asymptomatic extracranial carotid stenosis:

- 'Multidisciplinary team review is recommended to reach consensus decisions regarding the indications for, and treatment of, patients with

carotid stenosis regarding carotid endarterectomy, carotid stenting or optimal medical therapy (Class 1, Level C)

- For average-surgical-risk patients with an asymptomatic 60-99% stenosis, carotid endarterectomy should be considered in the presence of one or more imaging or clinical characteristics that may be associated with an increased risk of late stroke, provided 30 day stroke/death rates are less than or equal to 3% and patient life expectancy exceeds 5 years (Class 2a, Level B).

- For average-surgical-risk patients with an asymptomatic 60-99% stenosis in the presence of one or more imaging or clinical characteristics that may be associated with an increased risk of late stroke, carotid stenting may be an alternative to carotid endarterectomy, provided 30 day stroke/death rates are less than or equal to 3% and patient life expectancy exceeds 5 years (Class 2b, Level B).

- For asymptomatic patients 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/clinical characteristics that may be associated with an increased risk of late stroke on best medical therapy, carotid stenting may be considered provided anatomy is favourable, 30 day death/stroke rates are less than or equal to 3% and patient life expectancy exceeds 5 years (Class 2b, Level B.

- For patients with a 70% to 99% asymptomatic carotid stenosis, carotid interventions are not recommended for the prevention of cognitive impairment until a causal association between severe asymptomatic carotid stenoses and cognitive decline has been established (Class 3, Level B).'

The European Stroke Organisation published a guideline on endarterectomy and stenting for carotid artery stenosis in 2021 (Bonati et al.). This included the following expert consensus statements on carotid artery stent placement for asymptomatic carotid stenosis:

- '12/12 experts concluded that in patients with asymptomatic carotid stenosis in whom revascularisation is considered to be appropriate and who are less suitable for surgery, stenting may be suggested. We recommend careful consideration of the risks and benefits at a multidisciplinary team meeting.

- 12/12 experts concluded that the independently assessed risk of in-hospital stroke or death following endarterectomy or stenting for asymptomatic carotid stenosis should be as low as possible, ideally below 2%.'

This guideline was prepared before the results of the Asymptomatic Carotid Surgery Trial-2 (ACST-2) had been published. The authors noted that this study would considerably increase the evidence base and may lead to updates in the recommendations.

Related NICE guidance

Interventional procedures

- NICE interventional procedures guidance on carotid artery stent placement for symptomatic extracranial carotid stenosis (recommendation: normal [standard] arrangements)
- NICE interventional procedures guidance on transcervical extracorporeal reverse flow neuroprotection for reducing the risk of stroke during carotid artery stenting (recommendation: standard arrangements)

Professional societies

- The Vascular Society for Great Britain and Ireland
- British Society of Interventional Radiology
- UK Neurointervention Group
- British Society of Neuroradiologists
- British and Irish Association of Stroke Physicians
- Royal College of Radiologists.

Evidence from patients and patient organisations

NICE received 1 questionnaire from a patient who had the procedure (or their carers).

The patient's views on the procedure were consistent with the published evidence and the opinions of the professional experts.

Company engagement

NICE asked companies who manufacture a device potentially relevant to this procedure for information on it. NICE received 2 completed submissions. These were considered by the IP team and any relevant points have been taken into consideration when preparing this overview.

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6. Cole TS, Mezher AW, Catapano JS et al. (2020) Nationwide trends in carotid endarterectomy and carotid artery stenting in the post-CREST era. Stroke 51: 579–87
7. Gaba KA, Halliday A, Bulbulia R et al. (2021) Procedural risks of carotid intervention in 19,000 patients. Annals of Vascular Surgery 70: 326-331
8. Yang B, Ma Y, Wang T et al. (2021) Carotid endarterectomy and stenting in a Chinese population: safety outcome of the revascularization of extracranial carotid artery stenosis trial. Translational Stroke Research 12: 239-247
9. Jalbert JJ, Nguyen LL, Gerhard-Herman MD et al. (2015) Outcomes after carotid artery stenting in Medicare beneficiaries, 2005 to 2009. JAMA Neurology 72: 276-286
10. AbuRahma AF, Avgerinos ED, Chang RW et al. (2022) The Society for Vascular Surgery implementation document for management of extracranial cerebrovascular disease. Journal of Vascular Surgery 75: 26s-98s
11. Naylor R et al., European Society for Vascular Surgery (ESVS) 2023 Clinical Practice Guidelines on the Management of Atherosclerotic Carotid and Vertebral Artery Disease, European Journal of Vascular and Endovascular Surgery, https://doi.org/10.1016/j.ejvs.2022.04.01
12. Bonati LH, Kakkos S, Berkefeld J et al. (2021) European Stroke Organisation guideline on endarterectomy and stenting for carotid artery stenosis. European Stroke Journal 6: i-xlvii

Methods

NICE identified studies and reviews relevant to transfemoral carotid artery stent placement for asymptomatic extracranial carotid stenosis from the medical

literature. The following databases were searched between 2011 to 28/02/2023: MEDLINE, PREMEDLINE, EMBASE, Cochrane Library and other databases. Trial registries and the internet were also searched (see the literature search strategy). Relevant published studies identified during consultation or resolution that are published after this date may also be considered for inclusion.

The following inclusion criteria were applied to the abstracts identified by the literature search.

- Publication type: clinical studies were included with emphasis on identifying good quality studies. Abstracts were excluded if they did not report clinical outcomes. Reviews, editorials, and laboratory or animal studies, were also excluded and so were conference abstracts, because of the difficulty of appraising study methodology, unless they reported specific adverse events that not available in the published literature. Because of the size of the evidence base, a separate broad search was done to identify randomised controlled trials and systematic reviews.
- Patients with asymptomatic carotid stenosis.
- Intervention or test: transfemoral carotid artery stent placement.
- Outcome: articles were retrieved if the abstract contained information relevant to the safety, efficacy, or both.

If selection criteria could not be determined from the abstracts the full paper was retrieved.

Potentially relevant studies not included in the main evidence summary are listed in the section on other relevant studies.

Find out more about how NICE selects the evidence for the committee.

Table 4 literature search strategy

Two sets of searches were conducted – a precise search for all study designs and a more sensitive version that was limited by study design.

Databases	Date searched	Version/files
MEDLINE (Ovid)	19/12/2022	1946 to 2022 December 16
MEDLINE In-Process (Ovid)	19/12/2022	1946 to 2022 December 16
MEDLINE Epubs ahead of print (Ovid)	19/12/2022	December 16 022
EMBASE (Ovid)	19/12/2022	1974 to 2022 December 16
EMBASE Conference (Ovid)	19/12/2022	1974 to 2022 December 16
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	19/12/2022	Issue 12 of 12, December 2022
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	19/12/2022	Issue 11 of 12, November 2022
International HTA database (INAHTA)	19/12/2022	-

The following search strategies were used to identify papers in MEDLINE. A similar strategy was used to identify papers in other databases.

Precise search – not limited by study design

Medline search strategy

1 carotid artery diseases/ or carotid stenosis/
2 (Carotid* adj4 Arter* adj4 (diseas* or obstruct* or occlu* or obliterat* or disorder* or narrow* or plaque* or block* or stricture* or constrict*)).tw.
3 (Carotid* adj4 (ulcer* or stenos*)).tw.
4 (Carotid* adj4 (atherosclero* or athero-sclero* or arterioscler* or arterio-scler* or arteriopath*)).tw.
5 or/1-4
6 angioplasty, balloon/ or Angioplasty/
7 Dilatation/
8 Catheters/ or Catheterization/
9 (Balloon* adj4 (dilat* or cathet* or expand* or inflat* or angioplast*)).tw.
10 (Transluminal adj4 arter* adj4 dilat*).tw.
11 (endoluminal adj4 repair*).tw.
12 (carotid adj4 arter* adj4 (angioplast* or endovascular* or catheter* or cannul*)).tw.
13 or/6-12

14 exp carotid arteries/
15 stents/ or self expandable metallic stents/ or Blood Vessel Prosthesis Implantation/
16 14 and 15
17 (Carotid adj4 stent* adj4 (place* or tech* or implant* or device* or prosthe*)).tw.
18 (CAS adj4 (place* or tech* or implant* or device* or prosthe*)).tw.
19 or/16-18
20 13 and 19
21 5 and 20
22 ((Acculink or X?act or enroute or Roadsaver or Casper or MER or Cristallo Ideale or CGuard or SINUS Carotid RX or Precise or Exponent or Protege RX) adj2 stent*).tw.
23 (NexStent or WALLSTENT).tw.
24 22 or 23
25 5 and 24
26 21 or 25
27 Animals/ not humans/
28 26 not 27
29 limit 28 to english language

Broader search limited by study design

Databases	Date searched	Version/files
MEDLINE (Ovid)	28/02/2023	1946 to February 27, 2023
MEDLINE In-Process (Ovid)	28/02/2023	1946 to February 27, 2023
MEDLINE Epubs ahead of print (Ovid)	28/02/2023	February 27, 2023
EMBASE (Ovid)	28/02/2023	1974 to February 27, 2023
EMBASE Conference (Ovid)	28/02/2023	1974 to February 27, 2023
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	28/02/2023	Issue 2 of 12, February 2023
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	28/02/2023	Issue 2 of 12, February 2023
International HTA database (INAHTA)	28/02/2023	-

1 carotid artery diseases/ or carotid stenosis/
2 (Carotid* adj4 Arter* adj4 (diseas* or obstruct* or occlu* or obliterat* or disorder* or narrow* or plaque* or block* or stricture* or constrict*)).tw.

3 (Carotid* adj4 (ulcer* or stenos*)).tw.
4 (Carotid* adj4 (atherosclero* or athero-sclero* or arterioscler* or arterio-scler* or arteriopath*)).tw.
5 or/1-4
6 exp carotid arteries/
7 stents/ or self expandable metallic stents/ or Blood Vessel Prosthesis Implantation/
8 6 and 7
9 (Carotid adj4 stent*).tw.
10 (CAS adj4 (place* or tech* or implant* or device* or prosthe*)).tw.
11 or/8-10
12 ((Acculink or X?act or enroute or Roadsaver or Casper or MER or Cristallo Ideale or CGuard or SINUS Carotid RX or Precise or Exponent or Protege RX) adj2 stent*).tw.
13 (NexStent or WALLSTENT).tw.
14 or/11-13
15 5 and 14
16 Animals/ not humans/

Other relevant studies

Other potentially relevant studies to the IP overview that were not included in the main evidence summary (tables 2 and 3) are listed in table 5 below.

Observational studies with fewer than 1,000 people (apart from case reports of adverse events) and systematic reviews that were published before 2016 were excluded.

Table 5 additional studies identified

Article	Number of patients and follow up	Direction of conclusions	Reason study was not included in main evidence summary
Abbott AL, Paraskevas KI, Kakkos SK et al. (2015) Systematic Review of Guidelines for the Management of Asymptomatic and Symptomatic Carotid Stenosis. Stroke 46: 3288–301	Systematic review of guidelines	Of 28 guidelines with asymptomatic carotid artery stenosis procedural recommendations, 24 (86%) endorsed CEA (recommended it should or may be provided) for 50% to 99% average-surgical-risk asymptomatic carotid artery stenosis, 17 (61%) endorsed CAS, 8 (29%) opposed CAS, and 1 (4%) endorsed medical treatment alone. For asymptomatic carotid artery stenosis patients considered high-CEA-risk because of comorbidities, vascular anatomy, or undefined reasons, CAS was endorsed in 13 guidelines (46%).	A large body of evidence has been published since the review.

