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# S3 guideline on diagnosis, treatment, and aftercare of extracranial carotid stenosis

## Short version

Second edition 3 February 2020

AWMF register number: 004-028



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Second edition

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2. Deutsche Gesellschaft für Gefäßchirurgie und Gefäßmedizin/German Vascular Society (DGG, H.-H. Eckstein\*, M. Storck\*)
3. Deutsche Gesellschaft für Neurologie (DGN, P. Ringleb\*, D. Sander\*)
4. German Stroke Society (inkl. Deutsche Schlaganfallhilfe, R. Stingele, D. G. Nabavi)
5. Deutsche Gesellschaft für Ultraschall in der Medizin/ German Society for Ultrasound in Medicine (DEGUM, P. Ringleb\*, D.G. Navabi)
6. Deutsche Gesellschaft für Neuroradiologie (DGNR, A. Dörfler\*, J. Berkefeld\*)
7. Deutsche Röntgen-Gesellschaft (DRG, W. Gross-Fengels)
8. Deutsche Gesellschaft für Interventionelle Radiologie (DEGIR, P. Huppert,)
9. Deutsche Gesellschaft für Angiologie /Gesellschaft für Gefäßmedizin (DGA, H. Lawall\*, R. Langhoff \*)
10. Deutsche Gesellschaft für Kardiologie (DKG, H. Mudra, T. Zeller)
11. Deutsche Diabetes Gesellschaft (DDG, O. Schnell, K. Rittig)
12. Deutsche Gesellschaft für Geriatrie (DGG, Ch. Ploenes, H. Görtz)
13. Dachverband der Österreichischen Gefäßmedizinischen Gesellschaften (G. Fraedrich, B. Rantner)
14. Deutsche Gesellschaft für Thorax-, Herz- und Gefäßchirurgie (DGTHG, M. Czerny)
15. Deutsche Gesellschaft für Neurochirurgie (DGN, K. Schwerdtfeger)
16. German Society of Surgery (DGCH, M. Storck\*, M. Steinbauer)
17. German Society of Anaesthesiology and Intensive Care Medicine (DGAI, R. Litz, K. Engelhard)
18. Deutsche Gefäßliga e.V. (S. Schulte)
19. Deutscher Verband für Physiotherapie (ZVK) e.V. (A. Fründ)
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21. Deutscher Pflegerat (R. Schamberger, J. Hanl)
22. Deutsche Schlaganfallhilfe (D.G. Navabi, R. Stingele)

<sup>1</sup> English translations of scientific societies/organizations are given, whenever available

# 1 Preface

## 1.1 Rationale

Atherosclerotic plaques of the carotid artery are frequently detected in ultrasound examinations. The prevalence of a  $\geq 50\%$  carotid stenosis among adults is approximately 4%, and increases significantly above the age of 65 years to 6–15%. This translates to around 1 million patients in Germany living with a  $\geq 50\%$  carotid stenosis.

In most instances carotid-associated cerebral ischemia is caused by arterio-arterial thromboembolism, a hemodynamic cause of cerebral ischemia is rare in comparison. The spectrum of clinical symptoms ranges from transient retinal or hemispheric cerebral ischemia (a so-called transient ischemic attack, TIA), to severe disabling or fatal stroke. The overall risk of carotid-associated stroke is low, amounting to 1–2%/year in clinically asymptomatic  $\geq 50\%$  stenosis. However, the risk of recurrent stroke increases significantly in patients with symptomatic stenoses.

Approximately 15% of cerebral ischemias are caused by stenosis or occlusion of the extracranial carotid artery. Based on an annual total of over 200,000 ischemic strokes in Germany, the incidence of stroke caused by carotid stenoses is up to 30,000/year.

Prevention of carotid-associated strokes by conservative, endovascular, and surgical treatment methods is thus of high relevance. The first edition of this S3 guideline was published on the AWMF<sup>2</sup> website in 2012. Due to new study data, a revision became necessary and the second edition of this evidence-based consensus guideline is now presented.

## 1.2 Guideline objective and addressees

This guideline aims to ensure optimal nationwide evidence-based care of patients with extracranial atherosclerotic carotid stenosis. The guideline is intended for all parties involved in the diagnosis, treatment, and aftercare of patients. In accordance with the definition of guidelines, this guideline serves physicians and patients in decision-making regarding diagnostic and therapeutic measures. The guideline does not absolve physicians from their obligation to assess the best approach on an individual basis, depending on the patient's overall situation. Deviation from the guideline should be justified in the specific case.

The guideline provides a framework for out- and/or inpatient diagnostic and therapeutic procedures. The task on site is to continuously ensure the quality of treatment. This short version of the guideline includes all recommendations provided in the long version. A pocket guideline and an easy-read version for patients and relatives (patient guideline) are in preparation.

## 1.3 New in the second edition of the S3 guideline

- The content of the individual chapters has been reorganized to avoid repetition as far as possible. The key questions of the first edition of this S3 guideline have been revised in terms of content. Several new issues (e.g., perioperative management of carotid endarterectomy (CEA) or carotid artery stenting (CAS), risk assessment) are now presented in separate chapters/sections.
- A new up-to-date literature search was performed with particular focus on new national and international guidelines, systematic reviews, and relevant clinical trials (see also the guideline report).
- All systematic reviews published from 2014 onwards were subjected to external methodological evaluation (KSR assessments, see guideline report).
- All chapters are preceded by a "*Main aspects in brief*" paragraph, in which the most important recommendations are presented in free text.
- Based on an AWMF recommendation, the former category "good clinical practice (GCP)" has been replaced by "Expert consensus (EC)."

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<sup>2</sup> Association of the Scientific Medical Societies (Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften, AWMF) of Germany, <https://www.awmf.org>

- New recommendations, modified recommendations, and unchanged recommendations taken from the first edition are color coded (**NEW**, **MODIFIED**, or **UNCHANGED**).
- The background text of the individual chapter is structured according to the currentness of the studies and data. All new data are indicated in color code (**NEW** or **MODIFIED**).
- In accordance with AWMF specifications, all members of the Guideline Committee were required to provide detailed information regarding possible conflicts of interest (COI).
- For ease of reading, the masculine form is used throughout; this, however, signifies all genders.

#### 1.4 Grading the strength of recommendations and level of evidence (LoE)

There are three distinct grades of recommendations, the different quality, and strengths of which are indicated by the phrasing ("should," "should be considered," and "may be considered") as well as arrow symbols. Recommendations against an intervention are expressed in words and using arrows. The grade of the recommendation is usually determined by the quality of the evidence. Accordingly, a recommendation based on intermediate-level evidence will generally have an intermediate grade of recommendation. The listed recommendations are based on the evidence available in each case. Where evidence is lacking or incomplete, the consensus recommendations (EC = expert consensus) arrived at in multidisciplinary discussion are specified.