Abbott AL, Brunser AM, Giannoukas A et al. (2020) Misconceptions regarding the adequacy of best medical intervention alone for asymptomatic carotid stenosis. Journal of Vascular Surgery 71: 257–69	Review	Medical intervention (risk factor identification, lifestyle coaching, and medication) for stroke prevention has improved significantly. It is likely that no more than 6% of people with advanced asymptomatic carotid stenosis will now benefit from a carotid procedure during their lifetime. Stroke risk stratification studies using current optimal medical intervention alone are the highest research priority for identifying persons likely to benefit from adding a carotid procedure.	A more recent systematic review is included.
Abreu P, Nogueira J, Rodrigues FB et al. (2017) Intracerebral hemorrhage as a manifestation of cerebral hyperperfusion syndrome after carotid revascularization: systematic review and meta-analysis. Acta neurochirurgica 159: 2089-2097	Systematic review and meta-analysis n=28,956 (41 studies)	When comparing CAS with CEA, postprocedural intracerebral haemorrhage in the context of cerebral hyperperfusion syndrome was less frequent in CEA. It occurred less often in large series and was rare in asymptomatic patients. The most common risk factors were periprocedural hypertension and ipsilateral severe stenosis.	Review focuses on intracerebral haemorrhage.
Achim A, Lacko D, Huttl A et al. (2022) Impact of diabetes mellitus on early clinical outcome	Cohort study n=1,940 Follow up: 12 months	There was no significant difference between the 2 groups in terms of early and	Study focuses on impact of diabetes

and stent restenosis after carotid artery stenting. Journal of Diabetes Research 4196195		late MACCEs (composite of transient ischemic attack, major stroke, myocardial infarction, and death), with an early rate of 4% nondiabetics versus 5%, p=0.08 and 2% nondiabetics versus 2% diabetics, p=0.1 at 12 months. Overall stroke/death rate in the asymptomatic patients was 2%, and the restenosis rate was higher in the diabetes population (2% versus 1%, p=0.04).	mellitus on outcomes.
Adil MM, Saeed F, Chaudhary SA et al. (2016) Comparative outcomes of carotid artery stent placement and carotid endarterectomy in patients with chronic kidney disease and end-stage renal disease. Journal of Stroke and Cerebrovascular Diseases 25: 1721–27	Cohort study n=8,148 (CAS)	Both CAS and CEA were associated with 4-folds higher odds of in-hospital mortality in patients with end-stage renal disease and such observations raise concerns regarding the risk benefit ratio of carotid revascularisation in these patients.	Study focuses on impact of chronic kidney disease on outcomes.
Altibi AM, Saca EE, Dhillon H et al. (2019) Perioperative stroke in carotid artery stenting as a surrogate marker and predictor for 30-day postprocedural mortality - a pooled analysis of 156,000 patients with carotid artery disease. Neurology India 67: 1423-1428	Meta-analysis n=156,854 symptomatic and asymptomatic patients (146 studies)	Perioperative stroke drastically increases the risk of 30-day mortality. The occurrence of perioperative stroke exhibited high specificity but modest sensitivity in predicting 30-day mortality following CAS.	More recent systematic reviews are included.

Ancetti S, Paraskevas KI, Faggioli G et al. (2021) Effect of carotid interventions on cognitive function in patients with asymptomatic carotid stenosis: a systematic review. European Journal of Vascular and Endovascular Surgery	Systematic review and meta-analysis n=31 studies (non-randomised)	CEA and CAS rarely improved overall late cognitive function and the risk of significant cognitive decline was equally low (less than 2%). In the long term, most were either unchanged (69%) or mostly unchanged with 1 to 2 test scores improved (25%).	Review focuses on cognitive function.
Arhuidese IJ, Obeid T, Hicks CW et al. (2016) Outcomes after carotid artery stenting in hemodialysis patients. Journal of Vascular Surgery 63: 1511-6	Cohort study n=1,109 83% asymptomatic Follow up: median 2.5 years	Overall, 30-day perioperative stroke, myocardial infarction, and death rates were 6%, 6%, and 3%, respectively. Long-term freedom from stroke was 90% at 1 year, 85% at 2 years, and 76% at 4 years. Patient survival was 73% at 1 year and 29% at 4 years. Symptomatic status was the only significant predictor of stroke in a long-term period of 4 years (HR 1.92; 95% CI 1.12 to 3.29; $p<0.05$).	Study focuses on patients on haemodialysis.
Azzam AY, Ghozy S, Elswedy A et al. (2023) Carotid endarterectomy versus carotid stenting for asymptomatic carotid stenosis: Evaluating the overlapping meta-analyses of randomized controlled trials. European Journal of Radiology Open 10: 100460	Review of meta-analysis studies n=24,017 (13,835 CAS 10,182 CEA) 5 studies	Carotid endarterectomy reduced the rate of ischemic stroke and stroke-related mortality but led to a higher rate of intraoperative cranial nerve injury. There was no significant difference between carotid endarterectomy and carotid stenting in ipsilateral stroke and myocardial infarction events.	All 5 included meta-analyses are listed in table 5. More recent systematic reviews are included in tables 2 and 3.

Barkat M, Roy I, Antoniou SA et al. (2018) Systematic review and network meta-analysis of treatment strategies for asymptomatic carotid disease. Scientific Reports 8: 4458	Systematic review and network meta-analysis n=8,954 (11 trials)	This network meta-analysis demonstrates that CAS and CEA increase the risk of death and ipsilateral stroke at 30 days when compared with best medical therapy. The network meta-analysis results favour CEA in the long term, but this finding is less conclusive.	More recent studies are included.
Batchelder AJ, Saratzis A, Naylor AR (2020) Editor's choice - Overview of primary and secondary analyses from 20 randomised controlled trials comparing carotid artery stenting with carotid endarterectomy. European Journal of Vascular and Endovascular Surgery 58: 479–493	Systematic review n=3,467 asymptomatic (7 trials)	CAS confers higher rates of 30 day death or stroke than CEA. After 30 days, ipsilateral stroke is virtually identical for CEA and CAS. Key issues to be resolved include the optimal volume of CAS procedures to maintain competency, how to deliver better risk factor control and BMT and the role of CEA or CAS in preventing or reversing cognitive impairment.	Another systematic review has been summarised, which includes a lot of the same trials.
Bennett KM, Scarborough JE (2017) Carotid artery stenting is associated with a higher incidence of major adverse clinical events than carotid endarterectomy in female patients. Journal of Vascular Surgery 66: 794–801	Registry data n=5,751 (131 CAS)	290 (5%) patients from the CEA group and 16 (12%) from the CAS group sustained a major adverse clinical event in the first 30 days after their procedures. Within the propensity-matched cohort, this was 11% (14 patients) in the CAS group compared with 4% (5 patients; OR 1.01 [95% CI 1.01 to 7.77]; p=0.04) in the CEA group.	Non-randomised study, focusing on the effect of sex on outcomes.

Bertog SC, Grunwald IQ, Kuhn AL et al. (2013) Complications during carotid artery stenting. Journal of Cardiovascular Surgery 54: 67-82	Review	Complications and adverse events of carotid stenting include those that are related to the vascular access site, vessel spasm, dissection, perforation, thrombotic occlusion and haemodynamic instability and arrhythmias.	Review
Brott TG, Hobson RW, Howard G et al. (2010) Stenting versus endarterectomy for treatment of carotid-artery stenosis. New England Journal of Medicine 363: 11–23	Randomised controlled trial (CREST) n=2,502 Follow up: median 2.5 years	Among patients with symptomatic or asymptomatic carotid stenosis, the risk of the composite primary outcome of stroke, myocardial infarction, or death did not differ significantly in the group who had CAS and the group who had CEA. During the periprocedural period, there was a higher risk of stroke with stenting and a higher risk of myocardial infarction with endarterectomy.	More recent studies are included. Trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Brott TG, Howard G, Roubin GS et al. (2016) Long-term results of stenting versus endarterectomy for carotid-artery stenosis. The New England Journal of Medicine 374: 1021-31	Randomised controlled trial (CREST) n=2,502 Follow up: 10 years	Over 10 years of follow up, the results did not show a significant difference between patients who had stenting and those who had endarterectomy with respect to the risk of periprocedural stroke, myocardial infarction, or death and subsequent ipsilateral stroke. The rate of postprocedural ipsilateral stroke also did not differ between groups.	More recent studies are included. Trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).

Carvalho P, Coelho A, Mansilha A (2021) Effectiveness and safety of dual-layer stents in carotid artery disease: A systematic review. International Angiology 40: 97–104	Systematic review n=1,193 (20 articles)	Despite the theoretic advantage of reducing the risk for procedural embolic events when compared with conventional stents, high quality evidence is scarce. Also, safety issues regarding dual-layer stents in the emergency setting have been raised, particularly for thrombotic complications. Additional data from well-designed randomised controlled trials are needed to assert the true value of dual-layer stents.	Review focuses on a specific type of stent used for CAS.
Chang C-H, Lin J-W, Lin C-H et al. (2015) Effectiveness and safety of extracranial carotid stent placement: a nationwide self-controlled case-series study. Journal of the Formosan Medical Association 114: 274–81	Case series n=1,258 Follow up: 360 days	Within 1 year after CAS, 74 patients died and 80 had an ischaemic stroke. Of the 1,184 patients who were followed for 360 days, the RR for ischaemic stroke decreased to 0.21 (95% CI 0.08 to 0.51) between 31 and 180 days and 0.10 (95% CI 0.03 to 0.32) between 181 and 360 days. Statin therapy was associated with a reduced risk of death or ischaemic stroke in the first month (OR 0.53, 95% CI 0.32 to 0.90).	Studies with more patients or longer follow up are included.
Chang H, Rockman CB, Veith FJ et al. (2022) Outcomes of transfemoral carotid artery stenting and	Non-randomised comparative study	Among patients having carotid revascularisation for restenosis after prior ipsilateral CEA, TCAR	Study focuses on restenosis after previous CEA.

transcarotid artery revascularization for restenosis after prior ipsilateral carotid endarterectomy. Journal of Vascular Surgery 75: 561	n=3,508 (1,834 transfemoral CAS, 1,674 TCAR)	was associated with decreased odds of 30-day transient ischaemic attack compared with transfemoral CAS. However, the 2 treatment approaches were similarly safe in terms of the remaining perioperative outcomes, including stroke and death and stroke, death, and myocardial infarction.	
Cho YD, Kim S-E, Lim JW et al. (2018) Protected versus unprotected carotid artery stenting: Meta-analysis of the current literature. Journal of Korean Neurosurgical Society 61: 458–66	Systematic review n=20,670 CAS procedures	The use of protection device statistically significantly decreased stroke after CAS. However, its efficacy was not demonstrated in symptomatic patients.	Review focuses on the use of cerebral protection devices.
Choi JC, Johnston SC, Kim AS (2015) Early outcomes after carotid artery stenting compared with endarterectomy for asymptomatic carotid stenosis. Stroke 46: 120-5	Cohort study n=17,716 (3,962 CAS)	For asymptomatic carotid stenosis, CAS is associated with a substantially higher risk of postoperative stroke or in-hospital death than CEA even after adjustment for baseline differences in hospital and patient characteristics.	More recent studies are included.
Choi JH, Pile-Spellman J, Brisman JL (2014) US nationwide trends in carotid revascularization: hospital outcome and predictors of outcome from 1998 to 2007. Acta Neurologica Scandinavica 129: 85–93	Cohort study	The annual number of CEA decreased (137,877 to 111,658) and increased for CAS (2,318 to 14,415). In-hospital mortality after CEA decreased from 0.4% to 0.3% ($p<0.001$), whereas long-term facility (LTF) discharge increased from 8% to 11%	Study assesses trends in carotid revascularisation in the US between 1998 to 2007.

		(p<0.001). Discharge outcome improved for CAS in both categories (mortality 2% to 0.5%; LTF discharge 11% to 8%; p<0.001). The trend analysis revealed an increase in patient age and a worsening comorbid profile over time. Age, women, length of stay, atrial fibrillation, and carotid stenosis with infarction were important determinants of unfavourable hospital outcome.	
Chu S-S, Hu J, Tang L-W et al. (2021) The impact of diabetes mellitus on carotid artery stenting: a meta-analysis. Neurosurgical Review 44: 3039-3046	Systematic review and meta-analysis n=3,364	Compared with nondiabetic patients, diabetes did not increase the risk of the following: perioperative stroke, transient ischaemic attack, myocardial infarction, mortality, and composite of stroke or death in patients receiving CAS.	Review focuses on impact of diabetes on outcomes.
Clavel P, Hebert S, Saleme S et al. (2019) Cumulative incidence of restenosis in the endovascular treatment of extracranial carotid artery stenosis: A meta-analysis. Journal of NeuroInterventional Surgery 11: 916–23	Meta-analysis n=15,943 (40 studies)	This meta-analysis showed a low cumulative rate of restenosis at 12 months and ipsilateral stroke within 30 days after stenting. Older patients and those with hostile neck present a lower risk of in-stent restenosis. The use of an embolic protection device was not associated with a lower risk of stroke.	More recent systematic reviews are included.