**Table: Grading of level of evidence (LoE) and strength of recommendations**

Study quality	Level of evidence (LoE)	Recommendation	Description	Symbol
<b>Systematic review (meta-analysis) or randomized controlled trials or cohort studies of high quality</b>	1 (high)	"Should"	Strong recommendation	↑↑
<b>Randomized controlled trials or cohort studies of limited quality</b>	2–3 (intermediate)	"Should be considered"	Recommendation	↑
<b>Randomized controlled trials or cohort studies of poor quality, all other study designs</b>	4-5 (low)	"May be considered"	Open recommendation	↔
<b>Expert opinion</b>	None	Expert consensus	-	EC

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### 3 List of abbreviations

Abbreviation	
<b>ACA</b>	Anterior cerebral artery
<b>ACAS</b>	Asymptomatic Carotid Artery Study
<b>ACC</b>	American College of Cardiology
<b>ACES</b>	
<b>ACST</b>	Asymptomatic Carotid Surgery Trial
<b>ACSRS</b>	Asymptomatic Carotid Stenosis and Risk of Stroke
<b>AF</b>	Atrial fibrillation
<b>AHA</b>	American Heart Association
<b>ARR</b>	Absolute risk reduction
<b>ASA</b>	American Stroke Association
<b>BMT</b>	Best medical treatment
<b>CAS</b>	Carotid artery stenting
<b>CAVATAS</b>	Carotid and vertebral artery transluminal angioplasty study
<b>CCA</b>	Common carotid artery
<b>CCD</b>	Color-coded duplex ultrasonography
<b>CCT</b>	Cerebral computed tomography
<b>CEA</b>	Carotid endarterectomy
<b>Ce-MRA</b>	Contrast-enhanced magnetic resonance angiography
<b>CI</b>	Confidence interval
<b>CHD</b>	Coronary heart disease
<b>CNS</b>	Central nervous system
<b>CREST</b>	Carotid revascularization endarterectomy versus stenting trial
<b>CSTC</b>	Carotid Stenosis Trialist Collaboration
<b>CTA</b>	CT angiography
<b>COPD</b>	Chronic obstructive pulmonary disease
<b>DEGUM</b>	Deutsche Gesellschaft für Ultraschall in der Medizin (German Society for Ultrasound in Medicine)
<b>DSA</b>	Digital subtraction angiography
<b>DUS</b>	Duplex ultrasonography
<b>EAS</b>	European Atherosclerosis Society
<b>EC</b>	Expert consensus
<b>ECA</b>	External carotid artery
<b>ECST</b>	European Carotid Surgery Trial
<b>ESA</b>	European Society of Anaesthesiology
<b>ESC</b>	European Society of Cardiology
<b>ESO</b>	European Stroke Organization
<b>ESVS</b>	European Society for Vascular Surgery
<b>EVA3-S</b>	Endarterectomy versus angioplasty in patients with severe symptomatic carotid stenosis
<b>FGD-PET</b>	<sup>18</sup> F-fluorodeoxyglucose positron-emission tomography
<b>FU</b>	Follow-up
<b>GALA</b>	General Anaesthesia versus Local Anaesthesia Trial
<b>GCP</b>	good clinical practice
<b>GSM</b>	Greyscale median
<b>HPS</b>	Hyperperfusion syndrome
<b>HR</b>	Hazard ratio



<b>ICA</b>	Internal carotid artery
<b>ICSS</b>	International Carotid Stenting Study
<b>ITT</b>	Intention-to-treat
<b>LA</b>	Leukoaraiosis
<b>LDL</b>	Low-density lipoprotein
<b>LMWH</b>	Low-molecular-weight heparin
<b>LoE</b>	Level of evidence
<b>MA</b>	Meta-analysis
<b>MES</b>	Microembolic signals
<b>MI</b>	Myocardial infarction
<b>MRA</b>	Magnetic resonance angiography
<b>MRI</b>	Magnetic resonance imaging
<b>mRS</b>	modified Rankin score
<b>NASCET</b>	North American Symptomatic Carotid Endarterectomy Trial
<b>NIH</b>	National Institute of Health
<b>NIHSS</b>	National Institute of Health Stroke Scale
<b>NNT</b>	Number needed to treat
<b>NOAC</b>	Non-vitamin K antagonist oral anticoagulants (=DOAC/direct oral anticoagulants)
<b>OR</b>	Odds ratio
<b>PAOD</b>	Peripheral arterial occlusive disease
<b>PP</b>	Per-protocol
<b>PRF</b>	Pulse repetition frequency
<b>PTA</b>	Percutaneous transluminal angioplasty
<b>QS</b>	Quality assurance
<b>RCT</b>	Randomized controlled trial
<b>RF</b>	Risk factor
<b>RRR</b>	Relative risk reduction
<b>SAPPHIRE</b>	Stenting and angioplasty with protection in patients at high risk for endarterectomy
<b>SPACE</b>	Stent-protected angioplasty versus carotid endarterectomy in symptomatic patients
<b>SR</b>	Systematic review
<b>SSEP</b>	Somatosensory-evoked potentials
<b>TCD</b>	Transcranial Doppler/duplex sonography
<b>TE</b>	Thromboembolism
<b>TIA</b>	Transient ischemic attack
<b>UFH</b>	Unfractionated heparin
<b>UK</b>	United Kingdom
<b>VA Study No.309</b>	Veteran Affairs Trial No. 309
<b>VKA</b>	Vitamin K antagonists

## 4 Epidemiology of extracranial carotid stenosis

### 4.1 Main aspects in brief

- The prevalence of  $\geq 50\%$  carotid stenosis (according to NASCET) in the population is 4.2%.
- In Germany, approximately 15% of all cerebral ischemias are caused by a  $\geq 50\%$  stenosis or occlusion of the extracranial carotid artery.
- Population-based screening has revealed that current nicotine consumption, age, male sex, and a history of vascular disease are significantly associated with the presence of a  $\geq 50\%$  carotid stenosis.
- Differential CT and MRI analyses are also able to identify plaque ulceration and/or plaque hemorrhage in  $< 50\%$  stenosis.
- Detection of plaque hemorrhage in MRI is associated with a significantly increased risk of cerebral infarction in patients with an asymptomatic carotid stenosis.
- Due to optimized conservative treatment, the risk of ipsilateral cerebral infarction in **asymptomatic**  $\geq 50\%$  carotid stenosis has continually decreased and is currently around 1%/year.

### 4.2 How high is the prevalence of extracranial carotid stenosis in Germany?

No recommendations. The background text<sup>3</sup> was approved with strong consensus.

### 4.3 How high are the prevalence and incidence of carotid-associated cerebral ischemia in Germany?

No recommendations. The background text was approved with strong consensus.

### 4.4 Which clinical and morphological variables influence the occurrence of carotid-associated cerebral ischemia in asymptomatic carotid stenosis?

No recommendations. The background text was approved with strong consensus.

### 4.5 Which clinical and morphological factors influence the occurrence and prognosis of carotid-associated cerebral ischemia in symptomatic stenosis/after carotid-related cerebral ischemia?

No recommendations. The background text was approved with strong consensus.

### 4.6 How frequent is an occlusion of the extracranial internal carotid artery and how high is the risk of stroke arising from an acute/chronic carotid occlusion?

No recommendations. The background text was approved with strong consensus.