Coelho AP, Lobo M, Nogueira C et al. (2019) Overview of evidence on risk factors and early management of acute carotid stent thrombosis during the last two decades. Journal of Vascular Surgery 69: 952–64	Systematic review and meta-analysis n=60 (29 articles)	Acute carotid stent thrombosis incidence is higher in emergent, neurologically unstable patients. Antiplatelet noncompliance, antiplatelet resistance, long stenotic lesions, use of more than 1 stent, and dual-layer stents are also associated with increased risk.	Review focuses on risk factors for acute carotid stent thrombosis.
Cohen DJ, Stolker JM, Wang K et al. (2011) Health-related quality of life after carotid stenting versus carotid endarterectomy: results from CREST (Carotid Revascularization Endarterectomy Versus Stenting Trial). Journal of the American College of Cardiology 58: 1557–65	Randomised controlled trial (CREST) n=2,502	CAS is associated with better HRQOL during the early recovery period compared with CEA, particularly regarding physical limitations and pain, but these differences diminish over time and are not evident after 1 year. Although CAS and CEA are associated with similar overall HRQOL at 1 year, event-specific analyses confirm that stroke has a greater and more sustained impact on HRQOL than myocardial infarction.	Trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Columbo JA, Martinez-Camblor P, Stone DH et al. (2022) Procedural safety comparison between transcarotid artery revascularization, carotid endarterectomy, and carotid Stenting: perioperative and 1-year rates of stroke or death. Journal of the American Heart Association 11 (no. 19)	Registry n=118,566 (14,595 CAS; 34% asymptomatic)	The perioperative rate of stroke or death for asymptomatic patients was 1% for TCAR, 1% for CEA, and 2% for transfemoral-CAS ($p<0.001$). Symptomatic patients had the most favourable 1-year result with TCAR, which appears to provide a safe procedural	Study focuses on TCAR as an alternative to CEA and CAS.

		alternative to CEA and CAS for this higher risk cohort.	
Columbo JA, Martinez-Camblor P, MacKenzie TA et al. (2019) A comparative analysis of long-term mortality after carotid endarterectomy and carotid stenting. Journal of Vascular Surgery 69: 104-109	Cohort study n=33,650 (4,415 CAS; 52% asymptomatic)	The crude HR of all-cause mortality for CEA versus CAS was 0.75 (95% CI 0.70 to 0.81). This survival advantage persisted after adjustment for age, sex, and comorbidities (adjusted HR 0.75; 95% CI 0.69 to 0.82). This effect was confirmed on a propensity-matched analysis, with an HR of 0.76 (95% CI 0.69 to 0.85). Finally, these findings were robust to subanalyses that stratified patients by presenting symptoms and were more pronounced in symptomatic patients (adjusted HR 0.69; 95% CI 0.61 to 0.79) than in asymptomatic patients (adjusted HR 0.80; 95% CI 0.71 to 0.90).	More recent studies are included.
Cui L, Han Y, Zhang S et al. (2018) Safety of stenting and endarterectomy for asymptomatic carotid artery stenosis: a meta-analysis of randomised controlled trials. European Journal of Vascular and Endovascular Surgery 55: 614-624	Systematic review and meta-analysis n=3,901 (5 studies)	Among patients with asymptomatic carotid stenosis, stenting has a significantly higher rate of any periprocedural stroke and periprocedural minor stroke than CEA, and similar risk of periprocedural major stroke, periprocedural ipsilateral stroke, or myocardial infarction.	More recent systematic reviews are included.

de Vries EE, Meershoek AJA, Vonken EJ et al. (2019) A meta-analysis of the effect of stent design on clinical and radiologic outcomes of carotid artery stenting. Journal of Vascular Surgery 69: 1952-1961e1	Systematic review and meta-analysis n=46,728 procedures (68 studies)	Stent design is not associated with short- or intermediate-term clinical major adverse event rates in patients who have CAS. Open-cell stenting resulted in a higher number of subclinical postprocedural new ischaemic lesions compared with closed-cell stenting. An individualised patient data meta-analysis, including future studies with prospective homogenous study design, is required to adequately correct for known risk factors and to provide definite conclusions with respect to carotid stent design for specific subgroups.	Review includes symptomatic and asymptomatic patients and focuses on the effect of different stent designs.
DeCarlo C, Tanious A, Boitano LT et al. (2021) Addition of common carotid intervention increases the risk of stroke and death after carotid artery stenting for asymptomatic patients. Journal of Vascular Surgery 74: 1919-1928	Cohort study n=18,441	The addition of endovascular treatment of common carotid artery lesions with CAS is associated with almost double the risk of perioperative stroke or death in asymptomatic patients and should be avoided if possible.	Study focuses on impact of simultaneous treatment of tandem carotid lesions.
DeCarlo C, Tanious A, Boitano LT et al. (2021) Simultaneous treatment of common carotid lesions increases the risk of stroke and death after carotid artery stenting. Journal of	Cohort study n=1,950	The addition of endovascular treatment of tandem common carotid artery lesions with CAS is associated with a 3-fold increase in perioperative stroke and death and should be avoided if possible.	Study focuses on impact of simultaneous treatment of tandem carotid lesions.

Vascular Surgery 74: 592-598e1			
Domanin M, Isalberti M, Romagnoli S et al. (2017) Acute hemifacial ischemia as a late complication of carotid stenting. Journal of Vascular Surgery Cases and Innovative Techniques 3: 83-86	Case report n=1	**Acute hemifacial ischaemia** Case report of late occlusion of the external carotid artery after CAS with symptoms of acute homolateral facial ischaemia as well as pain, cyanosis, tongue numbness, and skin coldness. The patient had local thrombolysis and balloon angioplasty with regression of symptoms after recanalisation.	Case report
Dua A, Romanelli M, Upchurch GR Jr et al. (2016) Predictors of poor outcome after carotid intervention. Journal of Vascular Surgery 64: 663-70	Non-randomised comparative study n=1,756,445 (7,317 asymptomatic CAS)	For risk-matched asymptomatic and symptomatic patients, female gender ($p<0.001$) and performing 1 or 2 cases per year ($p<0.05$) were associated with higher cerebrovascular accident risk. In asymptomatic and symptomatic patients, predictors of myocardial infarction included congestive heart failure ($p<0.001$) and peripheral artery disease ($p<0.05$). For both asymptomatic and symptomatic patients, predictors of mortality included female gender ($p<0.001$) and performing 1 or 2 cases per year ($p<0.01$).	More recent studies are included.
Dzierwa K, Pieniazek P, Tekieli L et al. (2013)	Cohort study	"Tailored CAS" remains a safe procedure for	Small, non-randomised

Carotid artery stenting according to the "tailored CAS" algorithm performed in the very elderly patients: The thirty day outcome. Catheterization and Cardiovascular Interventions 82: 681-688	n=1,139	asymptomatic elderly as well as symptomatic and asymptomatic young patients.	study focusing on outcomes in very elderly patients.
Faggioli G, Pini R, Rapezzi C et al. (2013) Carotid revascularization in patients with ongoing oral anticoagulant therapy: The advantages of stent placement. Journal of Vascular and Interventional Radiology 24: 370-377	Cohort study n=1,222 procedures Follow up: 30 days	Oral anticoagulant therapy management significantly influences the results of carotid revascularisation. Because CAS with unmodified oral anticoagulant therapy had a better outcome than CEA with oral anticoagulant therapy conversion to heparin, carotid revascularisation strategies should favour CAS rather than CEA in this setting.	Small, non-randomised study focusing on management of oral anticoagulant therapy.
Feng Y, Bai X, Li S et al. (2020) Thirty-day outcome of carotid artery stenting in elderly patients: a single-center experience. World Neurosurgery 138: e311-e316	Cohort study n=1,029 Follow up: 30 days	CAS was safely performed in elderly patients. A family history of stroke, symptomatic status, and modified Rankin Scale score 3 or more indicating a neurologic deficit increased the risk of 30-day postoperative major adverse clinical events.	Small, non-randomised study focusing on short-term outcomes in elderly patients.
Foret T, Guillaumin M, Desmarets M et al. (2022) Association between carotid revascularization for asymptomatic stenosis and cognitive functions.	Systematic review n=20 studies	Only observational studies analysed the impact of CEA and CAS on cognitive functions. Data resulting from the analysis were too	No meta-analysis.

VASA. Zeitschrift fur Gefasskrankheiten 51: 138-149		heterogeneous for a meta-analysis.	
Fukushima Y, Nakahara I, Ohta T et al. (2015) Rare complication characterized by late-onset transient neurological symptoms without hyperperfusion after carotid artery stenting: A report of three cases. Interventional Neuroradiology 21: 72-79	Case reports n=3	**Transient neurological symptoms** Case reports of 3 patients who developed neurological symptoms over a period of 10 hours after CAS and improved within 2 days. None of the patients showed signs of fresh infarctions on diffusion-weighted imaging or hyperperfusion on single-photon emission computed tomography.	Case reports
Galinanes EL, Dombroviskiy VY, Hupp CS et al. (2014) Evaluation of readmission rates for carotid endarterectomy versus carotid artery stenting in the US Medicare population. Vascular and Endovascular Surgery 48: 217-23	Non-randomised comparative study n=235,247 procedures	Readmission rates for patients having CEA and CAS, respectively, were 9% and 11% at 30 days ($p<0.0001$); 13% and 18% at 60 days ($p<0.0001$) and 17% and 23% at 90 days ($p<0.0001$). Patients aged over 80 (OR=1.25; 95% CI 1.20 to 1.30) and patients with renal failure (OR=1.6; 95% CI 1.56 to 1.73), congestive heart failure (OR=1.6; 95% CI 1.57 to 1.73), diabetes (OR=1.4; 95% CI 1.27 to 1.52), and CAS (OR=1.2; 95% CI=1.15 to 1.25) were more likely to be readmitted.	Non-randomised comparative study, assessing readmission rates. More recent studies with longer term follow up are included.
Galyfos G, Sachsamanis G, Anastasiadou C et al. (2019) Carotid	Systematic review and meta-analysis	CEA is associated with a lower early all stroke risk compared with CAS, although other	More recent systematic reviews are included.

endarterectomy versus carotid stenting or best medical treatment in asymptomatic patients with significant carotid stenosis: a meta-analysis. Cardiovascular Revascularization Medicine 20: 413-423	n=8,771 (10 trials)	early or late outcomes did not show any difference between the 2 methods. Additionally, CEA seems to have a benefit over BMT against long-term ipsilateral stroke, although early outcomes are worse after CEA. No studies were available comparing CAS to BMT alone.	
Galyfos G, Geropapas G, Sigala F et al. (2016) Meta-analysis of studies evaluating the effect of cilostazol on major outcomes after carotid stenting. Journal of Endovascular Therapy 23: 186-195	Systematic review and meta-analysis n=1,297 (7 studies)	Cilostazol seems to decrease total in-stent restenosis rates in patients who have CAS without affecting MI/stroke/death events, both in the early and late settings.	Review assesses effect of cilostazol on outcomes.
Garriboli L, Jannello AM (2015) Delayed carotid wallstent shortening. International Journal of Surgery Case Reports 8: 68-70	Case report n=1 Follow up: 1 year	**Postoperative dislocation of stent** Case report of a postoperative dislocation of a carotid stent that happened 1 year after placement. After the first ultrasound control confirmed the correct position of the stent the following one, 9 months later, showed a severe restenosis because of proximal dislocation of the stent. The problem was solved with the positioning of a further stent more distally.	Case report
Giani L, Lovati C, Rosa S et al. (2015) Episodes of flushing, dyspnea	Case report n=1	**Flushing, dyspnoea and palpitations**	Case report

and hypertension after carotid stenting for severe carotid stenosis. Autonomic Neuroscience 193: 147-8		An 83-year-old woman who had CAS presented with episodes of flushing, dyspnoea and palpitations accompanied by transitory desaturation, hypertension, agitation and anxiety. Symptoms started 12 hours after the procedure. Each episode lasted 10 minutes. Five episodes in 3 days were observed.	
Giri J, Kennedy KF, Weinberg I et al. (2014) Comparative effectiveness of commonly used devices for carotid artery stenting: an NCDR Analysis (National Cardiovascular Data Registry). JACC. Cardiovascular Interventions 7: 171–77	Registry data n=12,135 procedures	In modern US practice, the Acculink/Accunet, Xact/Emboshield, and Precise/Angioguard carotid stenting systems are mostly used and are associated with similarly low rates of adverse events.	Non-randomised study, comparing different devices.
Goicoechea S, Walsh M, Soult M et al. (2022) Female gender increases risk of stroke and readmission after CEA and CAS. Journal of Vascular Surgery 75: 1935–44	Cohort study n=106,568 (2,156 CAS) asymptomatic and symptomatic	Female gender was associated with significantly increased rates of postoperative CVA/stroke in the asymptomatic and symptomatic cohorts as well as readmission in the asymptomatic cohort. Female gender was associated with higher rates of CVA/stroke following CEA, but not CAS.	Non-randomised study focusing on the impact of gender on outcomes.
Goode SD, Cleveland TJ, Gaines PA (2013) United Kingdom carotid artery stent registry:	UK registry n=1,154 (201 asymptomatic)	The 30-day all stroke and death rates for symptomatic patients were 6% and 2% for	More recent studies with more patients are included.

Short- and long-term outcomes. CardioVascular and Interventional Radiology 36: 1221-1231		those with asymptomatic disease. The 30 day mortality rate was 2% for symptomatic and 1% for asymptomatic patients. For symptomatic patients, the 7-year all-cause mortality rate was 22% and for asymptomatic patients 18%. The 7-year all-cause mortality and disabling stroke rates were 25% and 19%, respectively.	
Gorgulu S, Sahin M, Norgaz NT et al. (2022) Carotid artery stenting without embolic protection: a randomized multicenter trial (the CASWEP trial). Interventional neuroradiology 15910199221094388	Randomised controlled trial n=279	This study suggests that CAS without a carotid protection device is not associated with higher rates of peri-procedural transient ischaemic attack, stroke, and death or new ischaemic brain lesions compared with CAS with protection in selected symptomatic and asymptomatic patients with significant carotid artery stenosis provided that there is no visible thrombus.	Small trial, assessing the use of carotid protection devices in both symptomatic and asymptomatic patients.
Halliday A, Bulbulia R, Gray W et al. (2013) Status update and interim results from the asymptomatic carotid surgery trial-2 (ACST-2). European Journal of Vascular and Endovascular Surgery 46: 510-518	Randomised controlled trial (ACST-2) n=986 Follow up: 6 months	Early results suggest contemporary carotid intervention for asymptomatic stenosis has a low risk of serious morbidity and mortality, on par with other recent trials.	A more recent publication from the same trial is included.

Hasan B, Farah M, Nayfeh T et al. (2022) A systematic review supporting the Society for Vascular Surgery Guidelines on the management of carotid artery disease. Journal of Vascular Surgery 75: 99s-108se42	Systematic review and meta-analysis 6 studies on asymptomatic patients (n=5,498)	Medical management compared with carotid interventions in asymptomatic patients was associated with better early outcome during the first 30 days.	More recent studies are included.
Hayashi K, Horie N, Sakamoto I et al. (2014) A case of iliac artery injury treated by covered stent during carotid artery stenting. Acta Neurochirurgica 156: 561-4	Case report n=1	**Iliac artery injury** Case report of iliac artery injury during CAS treated successfully by insertion of a covered stent.	Case report
Heo S-H, Yoon K-W, Woo S-Y et al. (2017) Editor's choice - Comparison of early outcomes and restenosis rate between carotid endarterectomy and carotid artery stenting using propensity score matching analysis. European Journal of Vascular and Endovascular Surgery 54: 573-578	Retrospective non-randomised comparative study n=1,184 Follow up: mean 49 months	The CAS group showed a relatively higher 30 day incidence of major adverse clinical events (8% versus 2%; OR 3.3, 95% CI 1.63 to 6.51; p=0.001) but a lower incidence of procedure related complications (2% versus 5%; OR 0.20, 95% CI 0.08 to 0.53; p=0.001). During a mean follow up of 49 months (range 1 to 180 months), restenosis rates were higher after CAS than after CEA (2% versus 1% at 12 months and 5% versus 1% at 24 months, respectively, p=0.008).	More recent randomised studies are included.
Hicks CW, Nejim B, Aridi HD et al. (2019) Transfemoral carotid artery stents should be used with caution in patients with	Retrospective non-randomised comparative study n=53,337	More than one-third of patients who had carotid revascularisation for asymptomatic carotid artery stenosis had 60	More recent randomised studies are included.

asymptomatic carotid artery stenosis. Annals of Vascular Surgery 54: 1–11	Follow up: 2 years	to 79% stenosis. Having lower degree of stenosis was not protective against stroke and death for either CEA or CAS at either 30 days or 2 years postoperatively. Optimal medical management should be the first line in stroke prevention for asymptomatic patients with severe (60 to 79%) carotid stenosis.	
Hicks CW, Nejim B, Obeid T et al. (2018) Use of a primary carotid stenting technique does not affect perioperative outcomes. Journal of Vascular Surgery 67: 1736-1743e1	Cohort study n=10,074	Primary carotid stenting is associated with a similar risk of stroke and death compared with conventional CAS with angioplasty. The use of an embolic protection device is essential to good outcomes with both techniques.	Study assesses outcomes of CAS with angioplasty against CAS alone.
Hill MD, Brooks W, Mackey A et al. (2012) Stroke after carotid stenting and endarterectomy in the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST). Circulation 126: 3054-3061	Randomised controlled trial (CREST) n=2,272	Major stroke occurred in 13 (0.6%) patients. The estimated 4-year mortality after stroke was 21% compared with 12% for those without stroke. The adjusted risk of death at 4 years was higher after periprocedural stroke (hazard ratio, 2.78; 95% CI 1.63 to 4.76).	Trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Hopkins LN, White CJ, Foster MT et al. (2014) Carotid artery stenting and patient outcomes: the CABANA surveillance study. Catheterization and	Prospective cohort study n=1,097 Follow up: 30 days	The stroke rate (3%) was a major contributing factor in the overall major adverse event rate (5%). Mortality was 1% and the MI rate was	More recent studies with more patients or longer follow up are included.

cardiovascular interventions 84: 997-1004		0.5%. There was no statistically significant association between major adverse event rates among the centre experience tiers nor among the operator training categories.	
Howard VJ, Lutsep HL, Mackey A et al. (2011) Influence of sex on outcomes of stenting versus endarterectomy: a subgroup analysis of the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST). The Lancet. Neurology 10: 530-537	Randomised controlled trial (CREST) n=2,502	Periprocedural risk of events seems to be higher in women who have CAS than those who have CEA whereas there is little difference in men. Additional data are needed to confirm whether this differential risk should be considered in decisions for treatment of carotid disease in women.	Primary outcome data from the trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Huang J-H, Kao H-L, Hao W-R et al. (2011) Dislodged self-expanding carotid stent delivery sheath marker ring leading to emergent surgery. Annals of Vascular Surgery 25: e1-264	Case report n=1	**Dislodged stent delivery sheath** Case report in which the metallic marker ring on the delivery sheath dislodged and emergency surgery had to be performed to retrieve the locked stent.	Case report
Huibers AE, Westerink J, de Vries EE et al. (2018) Editor's Choice - Cerebral hyperperfusion syndrome After carotid artery stenting: a systematic review and meta-analysis. European Journal of Vascular and Endovascular Surgery 56: 322-333	Systematic review and meta-analysis n=8,731 (CAS) 33 studies	The pooled cerebral hyperperfusion risk was 5% (3 to 7%). Stroke occurred in 47% of patients with cerebral hyperperfusion, of which 54% were fatal or disabling. Average time from procedure to symptoms was 12 hours. Impaired cerebrovascular reserve was associated with a higher risk (RR	Review focuses on cerebral hyperperfusion .

		5.18; 95% CI 1.0 to 26.8; p=0.049). Symptomatic status was associated with a lower risk (RR 0.20; 95% CI 0.07 to 0.59; p=0.001)	
Hung C-S, Yeh C-F, Lin M-S et al. (2017) Impact of hospital volume on long-term neurological outcome in patients undergoing carotid artery stenting. Catheterization and cardiovascular Interventions	Cohort study n=3,248 Follow up: median 2 years	CAS performed in high-volume hospitals was associated with less new ischemic stroke after discharging from the index CAS, compared with those in low-volume hospitals.	Non-randomised study assessing the impact of hospital volume.
Hussain MA, Mamdani M, Tu JV et al. (2018) Long-term outcomes of carotid endarterectomy versus stenting in a multicenter population-based Canadian study. Annals of Surgery 268: 364-373	Cohort study n=15,525 asymptomatic and symptomatic	Compared with carotid endarterectomy, stenting was associated with an early and sustained approximately 55% increased hazard for major adverse events over long-term follow up. Although non-randomised, these results raise potential concerns about the interchangeability of carotid endarterectomy and stenting in the context of actual clinical practice.	Mixed population of symptomatic and asymptomatic patients.
Hussain MA, Bin-Ayeed SA, Saeed OQ et al. (2016) Impact of diabetes on carotid artery revascularization. Journal of Vascular Surgery 63: 1099-107e4	Systematic review n=16,264 (14 studies)	Diabetic patients are at an increased risk of perioperative stroke, death, and long-term mortality compared with nondiabetic patients who have carotid artery revascularisation.	Review focuses on impact of diabetes on CAS and CEA.
Hwan Park J, Cho C-S (2022) Early time carotid artery stent	Case reports n=2	**Stent shortening** 2 case reports of the downward shortening	Case report

shortening: A case report. Interdisciplinary Neurosurgery: Advanced Techniques and Case Management 29: 101597		of a stent after a CAS procedure, which were detected via computed tomography angiography the day after stenting.	
Jim J, Rubin BG, Ricotta JJ 2nd et al. (2012) Society for Vascular Surgery (SVS) Vascular Registry evaluation of comparative effectiveness of carotid revascularization procedures stratified by Medicare age. Journal of Vascular Surgery 55: 1313-1321	Registry data n=8,913 (3,397 CAS) Follow up: 30 days	Compared with CEA, CAS resulted in inferior 30-day outcomes in symptomatic and asymptomatic patients aged 65 years and over. These findings do not support the widespread use of CAS in patients aged 65 years and over.	More recent studies are included.
Jim J, Rubin BG, Landis GS et al. (2011) Society for Vascular Surgery Vascular Registry evaluation of stent cell design on carotid artery stenting outcomes. Journal of Vascular Surgery 54: 71-79	Registry data n=4,337 Follow up: 30 days	In-hospital and 30-day outcomes after CAS were not significantly influenced by stent cell design. Symptomatic patients had higher adverse event rates compared with the asymptomatic cohort.	More recent studies are included.
Jones MR, Howard G, Roubin GS et al. (2018) Periprocedural stroke and myocardial infarction as risks for long-term mortality in CREST. Circulation. Cardiovascular Quality and Outcomes 11: e004663	Randomised controlled trial (CREST) n=2,272 asymptomatic and symptomatic Follow up: 10 years	Patients with periprocedural events demonstrate a substantial increase in future mortality to 10 years. For stroke, this risk is largely confined to an early time frame while periprocedural MI or biomarker-only events confer a continuous increased mortality for 10 years.	Primary outcome data from the trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Jung J-M, Choi J-Y, Kim HJ et al. (2017) Long-term durability and outcomes of carotid stenting and carotid	Systematic review and meta-analysis	Although CAS may be more strongly associated with periprocedural stroke/death compared	More recent systematic reviews are included.

endarterectomy. Journal of NeuroInterventional Surgery 9: 750-755	n=8,184 (22 studies) Follow up: maximum 10 years	with CEA, it could be a good alternative to CEA in terms of long-term durability and outcomes.	
Kakkos SK, Kakisis I, Tsolakis IA et al. (2017) Endarterectomy achieves lower stroke and death rates compared with stenting in patients with asymptomatic carotid stenosis. Journal of Vascular Surgery 66: 607-617	Systematic review and meta-analysis n=3,709 (9 trials) Follow up: 1 year	Among patients with asymptomatic stenosis undergoing carotid intervention, there is moderate-quality evidence to suggest that CEA had significantly lower 30-day stroke and also stroke or death rates compared with CAS at the cost of higher cranial nerve injury and nonsignificantly higher myocardial infarction rates. The long-term efficacy of CEA in ipsilateral stroke prevention, taking into account perioperative stroke and death, was preserved during follow up.	More recent systematic reviews are included.
Kammler J, Blessberger H, Lambert T et al. (2017) In-stent restenosis after interventional treatment of carotid artery stenoses: a long-term follow up of a single center cohort. Clinical Research in Cardiology 106: 493-500	Retrospective cohort study n=1,165 procedures Follow up: median 19.6 months	3% (39/1,165) of patients had in-stent restenosis more than 70% during the follow-up period. In 13 of them, restenosis was caused by a mechanical collapse (stent crush) of the implanted stent. All patients were free of neurological events during follow up and 31 patients had a stent-in-stent implantation. A shorter stent length, a narrower stent diameter, performance	Study focuses on in-stent restenosis.