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<sup>3</sup> Background text available in German only on <https://www.awmf.org/leitlinien/detail/II/004-028.html>

## 5 Symptoms and diagnosis of carotid stenosis

### 5.1 Main aspects in brief

- Routine screening for carotid stenosis should not be performed.
- Whenever carotid stenosis is suspected, color-coded duplex ultrasonography (DUS) should be performed by an experienced examiner. If there is any doubt about grading of the carotid stenosis or DUS is complicated by additive intrathoracic or intracranial vascular processes or by hemodynamically relevant contralateral vascular alterations, additional CTA or MRA is recommended.
- The first step in distinguishing between asymptomatic and symptomatic stenosis comprises detailed medical history taking and clinical neurological examination. The distinction should be made by a neurologist experienced in stroke diagnostics.
- When a carotid stenosis has caused ipsilateral cerebral infarction, ipsilateral transient ischemic attack (TIA), or ipsilateral retinal ischemia during the previous 6 months, it is classified as symptomatic. If imaging demonstrates a recent ipsilateral, clinically silent ischemia, the stenosis can be regarded as symptomatic and treated accordingly. However, no comparative studies are available for this patient group.
- Planned revascularization of the carotid artery should be preceded in symptomatic patients by imaging of the brain parenchyma. Such imaging can also yield important additional information in asymptomatic patients.
- Before aortocoronary bypass surgery, DUS should be considered in patients  $\geq 70$  years, in patients with history of TIA or stroke or a carotid bruit, or in the presence of left main stem stenosis, to enable these patients to be better informed about the increased treatment-associated risk in the presence of carotid stenosis.

### 5.2 Definition of asymptomatic and symptomatic carotid stenosis

#### 5.2.1 Recommendations

Recommendations	Grade*	LoE°
<b>UNCHANGED:</b> The first step to distinguish between asymptomatic and symptomatic stenosis comprises detailed medical history and clinical neurological examination. The distinction should be made by a neurologist experienced in stroke diagnostics	EC	
<b>UNCHANGED:</b> A stenosis is classified as asymptomatic if no stenosis-associated symptoms have occurred during the previous 6 months	EC	
<b>MODIFIED:</b> When a carotid stenosis has caused ipsilateral cerebral infarction, ipsilateral transient ischemic attack (TIA), or ipsilateral retinal ischemia during the previous 6 months, it is classified as symptomatic	EC	
<b>MODIFIED:</b> If suitable imaging demonstrates a recent ipsilateral, clinically silent ischemia, the stenosis can be regarded as symptomatic and treated. However, no comparative studies are available for this patient group	EC	

## 5.2.2 Which scales are required, suitable, and recommendable for evaluating the severity of cerebral ischemia?

### 5.2.3 Recommendations

Recommendation	Grade*	LoE°
<b>UNCHANGED:</b> An established stroke scale should be used for quantification of clinical neurological symptoms. The NIH Stroke Scale is recommendable. To quantify the disability resulting from stroke, the modified Rankin scale should be used. To describe the degree of functional independence, the Barthel index should be used.		EC

## 5.3 Which examination techniques are valid for diagnosing and monitoring extracranial carotid stenosis?

### 5.3.1 Recommendations

Recommendations	Grade*	LoE°
<b>MODIFIED:</b> Auscultation should not be used to detect a stenosis of the internal carotid artery	↑	2
<b>MODIFIED:</b> Whenever carotid stenosis is suspected, color-coded duplex ultrasonography (DUS) should be performed by an experienced examiner	↑↑	1
<b>UNCHANGED:</b> If there is any doubt about grading of the carotid stenosis or DUS is complicated by additive intrathoracic or intracranial vascular processes or by hemodynamically relevant contralateral vascular alterations, additional CTA or MRA is recommended		EC
<b>MODIFIED:</b> Diagnostic digital subtraction angiography with selective probing of the carotid artery should not be performed routinely. This should only be performed when the results of noninvasive methods do not permit a conclusive statement and a therapeutic consequence results. The rate of complications should be under 0.5%	↑	1
<b>UNCHANGED:</b> When reporting the grade of a carotid stenosis, the diagnostic technique, and the definition of stenosis (NASCET) used for quantification should be stated		EC
<b>UNCHANGED:</b> If follow-up examinations are planned, a noninvasive method — generally DUS — should be used		EC
<b>UNCHANGED:</b> An increase in the degree of stenosis should be assumed from a difference of $\geq 10\%$		EC
<b>UNCHANGED:</b> Ultrasound examination should be performed according to DEGUM <sup>4</sup> recommendations		EC
<b>MODIFIED:</b> In the presence of extracranial carotid stenosis, the demonstration/exclusion of a tandem stenosis can be helpful to determine an individualized treatment indication		EC

<sup>4</sup> German Society for Ultrasound in Medicine (Deutsche Gesellschaft für Ultraschall in der Medizin, DEGUM)

**Table: Grading stenosis of the internal carotid artery according to the current DEGUM<sup>5</sup> criteria**

Stenosis grade (NAS CET definition) [%]		10	20–40	50	60	70	80	90	Occlusion
Stenosis grade old (ECST definition) [%]		45	50–60	70	75	80	90	95	Occlusion
<b>Main criteria</b>	1. B-mode scan	+++	+						
	2. Color Doppler ultrasound	+	+++	+	+	+	+	+	+++
	3. Peak systolic velocity at maximum stenosis [cm/s], approx.			200	250	300	350-400	100-500	
	4. Peak systolic velocity poststenotic [cm/s]					>50	<50	<30	
	5. Collaterals and precursors (periorbital arteries/ACA)					(+)	++	+++	+++
<b>Additional criteria</b>	6. Diastolic flow reduction prestenotic (CCA)					(+)	++	+++	+++
	7. Poststenotic flow disturbance			+	+	++	+++	(+)	
	8. End diastolic velocity at maximum stenosis [cm/s]			up to 100	up to 100	over 100	over 100		
	9. Confetti sign				(+)	++	++		
	10. Stenosis index ICA/CCA			≥2	≥2	≥4	≥4		

**Notes:** ACA: anterior cerebral artery. CCA: common carotid artery. ICA: internal carotid artery. Stenosis grade according to NAS CET [%]: the figures relate to a 10% range (±5%).

Criterion 2: Detection of low-grade stenosis (local aliasing effect) differentiated from non-stenosing plaque, visualization of flow direction in moderate and high-grade stenosis, and detection of vessel occlusion

Criterion 3: Applies to stenoses of length 1–2 cm, limited applicability in multivessel disease

Criterion 4: Measurement far distal, beyond the zone with jet stream and flow disturbance

Criterion 5: It is possible that only one collateral connection is affected: if the examination is extracranial only, the findings are of less value

Criterion 9: The confetti sign can only be detected at a low pulse repetition frequency (PRF)

## 5.4 Which diagnostic tests are required before planned surgery or intervention?

### 5.4.1 Recommendations

Recommendations	Grade*	LoE <sup>o</sup>
<b>UNCHANGED:</b> All patients with a carotid stenosis should undergo clinical neurological examination	EC	
<b>UNCHANGED:</b> Vascular risk factors should be systematically assessed in all patients with a carotid stenosis	EC	
<b>MODIFIED:</b> Due to the possible existence of additional prognostically relevant atherosclerotic diseases of other organ systems, cardiovascular and peripheral vascular examinations should be performed in patients with carotid artery stenosis according to the corresponding guidelines.	EC	
<b>NEW:</b> If CEA is considered, DUS assessment of the degree of stenosis should be confirmed by CTA or MRA or by repeated DUS performed by another qualified examiner	↑	1
<b>NEW:</b> If CAS is considered, DUS should be supplemented by CTA or MRA to obtain additional information about the aortic arch, stenosis morphology, and the extra- and intracranial circulation	↑↑	1
<b>UNCHANGED:</b> Planned revascularization of the carotid artery should be preceded in symptomatic patients by imaging of the brain parenchyma. Such imaging can also yield important additional information in asymptomatic patients	EC	