		of post-dilatation as well as stent type significantly influenced development of in-stent restenosis.	
Karpenko A, Bugurov S, Ignatenko P et al. (2021) Randomized controlled trial of conventional versus MicroNet-covered stent in carotid artery revascularization. JACC: Cardiovascular Interventions 14: 2377-2387	Randomised controlled trial n=100 Follow up: 30 days	Use of the MicroNet-covered stent in relation to a conventional carotid stent significantly reduced periprocedural cerebral embolism in CAS. Furthermore, cerebral embolism throughout 48 hours to 30 days post-CAS was abolished by the MicroNet-covered stent, while it was ongoing with the conventional single-layer stent.	Small randomised controlled trial, comparing 2 different types of stent.
Karpenko A, Starodubtsev V, Ignatenko P et al. (2020) Comparative analysis of carotid artery stenting and carotid endarterectomy in clinical practice. Journal of Stroke and Cerebrovascular Diseases 29: 104751	Retrospective cohort study n=2,006 Follow up: 30 days	In the asymptomatic subgroup (n=455), the 30-day rate of stroke was not significantly different between the CEA group and the CAS group (2% in both). The 5-year rate of stroke was not significantly higher for CAS than for CEA (5% versus 3%, p=0.3).	Randomised controlled trials with more asymptomatic patients are included.
Karth PA, Siddiqui S, Garbett D et al. (2013) Branch retinal artery occlusion after internal carotid artery angioplasty and stenting. Retinal Cases and Brief Reports 7: 402-405	Case report n=1	**Branch retinal artery occlusion** The patient developed a branch retinal arterial occlusion with visible emboli 24 hours after CAS and was found to have multiple anastomoses between the external carotid artery and ophthalmic artery because of	Case report

		carotid stenosis. He required a second, emergent angioplastic procedure.	
Keyhani S, Cheng E, Hoggatt K et al. (2022) Comparative effectiveness of carotid stenting to medical therapy among patients with asymptomatic carotid stenosis. Stroke 53: 1157–66	Retrospective cohort study n=3,060 (551 CAS) Follow up: 5 years	The observed rate of stroke or death within 30 days in the CAS arm was 2%. Using the target trial methodology, the 5-year risk of fatal and nonfatal stroke was similar among patients assigned to CAS (7%) compared with patients assigned to medical therapy (7%; risk difference, -0.1% [95% CI, -2.6% to 2.7%]). In an analysis that incorporated the competing risk of death, the risk difference between the 2 arms remained nonsignificant (risk difference, -1.5% [95% CI, -3.0% to 0.3%]).	Retrospective non-randomised comparative study.
Khatri R, Chaudhry SA, Vazquez G et al. (2012) Age differential between outcomes of carotid angioplasty and stent placement and carotid endarterectomy in general practice. Journal of Vascular Surgery 55: 72-8	Non-randomised comparative study n=495,331 (most were asymptomatic)	For patients who had CAS, age over 70 years was an important predictor of postoperative stroke (p=0.0025; OR 1.7, 95% CI 1.2 to 2.5) and cardiac complications postprocedure (p=0.045; OR 1.3, 95% CI 1.0 to 1.6).	More recent studies are included.
Kim HW, Regenhardt RW, D'Amato SA, et al. (2022) Asymptomatic carotid artery stenosis: a summary of current state of evidence for revascularization and	Review	Modern medical and surgical advances have continued to improve the outcomes of patients with carotid stenosis. Available decades-old level 1	No meta-analysis.

emerging high-risk features. Journal of NeuroInterventional Surgery. doi:10.1136/neurintsurg-2022-018732		evidence of asymptomatic carotid artery stenosis treatment has become outdated and new ongoing trials, like CREST-2, are needed to uncover the optimal management. Mounting evidence suggests that imaging-based identification of high-risk features may aid in selecting patients with higher risk who may maximally benefit from surgical revascularisation.	
Klarin D, Lancaster RT, Ergul E et al. (2016) Perioperative and long-term impact of chronic kidney disease on carotid artery interventions. Journal of Vascular Surgery 64: 1295-1302	Cohort study n=12,568 (822 CAS) 60% asymptomatic	For asymptomatic patients, the 30-day mortality among the chronic kidney disease groups were low (0.3% mild versus 1% moderate and 0.4% severe; p=0.004), as were the 30-day stroke rates (2% mild versus 1% moderate and 1% severe; p=0.238). The data suggests that both symptomatic and asymptomatic patients with carotid artery stenosis and chronic kidney disease can be offered intervention when they are carefully selected.	Study focuses on impact of chronic kidney disease.
Kohara K, Ishikawa T, Kobayashi T et al. (2018) Retinal artery occlusion during carotid artery stenting with distal embolic protection	Case reports n=2	**Retinal artery occlusion** 2 case reports of retinal artery occlusion that were thought to be caused by an embolus from the external	Case reports

device. Neuroradiology Journal 31: 504-508		carotid artery during carotid artery stenting with a distal embolic protection device for the internal carotid artery. It was likely that the debris that caused retinal artery occlusion passed through collaterals to retinal arteries from the external carotid artery, which was not protected by a distal embolic protection device.	
Kohat AK, Jayantee K, Phadke RV et al. (2014) Beware of parotitis induced by iodine-containing contrast media. Journal of Postgraduate Medicine 60: 75-76	Case report n=1	**Parotitis induced by iodine-containing contrast media** A 51-year-old man developed multiple small infarcts after a second stenting despite the use of distal protection. He also had painful parotid swelling which improved within a week.	Case report
Kokkinidis D, Chaitidis N, Giannopoulos S et al. (2020) Presence of contralateral carotid occlusion is associated with increased periprocedural stroke risk following CEA but not CAS: a meta-analysis and meta-regression analysis of 43 studies and 96,658 patients. Journal of Endovascular Therapy 27: 334-344	Meta-analysis n=96,658 (20,801 CAS)	CAS in the presence of a contralateral carotid occlusion is associated with an increased risk of periprocedural death but not stroke or transient ischaemic attack.	Review focuses on impact of contralateral carotid occlusion.
Kuliha M, Roubec M, Prochazka V et al. (2015) Randomized	Randomised controlled trial	There was a higher risk of silent infarction in the brain on MRI after CAS	Small trial, focusing on

clinical trial comparing neurological outcomes after carotid endarterectomy or stenting. The British Journal of Surgery 102: 194-201	n=150 (42% asymptomatic)	in comparison with CEA, but without measurable change in cognitive function.	neurological outcomes.
Kumar R, Batchelder A, Saratzis A et al. (2017) Restenosis after carotid interventions and its relationship with recurrent ipsilateral stroke: a systematic review and meta-analysis. European Journal of Vascular and Endovascular Surgery 53: 766-775	Systematic review and meta-analysis n=7,201 (11 trials)	CAS patients with untreated asymptomatic more than 70% restenosis had an extremely low rate of late ipsilateral stroke (1% over 50 months). Overall, 97% of all late ipsilateral strokes after CAS and 85% after CEA occurred in patients without evidence of significant restenosis or occlusion.	Review focuses on restenosis after carotid interventions.
Lal BK, Roubin GS, Rosenfield K et al. (2019) Quality assurance for carotid stenting in the CREST-2 Registry. Journal of the American College of Cardiology 74: 3071-3079	Registry n=2,141	The 30-day rate of composite stroke or death was 1% for asymptomatic, 3% for symptomatic, and 2% for all patients.	Studies with more patients or longer follow up are included.
Lal BK, Roubin GS, Jones M et al. (2019) Influence of multiple stents on periprocedural stroke after carotid artery stenting in the Carotid Revascularization Endarterectomy versus Stent Trial (CREST). Journal of Vascular Surgery 69: 800-806	Cohort study n=2,652	Strokes occurred in 118 (5%) of all CAS procedures, in 102 (4%) with the use of one stent, and in 16 (15%) with the use of 2 or 3 stents. After adjustment for demographics, lesion characteristics, and risk factors, the use of more than 1 stent resulted in 2.90 odds (95% CI 1.49 to 5.64) for a stroke.	Study focuses on the impact of multiple stents.

Lal BK, Beach KW, Roubin GS et al. (2012) Restenosis after carotid artery stenting and endarterectomy: A secondary analysis of CREST, a randomised controlled trial. The Lancet Neurology 11: 755-763	Randomised controlled trial (CREST) n=2,191 Follow up: 2 years	In 2 years, 58 patients who had CAS (Kaplan-Meier rate 6%) and 62 who had CEA (6%) had restenosis or occlusion (HR 0.90, 95% CI 0.63 to 1.29; p=0.58). Female sex (1.79, 1.25 to 2.56), diabetes (2.31, 1.61 to 3.31), and dyslipidaemia (2.07, 1.01 to 4.26) were independent predictors of restenosis or occlusion after the 2 procedures.	Secondary analysis of trial that is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Leclerc A, Goia A, Gilard V et al. (2022) Massive non-aneurysmal subarachnoid hemorrhage after cervical carotid angioplasty and stenting: A case report and review of the literature. Neuro-Chirurgie 68: 342-346	Case report n=1	**Massive non-aneurysmal subarachnoid haemorrhage** A 71-year-old man presented a massive non-aneurysmal subarachnoid haemorrhage 1 hour after angioplasty and stenting of the cervical segment of the left internal carotid artery. Medical and surgical management included external ventricular drain placement. Rebleeding occurred 2 days later, worsening the patient's clinical condition. Finally, the patient died 2 weeks later.	Case report
Li Y, Yang J-J, Zhu S-H et al. (2017) Long-term efficacy and safety of carotid artery stenting versus endarterectomy: A meta-analysis of randomized controlled	Meta-analysis n=7,005 (8 trials) asymptomatic and symptomatic	Carotid endarterectomy was found to be superior to stenting for short- and long-term outcomes, although endarterectomy was associated with a	More recent systematic reviews are included.

trials. PloS one 12: e0180804		higher risk of periprocedural myocardial infarction. Carotid endarterectomy should be offered as the first choice for carotid stenosis at present, however, more evidence is needed because rapid progress in concurrent devices and medical treatments is being made.	
Liang P, Soden P, Wyers MC et al. (2020) The role of transfemoral carotid artery stenting with proximal balloon occlusion embolic protection in the contemporary endovascular management of carotid artery stenosis. Journal of Vascular Surgery 72: 1701-1710	Retrospective non-randomised comparative study n=24,232	Compared with transfemoral CAS with distal embolic protection, transfemoral CAS with proximal balloon occlusion has similar major outcomes. However, transfemoral CAS with proximal balloon occlusion does not offer the same degree of embolic protection compared with TCAR with flow reversal, given the significantly higher risk of perioperative stroke or death.	Retrospective analysis, comparing transfemoral CAS using distal protection or proximal balloon occlusion against TCAR with flow reversal.
Lokuge K, de Waard DD, Halliday A et al. (2018) Meta-analysis of the procedural risks of carotid endarterectomy and carotid artery stenting over time. The British Journal of Surgery 105: 26-36	Meta-analysis n=296,274 (72,961 CAS) asymptomatic and symptomatic	Procedural stroke and death rates of CAS did not change significantly over time (5% among symptomatic and 3% among asymptomatic patients). There was substantial heterogeneity in event rates and recruitment periods were long.	More recent systematic reviews are included.
Luebke T, Brunkwall J (2016) Carotid artery stenting versus carotid endarterectomy:	Meta-analysis asymptomatic and symptomatic	Carotid artery stenting as compared with CEA was associated with a 61% increase in the	More recent systematic reviews are included.

updated meta-analysis, metaregression and trial sequential analysis of short-term and intermediate-to long-term outcomes of randomized trials. The Journal of Cardiovascular Surgery 57: 519-39		risk of periprocedural death or stroke (Peto OR 1.6, 95% CI 1.2 to 2.2, p=0.002). Carotid artery stenting as compared with CEA was associated with a 42% increase in the risk for the composite of periprocedural stroke or death plus ipsilateral stroke thereafter (Peto OR 1.4, 95% CI 1.1 to 1.9, p=0.0014).	
Mannheim D, Karmeli R (2017) A prospective randomized trial comparing endarterectomy to stenting in severe asymptomatic carotid stenosis. Journal of Cardiovascular Surgery 58: 814-817	Randomised controlled trial n=136 Follow up: mean 26 months	There was no difference in short- and long-term results between the 2 groups. Thirty day morbidity included: 1 stroke in each group with no myocardial infarction. Long-term results included 4 deaths in each group; none from stroke. One transient ischaemic attack was noted after CAS, and there were 3 cases of restenosis after CEA and 1 after CAS.	Small trial, which is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Matsumura JS, Hanlon BM, Rosenfield K et al. (2021) Treatment of carotid stenosis in asymptomatic, non-octogenarian, standard risk patients with stenting versus endarterectomy trials. Journal of Vascular Surgery 75:1276-83	Pooled analysis of 2 trials n=2,544 Follow up: 4 years	The prespecified, primary composite endpoint of any stroke, myocardial infarction, or death during the periprocedural period or ipsilateral stroke within 4 years after randomisation was 5% in both treatment groups (HR 1.02, 95% CI 0.7 to 1.5, p=0.91). CAS achieved comparable short- and	Data from the 2 trials is included in the systematic review by Müller et al. (2019).