<sup>5</sup> German Society for Ultrasound in Medicine (Deutsche Gesellschaft für Ultraschall in der Medizin, DEGUM)

#### 5.4.2 Is screening (of risk groups) rational?

#### 5.4.3 Recommendations

Recommendations	Grade*	LoE°
<b>UNCHANGED:</b> Routine screening for carotid stenosis should not be performed	↑↑	1
<b>MODIFIED:</b> In the presence of vascular risk factors and/or existing atherosclerotic disease in other territories, DUS of the carotid artery may be helpful. This examination should be limited to patients in whom therapeutic consequences can be anticipated	EC	
<b>UNCHANGED:</b> Due to the increased risk associated with stenosis progression, regular follow-up examinations are recommended for patients with $\geq 50\%$ asymptomatic carotid stenosis	EC	
<b>UNCHANGED:</b> In patients with $\geq 50\%$ asymptomatic carotid stenosis, the first follow-up should be performed 6 months after initial diagnosis. If the findings are unchanged, annual follow-up is recommended	EC	
<b>NEW:</b> The sonographic detection of atherosclerotic carotid plaques may affect the cardiovascular risk estimation	EC	
<b>NEW:</b> Patients with proven abdominal aortic aneurysm should be examined for stenosis of the internal carotid artery by DUS prior to the procedure, if therapeutic consequences may be anticipated	EC	

## 6 Treatment methods

### 6.1 Main aspects in brief

- The indication for invasive treatment of a carotid stenosis should be determined by an interdisciplinary team with involvement of a neurologist experienced in the diagnosis and treatment of carotid stenosis in consultation with the therapists.
- All patients with an asymptomatic or a symptomatic carotid stenosis should be recommended a balanced mixed whole-food diet and physical activity. Smoking must be ceased.
- All patients with a  $\geq 50\%$  asymptomatic atherosclerotic carotid stenosis should take 100 mg aspirin/day, providing the risk of hemorrhage is low.
- All patients with a  $\geq 50\%$  asymptomatic carotid stenosis should take a statin for long-term prevention of cardiovascular events (stroke, myocardial infarction, etc.). LDL cholesterol should be lowered in a risk-adapted manner according to current guidelines.
- In the presence of a 60–99% asymptomatic carotid stenosis, carotid endarterectomy (CEA) should be considered, provided there is no increased surgical risk and one or more clinical or imaging findings are available that are associated with an increased risk of carotid-related stroke in follow-up.
- In the presence of a 60–99% asymptomatic carotid stenosis, carotid artery stenting (CAS) may be considered, provided there is no increased treatment-associated risk and one or more clinical or imaging findings are available that are presumably associated with an increased risk of carotid-related stroke in follow-up.
- The periprocedural stroke/death rate should be as low as possible for CEA or CAS of an asymptomatic stenosis. The in-hospital stroke/death rate should be monitored by expert neurologists and should not exceed 2%.
- In patients with a 70–99% stenosis after retinal ischemia, TIA, or nondisabling stroke, CEA should be performed.
- CEA should also be performed in patients with a symptomatic 50–69% stenosis when no increased surgical risk is present. Male patients with a recent history of hemispheric symptoms (retinal ischemia, TIA, cerebral infarction mRS <3) will profit most.
- CAS may be considered in symptomatic patients with a 50–99% carotid stenosis and normal surgical risk.
- The complications rates of CEA and CAS for symptomatic carotid stenosis should be monitored by neurologists. The documented combined rate of periprocedural stroke and death during the hospital stay should not exceed 4% for all (early) elective CEA or CAS procedures.
- CEA should be performed as soon as possible (within 3–14 days) after the index event.
- Patients with disabling stroke (modified Rankin score (mRS) >2) may also be treated with CEA or CAS if a benefit in terms of secondary prophylaxis of neurological deterioration is anticipated. Patients should be neurologically stable prior to the intervention.
- CAS should be considered as an alternative to CEA in symptomatic patients with a high surgical risk.
- As a contralateral carotid occlusion can increase the risk of CEA treatment, the indication should be determined and the treatment method selected (CEA or CAS) based on clinical and morphological variables.
- Patients with acute stroke and embolic occlusion of a large intracranial artery in the context of an extracranial carotid stenosis or carotid occlusion should undergo endovascular revascularization without delay.
- In selected cases (e.g., stroke in evolution, free-floating thrombus, crescendo TIA), CEA or CAS should also be performed within the first hours after the index event in consultation with stroke specialists.

## 6.2 Who should determine the indication for a particular treatment technique and on which clinical and device-based findings should the decision be based?

### 6.2.1 Recommendations

Recommendation	Grade*	LoE°
<b>UNCHANGED:</b> The indication for invasive treatment of a carotid stenosis should be determined on an interdisciplinary basis with involvement of a neurologist experienced in the diagnosis and treatment of carotid stenosis in consultation with the therapists		EC

## 6.3 When is open surgery or endovascular treatment indicated for an asymptomatic carotid stenosis, including subgroups that are more likely to benefit from surgical, endovascular, or conservative treatment?

### 6.3.1 Recommendations for conservative treatment of asymptomatic carotid stenosis

Recommendations	Grade*	LoE°
<b>NEW:</b> All patients with an asymptomatic carotid stenosis should be recommended a balanced mixed whole-food diet and physical activity. Smoking must be ceased	↑↑	2a
<b>NEW:</b> All patients with a $\geq 50\%$ asymptomatic atherosclerotic carotid stenosis should take 100 mg aspirin/day, providing the risk of bleeding is low	↑	2a
<b>NEW:</b> In patients with diabetes mellitus and/or arterial hypertension, the diabetes and/or hypertension should be treated according to current guidelines		EC
<b>NEW:</b> All patients with a $\geq 50\%$ asymptomatic carotid stenosis should take a statin for long-term prevention of cardiovascular events (stroke, myocardial infarction, etc.). LDL cholesterol should be lowered in a risk-adapted manner according to current guidelines		EC
<b>UNCHANGED:</b> Patients with an asymptomatic carotid stenosis $< 60\%$ should be treated conservatively, since they do not benefit from invasive treatment		EC

### 6.3.2 Recommendations for surgical and endovascular treatment of asymptomatic carotid stenosis

Recommendations	Grade*	LoE°
<b>NEW:</b> In the presence of a 60–99% asymptomatic carotid stenosis, CEA should be considered provided there is no increased surgical risk and one or more clinical or imaging findings are available that are associated with an increased risk of carotid-related stroke in follow-up	↑	1
<b>NEW:</b> In the presence of a 60–99% asymptomatic carotid stenosis, CAS may be considered provided there is no increased treatment-associated risk and one or more clinical or imaging findings are available that are presumably associated with an increased risk of carotid-related stroke in follow-up	↔	2a
<b>NEW:</b> The periprocedural stroke/death rate should be as low as possible for CEA or CAS of an asymptomatic stenosis. The in-hospital stroke/death rate should be monitored by expert neurologists and should not exceed 2%	↑↑	2a