		long-term results to CEA.	
Mazzaccaro D, Giannetta M, Fancoli F et al. (2021) Endovascular treatment of extracranial carotid artery stenosis using a dual-layer micromesh stents: a systematic review. Expert Review of Medical Devices 18: 545-552	Systematic review n=797 (mostly asymptomatic, 13 papers)	During early follow up, complications occurred overall in 2% (16/797) of patients (12 strokes, 3 deaths, and 1 transient ischaemic attack). The study with the longest follow up reported a survival rate of 82% at 4 years and a stroke-free survival rate of 84% at 4 years.	Review focuses on specific type of stent.
Minc SD, Thibault D, Marone L (2022) Outcomes of carotid artery stenting in patients with radiation arteritis compared with those with atherosclerotic disease. Journal of Vascular Surgery 75: 1286-1292	Cohort study n=7,218	The CAS patients with radiotherapy had significantly greater mortality at all time points compared with those without it, even after adjusting for other covariates. No significant difference was found in the incidence of perioperative complications, reintervention, or restenosis between the 2 groups. The results suggest that for this high-risk group, CAS provides the same patency as it does for atherosclerotic carotid stenosis and avoids potentially morbid cranial nerve injury and wound healing complications.	Study focuses on patients with carotid stenosis caused by radiation arteritis.
Modrall JG, Chung J, Kirkwood ML et al. (2014) Low rates of complications for carotid artery stenting are associated with a high	Cohort study n=56,374	The stroke and death rate for CAS to treat carotid stenosis is inversely affected by the number of CAS and endovascular	More recent studies are included.

clinician volume of carotid artery stenting and aortic endografting but not with a high volume of percutaneous coronary interventions. Journal of Vascular Surgery 60: 70-76		aneurysm repair and thoracic endovascular aortic aneurysm repair procedures done by a clinician. In contrast, a high-volume experience with percutaneous coronary interventions is not associated with improved outcomes after CAS.	
Montorsi P, Caputi L, Galli S et al. (2020) Carotid Wallstent versus Roadsaver stent and distal versus proximal protection on cerebral microembolization during carotid artery stenting. JACC. Cardiovascular Interventions 13: 403-414	Randomised controlled trial n=104 Follow up: 6 months	In patients with high-risk, lipid-rich plaque undergoing CAS, the Mo.Ma device plus Roadsaver stent led to the lowest microembolic signals count.	Small randomised controlled trial, comparing different devices.
Moore WS, Voeks JH, Roubin GS et al. (2019) Duration of asymptomatic status and outcomes following carotid endarterectomy and carotid artery stenting in the Carotid Revascularization Endarterectomy vs Stenting Trial. Journal of Vascular Surgery 69: 1797-1800	Randomised controlled trial (CREST) n=1,181 asymptomatic Follow up: 4 years	In CREST, only a small minority of asymptomatic patients had previous ipsilateral symptoms. The outcomes of periprocedural stroke and death, periprocedural stroke and death, and ipsilateral stroke up to 4 years, and the primary end point did not differ for always asymptomatic patients compared with those who had previous symptoms.	Secondary analysis of trial that is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Moresoli P, Habib B, Reynier P et al. (2017) Carotid stenting versus	Systematic review and meta-analysis	The pooled incidences of any periprocedural stroke (RR 1.84; 95%	More recent systematic

endarterectomy for asymptomatic carotid artery stenosis: a systematic review and meta-analysis Stroke 48: 2150-2157	n=3,019 (11 reports of 5 trials)	CI 0.99 to 3.40), periprocedural non-disabling stroke (RR 1.95; 95% CI 0.98 to 3.89), and any periprocedural stroke or death (RR 1.72; 95% CI 0.95 to 3.11) trended toward an increased risk after CAS. We could not rule out clinically significant differences between treatments for long-term stroke (RR 1.24; 95% CI 0.76 to 2.03) and the composite outcome of periprocedural stroke, death or myocardial infarction, or long-term ipsilateral stroke (RR 0.92; 95% CI 0.70 to 1.21).	reviews are included.
Nana P, Kouvelos G, Brotis A. et al. (2021) Early outcomes of carotid revascularization in retrospective case series. Journal of Clinical Medicine 10: 1–12	Systematic review and meta-analysis n=16,043 (15 articles); 68% asymptomatic	CAS did not differ from CEA in terms of stroke (OR 0.98; 0.77 to 1.25; I^2=0%), myocardial ischemic events (OR 1.03; 0.72 to 1.48; I^2=0%) and all events (OR 1.0; 0.82 to 1.21; I^2=0%). Pooled stroke incidence in asymptomatic patients was 1% (95% CI 0 to 2%) for CEA and 1% for CAS (95% CI 0 to 2%). The 2 techniques did not differ in either outcome both in asymptomatic and symptomatic patients.	Other systematic reviews are included.
Nejim B, Mathlouthi A, Weaver L et al. (2020) Safety of carotid artery	Registry n=86,778 (95% asymptomatic)	Atrial fibrillation was associated with worse postoperative	Non-randomised study focusing

revascularization procedures in patients with atrial fibrillation. Journal of Vascular Surgery 72: 2069-2078e4		outcomes in patients with carotid artery disease. Symptomatic status is associated with a stroke or death risk that is higher than in recommended guidelines for CEA and particularly for CAS. Overall, CEA was associated with lower periprocedural intracerebral haemorrhage, mortality, and stroke or death in patients with atrial fibrillation compared with CAS.	on effect of atrial fibrillation.
Nejim B, Alshwaily W, Dakour-Aridi H et al. (2019) Age modifies the efficacy and safety of carotid artery revascularization procedures. Journal of Vascular Surgery 69: 1490-1503e3	Registry n=89,853 asymptomatic and symptomatic	The risk of 30-day stroke and 30-day stroke or death did not differ between the 2 procedures in asymptomatic young patients (less than 65 years). However, 30-day stroke and 30-day stroke or death occurred more often after CAS in asymptomatic patients who were 65 to 75 and 75 years old or older. The annualised incidence rates of ipsilateral stroke were similar between CAS and CEA in young asymptomatic patients but were higher after CAS in older age groups.	Non-randomised study focusing on effect of age.
Nevidomskyte D, Tang GL, Shin SH et al. (2019) Comparison of outcomes in women	Cohort study n=3,704	Hospital composite outcome of stroke and mortality following carotid interventions	Non-randomised study focusing on effect of

and men following carotid interventions in the Washington state's Vascular Interventional Surgical Care and Outcomes Assessment Program. Journal of Vascular Surgery 69: 1121-1128	(45% asymptomatic)	from 2010 to 2015 were noted to be similar for women and men. The notable exception to this finding was observed in a subcohort of women who had CAS for symptomatic carotid disease at age 80 years or older.	sex on outcomes.
Nolan BW, De Martino RR et al. (2012) Comparison of carotid endarterectomy and stenting in real world practice using a regional quality improvement registry. Journal of Vascular Surgery 56: 990-6	Registry n=8,079 procedures (430 CAS) asymptomatic and symptomatic	Asymptomatic patients had similar rates of stroke or death (CAS 0.7% versus CEA 0.9%, p=0.78) and stroke, death, or myocardial infarction (CAS 1% versus CEA 2%; p=0.40).	More recent studies are included.
Noori VJ, Aranson NJ, Malas M et al. (2021) Risk factors and impact of postoperative hypotension after carotid artery stenting in the Vascular Quality Initiative. Journal of Vascular Surgery 73: 975-982	Retrospective cohort study n=24,699 (44% asymptomatic)	Hypotension after CAS is associated with adverse neurologic and cardiac events as well as with prolonged length of stay and in-hospital mortality. A scoring tool may be valuable in stratifying patients at risk. Interventions aimed at preventing postoperative hypotension may improve outcomes with CAS.	Study focuses on impact of hypotension after CAS.
Obeid T, Arnaoutakis DJ, Arhuidese I et al. (2015) Poststent ballooning is associated with increased periprocedural stroke and death rate in carotid artery stenting. Journal	Retrospective cohort study n=3,772 (64% asymptomatic)	The overall perioperative stroke and death rate was 3%. Compared with pre-stent ballooning only technique, the combined pre- and post-stent ballooning technique had a 2.1-	Study focuses on the use of post-stent ballooning.

of Vascular Surgery 62: 616-23e1		fold increase in haemodynamic depression (OR 2.13; 95% CI 1.51 to 3.01, p<0.001) and 2.4-fold increase in perioperative stroke and death rate (OR 2.37; 95% CI 1.01 to 5.62, p<0.050).	
Paraskevas KI, Kalmykov EL, Naylor AR (2016) Stroke/death rates following carotid artery stenting and carotid endarterectomy in contemporary administrative dataset registries: a systematic review. European Journal of Vascular and Endovascular Surgery 51: 3-12	Systematic review More than 1,500,000 procedures from 21 registries	Data from contemporary administrative dataset registries suggest that stroke and death rates following CAS remain significantly higher than after CEA and often exceed accepted American Heart Association thresholds. There was no evidence of a sustained decline in procedural risk after CAS.	More recent studies are included.
Petr O, Brinjikji W, Murad MH et al. (2017) Selective-versus-standard poststent dilation for carotid artery disease: a systematic review and meta-analysis. AJNR. American Journal of Neuroradiology 38: 999-1005	Systematic review and meta-analysis n=19,683 (87 studies)	The meta-analysis demonstrated no significant difference in angiographic and clinical outcomes among series that performed standard post-stent angioplasty and those that performed post-stent angioplasty in only select patients.	Study focuses on the use of post-stent angioplasty.
Pieniazek P, Tekieli L, Musialek P et al. (2012) Carotid artery stenting according to the 'tailored-CAS' algorithm is associated with a low complication rate at 30 days: Data from the TARGET-CAS study.	Case series n=1,081 (48% asymptomatic)	CAS with embolic protection device and stent type selection on the basis of thorough non-invasive diagnostic work-up ('tailored - CAS') is safe. Advanced age was associated with an	More recent studies are included.

Kardiologia Polska 70: 378-386		increased risk of death and the presence of prior neurological symptoms was a predictor of death/stroke at 30 days. With the 'tailored-CAS' approach, 'high-risk' lesion features are eliminated as a risk factor. Hyperperfusion syndrome is a severe CAS complication which may lead to intracranial bleeding and death. Acute, iatrogenic embolic cerebral artery occlusion is rare and may be managed by combined intracranial mechanical and local thrombolytic therapy.	
Pini R, Faggioli G, Gallitto E et al. (2016) Carotid endarterectomy and stenting: A critical analysis of the last randomized controlled trials. Italian Journal of Vascular and Endovascular Surgery 23: 17-25	Meta-analysis of 4 randomised controlled trials n=5,922 procedures (1,181 asymptomatic)	In asymptomatic patients, there were no statistically significant differences in CEA and CAS groups in terms of death/stroke and death/stroke/myocardial infarction.	More recent trials are included.
Pini R, Faggioli G, Longhi M et al. (2014) Impact of postoperative transient ischemic attack on survival after carotid revascularization. Journal of Vascular Surgery 59: 1570-1576	Retrospective cohort study n=1,390 procedures Follow up: 5 years	Overall survival was significantly lower in patients with postoperative transient ischaemic attack (78% versus 97%, p<0.001) and postoperative stroke (68% versus 97%, p=0.03) compared with patients without neurological complications. By means of multivariate	More recent studies are included.

		Cox analysis, postoperative transient ischaemic attack and stroke were independent predictors of decreased survival (HR 3.10, 95% CI 1.01 to 9.72, p=0.04, and HR 3.87, 95% CI 1.13 to 13.19, p=0.03, respectively), other than age over 80 years, postoperative myocardial infarction, and chronic renal failure (HR 2.07, 95% CI 1.41 to 4.90, p=0.01; HR 4.33, 95% CI 2.74 to 23.79, p=0.04; HR 2.54, 95% CI 1.04 to 6.19, p=0.04, respectively).	
Pini R, Faggioli G, Paraskevas KI et al. (2022) Carotid artery stenting with double-layer stent: a systematic review and meta-Analysis. Journal of Endovascular Therapy	Systematic review and meta-analysis n=1,955 (14 studies)	The overall 30-day stroke rate in CAS with double-layer stents is low (1%), with similar results in symptomatic and asymptomatic patients. Acute occlusion of double-layer stents is rare (1%). Further studies are necessary to reduce the publication bias for asymptomatic patients.	Review focuses on 1 type of stent used for CAS.
Poorthuis MHF, Brand EC, Halliday A et al. (2020) A systematic review and meta-analysis of complication rates after carotid procedures performed by different specialties. Journal of Vascular Surgery 72: 335-343e17	Systematic review and meta-analysis n=294,638 (38,605 CAS) 35 studies	For CAS, no differences in procedural stroke or death were found by operator specialty.	Review focuses on operator specialty.