**Table: Correlation between the risk of late stroke in patients with an asymptomatic 50–99% carotid stenosis and clinical and imaging/morphological variables (adapted from ESVS 2018 and ESC 2018)**

Clinical variables / study	Stroke rate/interval	OR/HR/ARR (95% CI), <i>p</i> -value
Men <75 years, 60–99% stenosis, ACST-1	BMT: 12.3% in 5 years CEA: 5.8% in 5 years BMT: 18.1% in 10 years CEA: 12.7% in 10 years	ARR: 6.5% (3.6–9.4), <i>p</i> <0.0001 ARR: 5.5% (0.9–10.0), <i>p</i> =0.02
Women <75 years, 60–99% stenosis, ACST-1	BMT: 8.4% in 5 years CEA: 5.9% in 5 Years BMT: 16.0% in 10 years CEA: 10.2% in 10 years	ARR: 2.5% (-1.2–6.1), n.s. ARR: 5.8% (0.1–11.4), <i>p</i> =0.05
*Contralateral TIA/stroke in 60–99% stenosis, ACSRS study	YES: 3.4%/year* NO: 1.2%/year*	RR 3.0 (1.9–4.73), <i>p</i> =0.0001
Imaging / Morphological variables / study	Stroke rate/interval	OR/HR/ARR (95% CI), <i>p</i> -value
*Silent infarction in CCT in 60–99% stenosis, ACSRS study	YES: 3.6%/year NO: 1.0%/year	3.0 (1.46–6.29), <i>p</i> =0.002
Stenosis grade, meta-analysis	50–70% vs. >70–99%	1.6% vs. 2.4%/year
*Progression of 50–99% carotid stenosis, ACSRS study: Regression 3.8%, unchanged (76.4%), progression (19.8%)	Regression: 0%/year Unchanged: 1.1%/year Progression: 2.0%/year	1.92 (1.14–3.25), <i>p</i> =0.05
*Progression of 70–99% carotid stenosis in ACST-1: IRR (incidence rate ratio) reported, univariate analysis for each ipsilateral neurological event in FU (≥5 years)	Regression Unchanged Progression by 1 grade Progression by 2 grades	0.7 (0.4–1.3) Comparator 1.6 (1.1–2.4) 4.7 (2.3–9.6)
*Plaque echolucency in DUS in ≥50% carotid stenosis, MA	Echolucent 4.2%/year vs. echogenic 1.6%/year	RR 2.61 (1.47–4.63), <i>p</i> =0.001
*Carotid plaque imaging in MRI, MA: Data for asymptomatic 50–79% stenosis, FU 19–38 months	Hemorrhage YES vs. NO	3.66 (2.70–4.95), <i>p</i> <0.01
*CTA-based morphology of 30–99% extracranial carotid stenosis, MA: CTA performed 2 weeks–6 months after neurological event	Soft plaques Plaque ulceration Increased CCA wall thickness Calcified plaque	OR 2.9 (1.4–6.0) OR 2.2 (1.4–3.4) OR 6.2 (2.5–15.6) OR 0.5 (0.4–0.7)
*Plaque area (70–99% stenosis, CT analysis, ACSRS study): Data from ESVS guideline 2018	<40 mm <sup>2</sup> : 1.0%/year 40–80 mm <sup>2</sup> : 1.4%/year >80 mm <sup>2</sup> : 4.6%/year	HR 1.0 2.08 (1.05–4.12) 5.81 (2.67–12.67)
*Juxtaluminal black area, computer-based DUS plaque analysis (50–99% carotid stenosis, ACSRS study)	<4 mm <sup>2</sup> : 0.4%/year 4–8 mm <sup>2</sup> : 1.4%/year 8–10 mm <sup>2</sup> : 3.2%/year >10 mm <sup>2</sup> : 5.0%/year	Trend <i>p</i> <0.001
*Spontaneous microembolization (TCD), MA	YES vs. NO	OR 7.5 (2.24–24.89), <i>p</i> =0.001
*Spontaneous microembolization (TCD) PLUS predominantly hypoechogenic plaques: ACES study, multicentric, FU 1.8 years	YES: 8.9%/year NO: 0.8%/year	OR 10.6 (2.98–37.8), <i>p</i> =0.0003
*Limited cerebrovascular reserve capacity in 70–99% carotid stenosis, MA: Subgroup of the ACES study, FU 1.8 years	YES vs. NO	OR 6.14 (1.27–29.5), <i>p</i> =0.02
Limited cerebrovascular reserve capacity in 70–99% carotid stenosis, MA (TCD, 9 studies, FU 750 days), only asymptomatic stenosis ( <i>n</i> =330)	Percentage increase in flow velocity <20% vs. >20%	HR 2.90 (1.02–8.30)

\*only ipsilateral stroke, \*also listed in the ESVS and ESC guidelines

Prospective studies only, median age and follow-up (FU), BMT=best medical treatment, MA=meta-analysis

## 6.4 When and at which timepoint are CEA or CAS indicated in patients with a symptomatic carotid stenosis, including subgroups that are more likely to benefit from surgical, endovascular, or conservative treatment?

### 6.4.1 Recommendations for conservative treatment of symptomatic carotid stenosis

Recommendations	Grade*	LoE°
<b>NEW:</b> All patients with an asymptomatic carotid stenosis should be recommended a balanced mixed whole-food diet and physical activity. Smoking must be ceased	↑↑	2a
<b>NEW:</b> Patients with a symptomatic carotid stenosis should be treated with platelet inhibition (aspirin 100 mg or clopidogrel 75 mg)	↑↑	2a
<b>NEW:</b> In patients presenting with a mild neurological syndrome (TAI with a high risk of recurrence, NIHSS ≤4) within 12 hours of symptom onset, dual platelet inhibition may be considered for 10–21 days with 100 mg ASS and 75 mg clopidogrel after loading with 300 mg clopidogrel	↔	2a
<b>NEW:</b> In patients with diabetes mellitus and/or arterial hypertension, the diabetes and/or hypertension should be treated according to current guidelines	EC	
<b>NEW:</b> All patients with a symptomatic carotid stenosis should take a statin for long-term prevention of cardiovascular events. LDL cholesterol should be lowered in a risk-adapted manner according to current guidelines	EC	
<b>UNCHANGED:</b> Patients with a symptomatic carotid stenosis <50% should be treated conservatively, since they do not benefit from invasive treatment	↑↑	1a

### 6.4.2 General recommendations for surgical and endovascular treatment of symptomatic carotid stenosis

Recommendations	Grade*	LoE°
<b>MODIFIED:</b> In patients with a 70–99% stenosis after retinal ischemia, TIA, or nondisabling stroke, CEA should be performed	↑↑	1a
<b>MODIFIED:</b> CEA should also be performed in patients with a symptomatic 50–69% stenosis when no increased surgical risk is present. Male patients with a recent history of hemispheric symptoms (retinal ischemia, TIA, cerebral infarction mRS <3) will profit most	↑	2a
<b>MODIFIED:</b> CAS may be considered in symptomatic patients with a 50–99% carotid stenosis and normal surgical risk	↔	2a
<b>MODIFIED:</b> The complications rates of CEA and CAS for symptomatic carotid stenosis should be monitored by neurologists. The documented combined rate of periprocedural stroke and death during the hospital stay should not exceed 4% for all (early) elective CEA or CAS procedures	EC	
<b>MODIFIED:</b> In addition to patient-specific and anatomic factors, the treatment decision should also consider the patient's preferences. This requires that the patient be provided with adequate information and explanations according to his individual needs	EC	

### 6.4.3 Personalized recommendations for subgroups with symptomatic stenosis who are more likely to profit from CEA, CAS, or BMT only

Recommendations	Grade*	LoE°
<b>UNCHANGED:</b> CEA should be performed as soon as possible (within 3–14 days) after the index event	↑↑	2
<b>MODIFIED:</b> Patients with disabling stroke (mRS >2) may also be treated with CEA or CAS if a benefit in terms of secondary prophylaxis of neurological deterioration is anticipated. Patients should be neurologically stable prior to the intervention	EC	
<b>NEW:</b> CEA and CAS should only be considered in patients with symptomatic <50% stenosis if stenosis-associated symptoms recur under best medical treatment. In these rare situations, interdisciplinary consensus should always be obtained	EC	
<b>NEW:</b> In patients with pseudo-occlusions and recurrent symptoms under best medical treatment, CEA or CAS can be considered	EC	
<b>NEW:</b> CEA may have advantages over CAS in the following situations: <ul style="list-style-type: none"> <li>▪ Patients ≥70 years</li> <li>▪ Early elective CEA after a neurological/retinal index event</li> <li>▪ Long-segment, severely calcified, elongated, or ulcerated stenosis</li> <li>▪ Complicated approach for CAS: aortic arch type III, aortic arch calcification</li> </ul>	EC	
<b>UNCHANGED:</b> CAS should be considered as an alternative to CEA in symptomatic patients with a high surgical risk	↑	2
<b>UNCHANGED:</b> CAS can have advantages over surgery in the following situations, provided performed in an experienced center with adherence to quality criteria: <ul style="list-style-type: none"> <li>▪ Restenosis after CEA</li> <li>▪ Radiogenic stenosis</li> <li>▪ Anatomically high carotid bifurcation (above the C2 level)</li> <li>▪ Tandem stenosis with high-grade intracranial stenosis</li> <li>▪ Tandem stenosis with high-grade intrathoracic stenosis</li> <li>▪ Contralateral paresis of recurrent laryngeal nerve</li> </ul>	EC	
<b>NEW:</b> As a contralateral occlusion can increase the risk of treatment, the indication should be determined and the treatment method selected (CEA or CAS) based on clinical and morphological variables	EC	

## 6.5 Emergency CEA and emergency CAS

### 6.5.1 Recommendations

Recommendations	Grade*	LoE°
<b>NEW:</b> Patients with acute stroke and embolic occlusion of a large intracranial artery in the context of an extracranial carotid stenosis or carotid occlusion should undergo endovascular revascularization without delay	↑↑	1a
<b>MODIFIED:</b> In selected cases (e.g., stroke in evolution, free-floating thrombus, crescendo TIA), CEA or CAS should also be performed within the first hours after the index event in consultation with stroke specialists	↑	2

## 6.6 How should patients with a high-grade carotid stenosis and planned coronary bypass surgery be treated? Surgically or endovascularly? Simultaneously or sequentially?

### 6.6.1 Recommendations

Recommendations	Grade*	LoE°
<b>NEW:</b> In patients with retinal ischemia, TIA, or stroke in the past 6 months, carotid DUS or another noninvasive diagnostic procedure should be performed before planned coronary bypass surgery	↑↑	1a
<b>NEW:</b> In patients without retinal ischemia, TIA, or stroke in the past 6 months, carotid DUS may be considered before planned coronary bypass surgery in the following situations: age over 70 years, multivessel coronary artery disease, PAOD, or carotid bruit	↔	2a
<b>NEW:</b> The differential indication for simultaneous surgery or sequential treatment of carotid stenosis should be determined in a multidisciplinary team (cardiology, cardiac surgery, neurology, vascular surgery, neuroradiology)	EC	
<b>NEW:</b> In patients with a symptomatic 50–99% carotid stenosis and planned coronary bypass surgery, sequential or simultaneous CEA of the carotid stenosis should be performed. The decision should be based primarily on the leading clinical symptoms	↑↑	2a
<b>NEW:</b> In the presence of bilateral 70–99% asymptomatic carotid stenoses or a unilateral 70–99% stenosis and a contralateral carotid occlusion and required coronary bypass surgery, simultaneous or sequential revascularization of the carotid stenosis may be considered	↔	2a

## 6.7 CEA/CAS from the patient's perspective—impact on quality of life

No recommendations

## 6.8 What are the long-term clinical and morphologic outcomes after CEA and CAS?

No recommendations

## 7 Surgical treatment

### 7.1.1 Main aspects in brief

- The selection of the surgical technique (eversion CEA, conventional CEA with patch) should depend on the operating surgeon's personal experience. A patch should always be applied in conventional CEA.
- The decision to deploy a temporary shunt should be based on any observed clamping ischemia or preoperative demonstration of poor cerebral collateral blood supply.
- Intraoperative duplex ultrasonography and/or angiography should be performed for intraoperative quality assurance. Upon detection of a >50% residual stenosis, large free-floating plaques, thromboses, or a dissection, immediate correction should be undertaken.
- Since there is no distinct difference between the 30-day results after local/regional anesthesia or general anesthesia, either can be used. In choosing between the two, the patient's preference and the individual experience and competency of the anesthesiology/vascular surgery team should be considered.
- The anesthesiology/vascular surgery team should offer the option of ultrasound-guided local/regional anesthesia because clamping ischemia can be detected earlier in awake patients.
- In the presence of clinical signs of CHD, elective CEA should be preceded by guideline-conform stepwise diagnostic workup including noninvasive and invasive techniques, to minimize the perioperative and long-term risk of myocardial infarction.
- When evaluating the risks and benefits of CEA, functional parameters (activities of daily living, functional autonomy, progressive deterioration of general health) should be considered.
- All patients should take acetylsalicylic acid (aspirin 100 mg) before and after CEA, long-term aspirin therapy should not be interrupted.
- Preoperative platelet inhibition should be bridged with low-molecular-weight heparin for 3–5 days preoperatively and 1–2 days postoperatively, according to the individual risk.
- Whenever intraoperative clamping ischemia is suspected, an intraluminal shunt should be deployed in awake patients and in patients under general anesthesia.
- Whenever intraoperative cerebral embolism is suspected, the operated carotid bifurcation and the intracranial vessels should be examined immediately with angiography or duplex ultrasonography.
- In the presence of a neurological deficit in the early postoperative period and sonographically detected arterial thrombosis in the operated carotid bifurcation, immediate revision surgery should be performed if this will enable the cause of the neurological deficit to be removed. Timely CTA may be helpful in determining the indication.
- Acute occlusions of intracranial arteries should be treated with an endovascular technique also after CEA.
- Management and monitoring of perioperative hypertension is important to avoid hyperperfusion syndrome (HPS) in the early postoperative period and/or intracranial hemorrhage.
- Whenever early postoperative hyperperfusion syndrome (HPS) and/or intracranial hemorrhage is suspected, neurological examination and cerebral CT (CCT) or MRI of the brain should be performed immediately.
- Upon detection of early postoperative HPS and/or intracranial hemorrhage, systolic blood pressure should not exceed 140 mmHg and stroke unit treatment should be performed. A complication-related intracranial mass bleeding may require surgical treatment.