Poorthuis MHF, Brand EC, Halliday A et al. (2019) High operator and hospital volume are associated with a decreased risk of death and stroke after carotid revascularization: a systematic review and meta-analysis. Annals of Surgery 269: 631-641	Systematic review and meta-analysis 87 studies	A decreased risk of death or stroke after CAS was found for high operator volume compared with low operator volume with an adjusted OR of 0.43 (95% CI 0.20 to 0.95; 1 cohort), and an unadjusted RR of 0.50 (95% CI 0.32 to 0.79; 1 cohort); for high hospital volume compared with low hospital volume with an adjusted OR of 0.46 (95% CI 0.26 to 0.80; 1 cohort), and no significant decreased risk in a pooled unadjusted RR of 0.72 (95% CI 0.49 to 1.06; 2 cohorts).	Review focuses on operator and hospital volume.
Qureshi AI, Chaudhry SA, Hussein HM et al. (2012) A comparison of outcomes associated with carotid artery stent placement performed within and outside clinical trials in the United States. Journal of Vascular Surgery 56: 317-23	Cohort study n=81,638	CAS procedures performed as part of clinical trials were associated with lower rates of in-hospital mortality and composite endpoint of stroke, cardiac events, and death in US. These findings highlight the need for strategies that ensure appropriate adoption of CAS to ensure that the benefits observed in clinical trials can be replicated in general practice.	More recent studies are included.
Rahim AA, Thabet MA, Galal AM et al. (2022) Stroke incidence between stenting and endarterectomy for asymptomatic carotid	Best evidence topic 6 randomised controlled trials	The best evidence shows no statistically significant difference in the periprocedural and the long-term non-procedural stroke	No meta-analysis. All 6 trials are included in

artery stenosis. Annals of Medicine and Surgery 79: 104083		incidence among carotid artery stenting and carotid endarterectomy in asymptomatic carotid artery stenosis. However, in high-risk patients, carotid artery stenting may be a better option.	table 2 or table 5.
Reiff T, Eckstein HH, Mansmann U et al. (2019) Angioplasty in asymptomatic carotid artery stenosis vs. endarterectomy compared to best medical treatment: one-year interim results of SPACE-2. International Journal of Stroke	Randomised controlled trial n=513 Follow up: 1 year	The low sample size of this prematurely stopped trial of 513 patients implies that its power is not sufficient to show that CEA or CAS is superior to a modern medical therapy in the primary prevention of ischemic stroke in patients with an asymptomatic carotid stenosis up to 1 year after treatment. Also, no evidence for differences in safety between CAS and CEA during the first year after treatment could be derived.	A more recent publication from the same trial is included.
Rockman CB, Garg K, Jacobowitz GR et al. (2011) Outcome of carotid artery interventions among female patients, 2004 to 2005. Journal of Vascular Surgery 53: 1457-64	Cohort study n=54,658 procedures	Asymptomatic women had a significantly lower perioperative stroke rate after CEA than after CAS (1% versus 2%, p<0.001).	More recent studies are included.
Roh J-H, Cho HJ, Lee J-H et al. (2020) Role of carotid artery stenting in prevention of stroke for asymptomatic carotid stenosis: Bayesian cross-design and	Network meta-analysis 18 studies	The risk for periprocedural stroke tended to increase in CAS, compared with CEA (OR 1.86; 95% credible interval [CrI], 0.62 to 4.54). However,	More recent studies are included.

network meta-analyses. Korean Circulation Journal 50: 330-342		estimates for periprocedural myocardial infarction were quite heterogeneous. Despite a trend of decreased risk with CAS in randomised controlled trials (OR 0.70; 95% CrI 0.27 to 1.24), the risk was similar in non-randomised comparative studies (OR 1.02; 95% CrI, 0.87 to 1.18). In indirect comparisons of medical treatment and CAS, medical treatments showed a tendency to have a higher risk for the composite of periprocedural death, stroke, myocardial infarction, or nonperiprocedural ipsilateral stroke (OR 1.30; 95% CrI, 0.74 to 2.73).	
Rosenfield K, Matsumura JS, Chaturvedi S et al. (2016) Randomized trial of stent versus surgery for asymptomatic carotid stenosis. The New England Journal of Medicine 374: 1011-20	Randomised controlled trial (ACT-1) n=1,453 (all asymptomatic) Follow up: 5 years	Stenting was noninferior to endarterectomy with regard to the rate of the primary composite end point at 1 year. In analyses that included up to 5 years of follow up, there were no significant differences between the study groups in the rates of non-procedure-related stroke, all stroke, and survival.	Trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Ruzsa Z, Nemes B, Pintér L et al. (2014) A	Randomised controlled trial	The transradial approach for carotid	Small trial, comparing 2

randomised comparison of transradial and transfemoral approach for carotid artery stenting: RADCAR (RADial access for CARotid artery stenting) study. EuroIntervention 10: 381-391	n=260	artery stenting is safe and efficacious; however, the crossover rate is higher with transradial access.	different approaches for CAS.
Sannino A, Giugliano G, Toscano E et al. (2018) Double layered stents for carotid angioplasty: A meta-analysis of available clinical data. Catheterization and Cardiovascular Interventions 91: 751-757	Meta-analysis n=635 (10 studies)	This meta-analysis suggests that dual-layered carotid stents could be safely used for the treatment of extracranial carotid artery stenosis, with a relatively low rate of procedural unsuccess, and allow achieving a quite low rate of postprocedural adverse events.	Review focuses on 1 type of stent used for CAS.
Sardar P, Chatterjee S Aronow H et al. (2017) Carotid artery stenting versus endarterectomy for stroke prevention: a meta-analysis of clinical trials. Journal of the American College of Cardiology 69: 2266-2275	Meta-analysis n=6,526 (5 trials) Follow up: mean 5 years	CAS and CEA were associated with similar rates of a composite of periprocedural death, stroke, myocardial infarction, or non-periprocedural ipsilateral stroke. The risk of long-term overall stroke was significantly higher with CAS and was mostly attributed to periprocedural minor stroke. CAS was associated with lower rates of periprocedural myocardial infarction and cranial nerve palsy than CEA.	More recent systematic reviews are included.
Sastry RA, Pertsch NJ, Sagaityte E et al. (2021) Early outcomes after carotid endarterectomy and carotid artery	Cohort study n=84,191 (81,361 CAS)	In a propensity-matched analysis of a large, prospectively collected, national, surgical database, CAS	Mixed population of asymptomatic and

stenting: a propensity-matched cohort analysis. Neurosurgery 89: 653-663		was associated with increased odds of periprocedural stroke, which increased over time. Rates of MI and death were not significantly different between the 2 procedures.	symptomatic patients.
Schneider EB, Black JH 3rd, Hambridge HL et al. (2012) The impact of race and ethnicity on the outcome of carotid interventions in the United States. The Journal of Surgical Research 177: 172-7	Cohort study n=394,835 (47,385 CAS) Asymptomatic and symptomatic	After CAS, there were no racial or ethnic differences in mortality. On univariate analysis, the risk of stroke was greatest in black patients after CAS (p=0.03). However, this was not significant on multivariable analysis.	Non-randomised study focusing on impact of race and ethnicity.
Shi H, Cai Y, Du J J et al. (2016) Comparative study of stenting and drug treatment in patients with asymptomatic severe internal carotid stenosis. Chinese Journal of Cerebrovascular Diseases 13: 623-628 and 633	Randomised controlled trial n=200	Patients with unilateral asymptomatic internal carotid artery stenosis have cognitive dysfunction. Compared with the simple drug treatment, CAS combined with drug therapy is more conducive to improving the cognitive function by improving cerebral blood flow perfusion.	More recent and larger trials are included.
Shishehbor MH, Venkatachalam S, Gray WA et al. (2014) Experience and outcomes with carotid artery stenting an analysis of the CHOICE study (carotid stenting for high surgical-risk patients; Evaluating outcomes through the collection of clinical evidence). JACC: Cardiovascular	Prospective single-arm study (CHOICE) n=5,841 (mostly asymptomatic)	Operator experience, represented by time-related variables, was closely associated with technical performance and 30-day death, stroke and myocardial infarction. The time interval between CAS procedures and the time from first CAS to subsequent CAS are important measures of operator experience.	Study focuses on operator experience.

Interventions 7: 1307-1317		Technical performance based on embolic protection device dwell time is a statistically significant predictor for 30-day death, stroke and myocardial infarction.	
Silver FL, Mackey A, Clark WM et al. (2011) Safety of stenting and endarterectomy by symptomatic status in the Carotid Revascularization Endarterectomy Versus Stenting Trial (CREST). Stroke; a journal of cerebral circulation 42: 675-680	Randomised controlled trial (CREST) n=1,181 asymptomatic Follow up: 4 years	For asymptomatic patients, the stroke and death rates were 3% for CAS and 1% for CEA (HR 1.88; 95% CI 0.79 to 4.42; p=0.15). Rates were lower for those aged less than 80 years.	Trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Simons JP, Goodney PP, Baril DT et al. (2013) The effect of postoperative stroke and myocardial infarction on long-term survival after carotid revascularization. Journal of Vascular Surgery 57: 1581-8	Cohort study n=8,315 CAS and CEA (65% asymptomatic)	During the first year after operation, postoperative stroke conferred a twofold lower survival than that after postoperative MI. By 5 years after operation, these survival curves converged, and the survival disadvantage associated with stroke became similar to that of MI. These data suggest that different postoperative complications after carotid revascularisation have different implications for patients, with decreased short-term survival in patients experiencing a postoperative stroke.	More recent studies are included.

Simonte G, Fiorucci B, Isernia G et al. (2017) Long-term results of tapered stents in endovascular treatment of carotid stenosis. Annals of Vascular Surgery 45: 79-84	Cohort study n=1,368 procedures	The use of conic stents appears to be associated with similar perioperative results when compared with straight stents. Late outcomes suggest a lower risk of restenosis and late neurological events in patients with conical shape stents.	Study focuses on specific type of stent.
Stabile E, Giugliano G, Cremonesi A et al. (2016) Impact on outcome of different types of carotid stent: Results from the European Registry of Carotid Artery Stenting. EuroIntervention 12: e265-e270	Registry n=1,604	Overall, the 30-day stroke and death rate was 1%. At 30 days, 19 strokes occurred (1%): 8 in the group of patients who had a closed-cell (1%), 2 in those with a hybrid-cell (0.4%), 3 in those with a less than 7.5 mm^2 open cell (1%), and 6 in those treated with a more than 7.5 mm^2 open-cell stent (3%) (p=0.045).	Study assesses the impact of different kinds of stent.
Stabile E, de Donato G, Musialek P et al. (2018) Use of dual-layered stents in endovascular treatment of extracranial stenosis of the internal carotid artery: results of a patient-based meta-analysis of 4 clinical studies. JACC. Cardiovascular Interventions 11: 2405-2411	Meta-analysis n=556 (4 studies)	Dual-layered stents can be safely used for CAS, and their use minimises the incremental risk related to symptomatic status and other risk factors.	Review focuses on 1 type of stent used for CAS.
Stabile E, Salemme L, Sorropago G et al. (2010) Proximal endovascular occlusion for carotid artery stenting: results from a prospective registry of	Registry n=1,300 72% asymptomatic Follow up: 30 days	The use of proximal endovascular occlusion for CAS is safe and effective in an unselected patient population. Anatomical or clinical conditions of	Study focuses on impact of proximal endovascular occlusion.