## 7.2 Do the success, complications, and recurrence rates of eversion CEA differ from those of conventional CEA with or without patch?

### 7.2.1 Recommendations

Recommendations	Grade*	LoE°
<b>MODIFIED:</b> The selection of the surgical technique (eversion CEA, conventional CEA with patch) should depend on the operating surgeon's personal experience.	↑↑	1a
<b>MODIFIED:</b> A patch should always be applied in conventional CEA, as direct suturing is associated with a higher rate of complications. There is scarce evidence for or against individual patch materials	↑↑	1a

## 7.3 In which patients with a high-grade extracranial carotid stenosis should intraoperative shunt deployment be obligatory or selective?

### 7.3.1 Recommendations

Recommendation	Grade*	LoE°
<b>MODIFIED:</b> The decision to deploy a temporary shunt should be based on any observed clamping ischemia or preoperative demonstration of poor cerebral collateral blood supply. There is no adequate evidence to support obligatory shunt deployment during surgical carotid reconstruction	↑	2a

## 7.4 Does intraoperative neuromonitoring during surgery under general anesthesia improve outcomes? If "yes," what is the value of the individual monitoring techniques?

### 7.4.1 Recommendations

Recommendation	Grade*	LoE°
<b>MODIFIED:</b> During CEA under general anesthesia, intraoperative neuromonitoring should be considered to check for sufficient collateral blood supply and, in the presence of pathologic findings, to determine the indication for selective shunting or blood pressure augmentation in the case of clamping ischemia	↑	2a

## 7.5 **NEW:** Do intraoperative monitoring techniques improve outcomes? If "yes," what is the value of the individual monitoring techniques?

### 7.5.1 Recommendations

Recommendations	Grade*	LoE°
<b>NEW:</b> Intraoperative duplex ultrasonography and/or angiography should be performed for intraoperative quality assurance to minimize the risk of periprocedural stroke	↑	2b
<b>NEW:</b> Whenever a >50% residual stenosis and/or large free-floating plaques or thromboses and/or a dissection are detected, immediate correction should be performed	EC	

## 7.6 Which type of anesthesia should be preferred for surgical treatment?

### 7.6.1 Recommendations

Recommendations	Grade*	LoE°
<b>UNCHANGED:</b> Since there is no distinct difference between the 30-day results after local/regional anesthesia or general anesthesia, either can be used. In choosing between the two, the patient's preference and the individual experience and competency of the anesthesiology/vascular surgery team should be taken into account	↑↑	1
<b>NEW:</b> The anesthesiology/vascular surgery team should offer the option of local/regional anesthesia, because clamping ischemia can be detected earlier in awake patients	↑	2c
<b>NEW:</b> Locoregional anesthesia should be performed as superficial cervical plexus block under ultrasound guidance	↑	2a

## 7.7 **NEW:** Evidence-based estimation of the perioperative risk—which clinical factors are associated with an increased risk?

### 7.7.1 Recommendations

Recommendations	Grade*	LoE°
<p><b>NEW:</b> When determining whether CEA is indicated and to estimate the preventive value of surgery, it should be considered that the following comorbidities may negatively influence the treatment-associated risk and prognosis of CEA:</p> <ul style="list-style-type: none"> <li>▪ Coronary heart disease (CHD)</li> <li>▪ Heart failure (ejection fraction &lt;30%, pathologic cardiac stress test)</li> <li>▪ Arterial hypertension (especially elevated diastolic blood pressure)</li> <li>▪ Diabetes mellitus (especially if treated with insulin)</li> <li>▪ Respiratory failure (especially COPD)</li> <li>▪ Severe kidney failure</li> <li>▪ Known peripheral arterial occlusive disease</li> <li>▪ Nicotine abuse (current or past)</li> </ul>	↑↑	2a
<p><b>MODIFIED:</b> When determining whether CEA is indicated and explaining the procedure to the patient, one should consider that the perioperative risk of stroke and death is higher for symptomatic than for asymptomatic carotid stenoses.</p>	↑↑	2a
<p><b>UNCHANGED:</b> When determining whether CEA is indicated, one should consider that the perioperative risk of stroke and death is not higher for early elective CEA (within 2 weeks after the index event) than after delayed CEA (&gt;2 weeks).</p>	↑↑	2a
<p><b>UNCHANGED:</b> When determining whether CEA is indicated, one should consider that perioperative mortality in both men and women increases with advancing age, but the perioperative stroke rate does not.</p>	↑↑	2a
<p><b>NEW:</b> In the presence of clinical signs of CHD, elective CEA should be preceded by guideline-conform stepwise diagnostic workup including noninvasive and invasive techniques, to minimize the perioperative and long-term risk of myocardial infarction</p>	↑↑	2a
<p><b>NEW:</b> In the absence of clinical signs of CHD, noninvasive tests may be considered prior to elective CEA, to minimize the perioperative and long-term risk of myocardial infarction</p>	↔	2b
<p><b>NEW:</b> When evaluating the risks and benefits of CEA, functional parameters (activities of daily living, functional autonomy, progressive deterioration of general health) should be considered</p>	↑	2a



## 7.8 **NEW:** Evidence-based estimation of the perioperative risk II—which anatomic and morphologic factors are associated with an increased risk?

### 7.8.1 Recommendations for estimation of the risk associated with anatomic and morphologic variables

Recommendation	Grade*	LoE°
<p><b>NEW:</b> When determining whether CEA is indicated, one should take into account that the following anatomic morphological variables are associated with higher procedural risk:</p> <ul style="list-style-type: none"> <li>▪ Tracheostomy</li> <li>▪ Contralateral paresis of recurrent laryngeal nerve</li> <li>▪ High carotid bifurcation (C2 or above)</li> <li>▪ Contralateral carotid occlusion</li> <li>▪ Moderate (50 to 69%) stenosis (versus 70 to 99% stenosis)</li> <li>▪ Insufficient intracranial collateral blood supply</li> </ul>	↑	2b
<p><b>NEW:</b> In determining the indication for surgical treatment of a recurrent carotid stenosis or a carotid stenosis in a previously irradiated region, the increased risk of a usually transient cranial nerve lesion should be considered</p>	↑↑	2a