1,300 patients. Journal of the American College of Cardiology 55: 1661-7		high surgical risk were not associated with an increased rate of adverse events.	
Staubach S, Hein-Rothweiler R, Hochadel M et al. (2012) The role of endovascular expertise in carotid artery stenting: results from the ALKK-CAS-Registry in 5,535 patients. Clinical Research in Cardiology 101: 929-37	Registry n=5,535 47% asymptomatic	The results show a gradual reduction of in-hospital stroke rates with increasing centre experience.	Study focuses on operator experience.
Stolker JM, Mahoney EM, Safley DM et al. (2010) Health-related quality of life following carotid stenting versus endarterectomy: results from the SAPPHIRE (Stenting and Angioplasty with Protection in Patients at HIgh Risk for Endarterectomy) trial. JACC. Cardiovascular interventions 3: 515-523	Randomised controlled trial n=334 Follow up: 12 months	Among patients at high surgical risk, CAS was associated with less health status impairment during the first 2 weeks of recovery when compared with CEA. However, these differences had resolved by 1 month after the procedure, and no other differences between revascularisation strategies in health-related quality of life were found.	More recent and larger trials are included.
Sugie A, Yamada M, Yokoyama K et al. (2020) Carotid free-floating thrombus in a stent 6 months after carotid artery stenting. World Neurosurgery 141: 236-239	Case report n=1 Follow up: 6 months	**Carotid free-floating thrombus after CAS** Case report of a 64-year-old man who had CAS for asymptomatic right carotid artery stenosis. Six months after CAS, he was admitted to the emergency department 1 hour after onset of left hemiparesis and dysarthria. His NIHSS	Case report

		score was 10. His medical history was notable for hypertension, chronic renal insufficiency, and type 2 diabetes mellitus. Carotid ultrasonography showed a dumbbell-shaped carotid free-floating thrombus attached to the carotid stent that was moving in synchrony with his heartbeat. It was completely removed using an endovascular approach.	
Sun Y, Ding Y, Meng K et al. (2021) Comparison the effects of carotid endarterectomy with carotid artery stenting for contralateral carotid occlusion. PloS one 16: e0250580	Systematic review and meta-analysis n=6,953 (6 studies) asymptomatic and symptomatic	This study found that CEA and CAS resulted in similar outcomes for patients with contralateral carotid occlusion, while the risk of death was reduced in patients treated with CEA.	Review focuses on impact of contralateral carotid occlusion.
Tekieli L, Musialek P, Kablak-Ziembicka A et al. (2019) Severe, recurrent in-stent carotid restenosis: Endovascular approach, risk factors. Results from a prospective academic registry of 2637 consecutive carotid artery stenting procedures (TARGET-CAS). Postepy w Kardiologii Interwencyjnej 15: 465-471	Registry n=2,637 Follow up: minimum 12 months	Endovascular treatment of carotid in-stent restenosis is safe. Bilateral and high-grade carotid artery stenosis may increase the risk of restenosis.	Study focuses on recurrent in-stent restenosis.
Texakalidis P, Chaitidis N, Giannopoulos S et al. (2019) Carotid	Systematic review and meta-analysis	This study shows that CEA is associated with a statistically significant	Review focuses on outcomes in

revascularization in older adults: a systematic review and meta-analysis. World Neurosurgery 126: 656-663	n=5,955 (9 studies)	lower risk of 30-day stroke in the elderly population compared with transfemoral CAS with distal or proximal protection. No differences were noted in the rates of periprocedural transient ischaemic attack, myocardial infarction, death, and cranial nerve injury between CEA and CAS in the original pooled analysis.	adults aged over 80 years.
Texakalidis P, Tzoumas A, Giannopoulos S et al. (2019) Risk factors for restenosis after carotid revascularization: a meta-analysis of hazard ratios. World Neurosurgery 125: 414-424	Systematic review and meta-analysis n=17,106 (18 studies)	Diabetes, dyslipidemia, female gender, renal failure, hypertension, and smoking were associated with an increased risk of restenosis, and patch endarterectomy and symptomatic status at presentation were associated with a decreased risk of carotid restenosis. Both female gender and current smoking status were only associated with recurrent stenosis after CEA, and hypertension was only associated with restenosis after CAS.	More recent systematic reviews are included.
Texakalidis P, Giannopoulos S, Kokkinidis DG et al. (2018) Carotid artery endarterectomy versus carotid artery stenting for patients with contralateral carotid occlusion: a systematic	Systematic review and meta-analysis n=6,346 (5 studies)	Subgroup analyses of symptomatic and asymptomatic patients did not yield significant differences for stroke, MI, and death. Patients with contralateral carotid occlusion can safely	Review focuses on impact of contralateral carotid occlusion.

review and meta-analysis. World Neurosurgery 120: 563-571e3		undergo both CAS and CEA with similar risks of stroke, MI, and major adverse clinical events. However, patients treated with CEA have a lower risk of 30-day periprocedural mortality.	
Timaran CH, Mantese VA, Malas M et al. (2013) Differential outcomes of carotid stenting and endarterectomy performed exclusively by vascular surgeons in the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST). Journal of Vascular Surgery 57: 303-308	Randomised controlled trial (CREST) n=1,181 asymptomatic	When performed by surgeons, CAS and CEA have similar net outcomes, although the periprocedural risks vary (lower stroke with CEA and lower myocardial infarction with CAS). These data suggest that appropriately trained vascular surgeons may safely offer both CEA and CAS for the prevention of stroke.	Trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).
Tomai F, De Persio G, Petrolini A et al. (2017) Acute pseudoaneurysm following carotid artery stenting. JACC. Cardiovascular Interventions 10: 622-623	Case report n=1	**Pseudoaneurysm** 7 days after CAS, the patient had a pulsatile neck mass and CT showed 2 large pseudoaneurysms at both proximal and distal stent edges, requiring urgent endovascular treatment. Two overlapping stents were implanted with complete exclusion of the pseudoaneurysms, without any complication.	Case report
Tsai M-L, Mao C-T, Chen D-Y et al. (2015) Short- and long-term major cardiovascular adverse events in carotid artery	Cohort study n=2,849 Follow up: mean 2.5 years	Periprocedural acute renal failure significantly increased the mortality rate and the number of major adverse cardiovascular	More recent or larger studies are included.

interventions: A nationwide population-based cohort study in Taiwan. PLoS ONE 10: e0121016		events, and the predict power persisted more than 1 year after the procedure. Age and diabetes mellitus were significant risk factors to predict acute myocardial infarction after carotid artery stenting.	
Turley RS, Freischlag K, Truong T et al. (2019) Carotid stenting and endarterectomy and contralateral carotid occlusion. Journal of Vascular Surgery 70: 824-831	Non-randomised comparative study n=12,370 procedures (422 CAS)	There is currently a bias that contralateral carotid occlusion confers a higher risk on patients undergoing carotid procedures and this notion is manifest in the proportion of CEA and CAS procedures done in the setting of contralateral carotid occlusion. This study observes that it provides only a minor influence on periprocedural stroke risk and that other factors are more closely tied to outcomes of CEA and CAS.	Non-randomised study, focusing on impact of contralateral carotid occlusion.
Varetto G, Frola E, Gibello L et al. (2019) A rare nitinol double-layer micromesh carotid stent complication: late thrombosis-first case reported in literature. Annals of Vascular Surgery 58: 380	Case report n=1	**Late thrombosis** Case report of a 66-year-old female patient treated for asymptomatic carotid stenosis complicated by a symptomatic partial stent thrombosis occurred 3 months after carotid artery stenting.	Case report
Voeks JH, Howard G, Roubin GS et al. (2011) Age and outcomes after carotid stenting and endarterectomy: the	Randomised controlled trial (CREST) n=2,502	For CAS, risk for the primary end point increased with age ($p<0.0001$) by 1.77-times (95% CI 1.38 to	Trial is included in systematic reviews by Wang et al.

carotid revascularization endarterectomy versus stenting trial. Stroke 42: 3484-90		2.28) per 10-year increment; however, there was no evidence of increased risk for CEA-treated patients (p=0.27). Stroke events were the primary contributor to the overall effect modification (p interaction=0.033), with equal risk at 64 years. The treatment-by-age interaction for CAS and CEA was not altered by symptomatic status (p=0.96) or by sex (p=0.45).	(2022) and Müller et al (2019).
Watanabe M, Chaudhry Saqib A, Adil MM et al. (2015) The effect of atrial fibrillation on outcomes in patients undergoing carotid endarterectomy or stent placement in general practice. Journal of Vascular Surgery 61: 927-32	Cohort study n=672,074 mostly asymptomatic 80,878 CAS	The analysis suggests that almost 10% of CAS and CEA is done in patients with atrial fibrillation in general practice, and higher rates of adverse events are observed among these patients, particularly those who have CEA.	Study focuses on effect of atrial fibrillation on outcomes.
Weinberg I, Beckman JA, Matsumura JS et al. (2018) Carotid stent fractures are not associated with adverse events results from the ACT-1 multicenter randomized trial (carotid angioplasty and stenting versus endarterectomy in asymptomatic subjects who are at standard risk for carotid endarterectomy with significant extracranial carotid stenotic	Randomised controlled trial (ACT-1) n=1,021 Follow up: mean 3 years	Of 1021 patients, 939 had at least 1 X-ray during the follow-up period. Stent fracture was reported in 51 (5%) patients. With a maximum follow-up period of 5 years, adverse clinical outcomes occurred in 39 patients with at least 1 X-ray during the follow-up. Of 826 (81%) patients who had both duplex ultrasound and X-ray, 822 were interpretable. There	Trial is included in systematic reviews by Wang et al. (2022) and Müller et al (2019).

disease). Circulation 137: 49-56		was no association between stent fracture and the primary end point (p=0.86) or with restenosis (p=0.53)	
White CJ, Brott TG, Gray WA et al. (2022) Carotid artery stenting: JACC state-of-the-art review. Journal of the American College of Cardiology 80: 155-170	Review	The review supports a recommendation to approve CAS in selected candidates who are symptomatic with a carotid stenosis between 50% and 99% and for asymptomatic patients with carotid stenosis between 70% and 99% for stroke prevention. Optimised CAS strategies have allowed experienced operators to better assess procedure risk before CAS and have led to continued improvement in CAS outcomes. New technologies including enhanced embolic protection devices and dual-layered stents should result in further improvement.	Other systematic reviews are included.
Xin W, Yang S, Li Q et al. (2021) Endarterectomy versus stenting for the prevention of periprocedural stroke or death in patients with symptomatic or asymptomatic carotid stenosis: a meta-analysis of 10 randomized trials. Annals of Translational Medicine 9: 256	Systematic review and meta-analysis n=9,527 (10 trials) 2,770 asymptomatic	Among patients with asymptomatic CS, the rates of minor stroke and stroke in general were higher with stenting than with CEA. Based on the current data, CEA is more beneficial than CAS for 30-day stroke prevention.	A more recent systematic review is included.

Young KC, Jahromi BS (2011) Does current practice in the United States of carotid artery stent placement benefit asymptomatic octogenarians? AJNR. American Journal of Neuroradiology 32: 170-3	Cohort study n=249,592 (31,197 CAS)	CAS is independently associated with increased in-hospital stroke or death (excluding cardiac complications from the composite outcome). In those 80 years old and above, CAS as currently performed may not improve the natural history of asymptomatic carotid stenosis, because in-hospital stroke or death rates following CAS approached 3% in this group.	More recent studies are included.
Yuan G, Zhou S, Wu W et al. (2018) Carotid artery stenting versus carotid endarterectomy for treatment of asymptomatic carotid artery stenosis. International Heart Journal 59: 550-558	Systematic review and meta-analysis n=4,414 (5 studies)	The results suggested that CAS is associated with significantly lower risk of MI and a slightly higher risk of stroke than those with CEA. Both procedures seemed equivalent in terms of the risk of death. In the subgroup analysis, decreased risk of MI after CAS was significant only in the mixed patient group but not in the asymptomatic patient group, whereas the risk of stroke after CAS remained higher in both the mixed and asymptomatic groups.	More recent systematic reviews are included.
Yuo TH, Sidaoui J, Marone LK et al. (2015) Revascularization of asymptomatic carotid stenosis is not appropriate in patients on dialysis. Journal of	Cohort study n=2,131 asymptomatic (326 CAS)	Patients on dialysis have high perioperative and long-term stroke or death rates after CEA or CAS for asymptomatic stenosis, with a median survival	Study focuses on patients on dialysis.

Vascular Surgery 61: 670-674		that is less than recommended by current guidelines. As a result, carotid intervention in these patients appears to be inappropriate.	
Zapata-Arriaza E, Moniche F, Gonzalez A et al. (2016) Predictors of restenosis following carotid angioplasty and stenting. Stroke 47: 2144-7	Cohort study n=1,060 Follow up: median 12 months	9% (97) of patients experienced restenosis during follow up. Occurrence of restenosis was associated with ipsilateral stroke during follow up p=0.049). After Cox regression analysis, hypertension (HR 6.2; 1.9 to 19.9; p=0.002), impaired vasoreactivity (HR 1.7; 1.09 to 2.8; p=0.019), and angioplasty without stent (HR 2.9; 1.2 to 6.8; p=0.012) were independent risk predictors of more than 70% restenosis.	Larger or more recent studies are included.
Zevallos CB, Farooqui M, Quispe-Orozco D et al. (2022) Acute carotid artery stenting versus balloon angioplasty for tandem occlusions: a systematic review and meta-analysis. Journal of the American Heart Association 11: e022335	Systematic review and meta-analysis n=3,014 (34 studies)	Carotid artery stenting and a retrograde approach had higher odds of successful reperfusion and good functional outcomes at 3 months than balloon angioplasty and an anterograde approach, respectively, in patients with tandem occlusions. A randomised controlled trial comparing these techniques with structured antithrombotic regimens and safety outcomes will offer	Review focuses on the effect of tandem occlusions on outcomes.

		definitive guidance in the optimal management of this complex disease.	