## 7.9 **NEW:** Perioperative medical management in CEA patients

### 7.9.1 Recommendations for perioperative medical management

Recommendations	Grade*	LoE°
<p><b>UNCHANGED:</b> All patients should take acetylsalicylic acid (aspirin 100 mg) before and after CEA, long-term aspirin therapy should not be interrupted</p>	↑↑	1b
<p><b>NEW:</b> In the interval between neurological index event and CEA of a symptomatic carotid stenosis, dual platelet inhibition with aspirin (100 mg) and clopidogrel (75 mg) may be considered to minimize the risk of recurrent cerebral ischemia</p>	↔	2b
<p><b>NEW:</b> To reduce the perioperative stroke risk, CEA under dual platelet inhibition with aspirin (100 mg) and clopidogrel (75 mg) may be considered</p>	↔	1b
<p><b>NEW:</b> In patients at an increased risk of gastrointestinal bleeding with aspirin or clopidogrel, proton pump inhibitors should be administered</p>	EC	
<p><b>NEW:</b> Preoperative estimation of the individual risk of venous thromboembolism should be performed before interventions on the extracranial carotid artery</p>	EC	
<p><b>NEW:</b> Before clamping the carotid artery, an i.v. bolus of heparin should be administered. Heparin antagonism with protamine after clamp release (dose identical to heparin) may be considered in order to reduce the number of cervical hematomas requiring surgery</p>	EC	
<p><b>NEW:</b> Preoperative platelet inhibition (atrial fibrillation, artificial heart valve, lung embolism) should be bridged according to the individual risk of bleeding and thromboembolism</p>	EC	
<p><b>NEW:</b> All patients should be treated before and after CEA with a statin, long-term statin therapy should not be interrupted</p>	↑↑	2a
<p><b>NEW:</b> Beta-blocker and/or oral antiarrhythmic agents should be continued perioperatively</p>	↑↑	2a
<p><b>NEW:</b> In patients with diabetes mellitus, blood sugar should be strictly monitored before CEA (daily profile, target value &lt;180 mg/dl, &lt;10 mmol/L). Hypoglycemia should be avoided perioperatively</p>	↑↑	2a

## 7.10 Optimal management of procedure-specific complications

### 7.10.1 Recommendations for complication management

Recommendations	Grade*	LoE°
<b>UNCHANGED:</b> Whenever intraoperative clamping ischemia is suspected; an intraluminal shunt should be deployed in awake patients and in patients under general anesthesia	↑	2a
<b>MODIFIED:</b> Whenever intraoperative cerebral embolism is suspected; the operated carotid bifurcation and the intracranial vessels should undergo immediate evaluation with angiography or duplex ultrasonography	EC	
<b>MODIFIED:</b> In the presence of a neurological deficit in the early postoperative period and sonographically detected arterial thrombosis in the operated carotid bifurcation, immediate revision surgery should be performed if this will enable the cause of the neurological deficit to be removed. Timely CTA may be helpful in determining the indication	EC	
<b>MODIFIED:</b> Acute occlusions of intracranial arteries should be treated with an endovascular technique also after CEA	↑↑	2a
<b>MODIFIED:</b> Whenever early postoperative hyperperfusion syndrome (HPS) and/or intracranial hemorrhage is suspected, neurological examination and cerebral CT (CCT) or MRI of the brain should be performed immediately	↑↑	2a
<b>MODIFIED:</b> Upon detection of early postoperative HPS and/or intracranial hemorrhage, systolic blood pressure should not exceed 140 mmHg and stroke unit treatment should be performed. A complication-related intracranial mass bleeding may require surgical treatment. The patient should be monitored in the neurological ICU	EC	
<b>UNCHANGED:</b> Cardiovascular, pulmonary, and other general complications after CEA should be treated according to internal and intensive medicine standards and guidelines and involve specialists in these fields. The staff and technical equipment required to treat complications should be available	EC	
<b>UNCHANGED:</b> Whenever a cranial nerve lesion is suspected, central paresis should be distinguished from peripheral paresis. In the case of iatrogenic nerve lesions without clinical and neurophysiological signs of reinnervation, surgical exposure and, if necessary, reconstruction should be performed after 3–4 months	EC	
<b>NEW:</b> Early and late infections of cervical soft tissue should be treated with antibiotics according to test results. Abscesses should be opened surgically, prosthetic material should be replaced with autologous vein or biological material	EC	
<b>UNCHANGED:</b> Postoperative hemorrhage/hematoma with dyspnea and/or dysphagia represents an emergency situation which must undergo immediate surgical revision	EC	

## 8 Endovascular treatment

### 8.1.1 Main aspects in brief

- Primary stenting with a self-expanding stent is the method of choice for endovascular treatment of carotid stenosis.
- There is no clear evidence from studies addressing the role of the stent design or the use of protection devices against embolic complications. With appropriate handling, stents with good plaque coverage, filters, or endovascular clamping systems can improve the safety of CAS.
- In determining the indication for CAS, potential risk factors such as symptom status, advanced age, or a short interval between symptoms and revascularization should be considered. Risks related to vessel anatomy and plaque morphology should be anticipated based on pre-interventional imaging.
- Severe comorbidities should be considered in determining the indication for CAS, particularly in asymptomatic patients in whom there may be no expected benefit of revascularization due to limited life expectancy.
- In patients with acute stroke and tandem stenosis with extracranial carotid stenosis and downstream intracranial embolism, endovascular treatment with emergency stenting and thrombectomy is indicated.
- CAS requires adequate dual platelet inhibition.
- Peri- and postinterventional cardiovascular monitoring is necessary to detect possible bradycardia, hypotension, and blood pressure increase, and to treat as required.
- Hospitals offering CAS must ensure that complications such as intracranial embolism are identified and adequately treated without delay.

### 8.2 In patients with high-grade extracranial carotid stenosis, do the success, complications, and recurrence rates of PTA alone differ from those of PTA with a stent?

#### 8.2.1 Recommendations

Recommendation	Grade*	LoE°
<b>UNCHANGED:</b> Primary stenting should be used for endovascular treatment of carotid stenosis	↑↑	2b

### 8.3 Which materials (catheter, stents, protection systems) should be preferred for CAS?

#### 8.3.1 Recommendations

Recommendations	Grade*	LoE°
<b>UNCHANGED:</b> For carotid stenting, self-expanding stents approved for this indication should be used	↑↑	2a
<b>UNCHANGED:</b> The best possible protection against embolic complications should be strived for by using stents with good plaque coverage and, if necessary, protection devices	↑	3

## 8.4 Evidence-based estimation of the peri-interventional risk—which clinical factors are associated with an increased risk?

### 8.4.1 Recommendations

Recommendations	Grade*	LoE°
<b>UNCHANGED:</b> When determining whether CAS is indicated, one should consider whether the patient's age and comorbidities may increase the risk of extracerebral complications or limit the prophylactic benefit of the intervention		EC
<b>NEW:</b> When determining whether CAS is indicated and explaining the procedure to the patient, one should consider that the peri-interventional risk of stroke and death is higher for symptomatic than for asymptomatic carotid stenoses	↑↑	2
<b>NEW:</b> Before deciding to perform CAS, one should carefully weigh up the benefits and risks. The risks may be greater in patients over 70 years of age and after recent cerebral or ocular ischemia. It may be advisable to consider CEA as an alternative	↑	2a

## 8.5 Evidence-based estimation of the peri-interventional risk—which anatomic and morphologic factors are associated with an increased risk?

### 8.5.1 Recommendations

Recommendations	Grade*	LoE°
<b>NEW:</b> When determining whether CAS is indicated, anatomic and plaque morphology factors should be considered. Particularly the following variables are associated with a higher procedural risk: <ul style="list-style-type: none"> <li>▪ Pronounced aortic elongation (especially type III aortic arch)</li> <li>▪ Stenosis of the left carotid artery</li> <li>▪ Angulation of the carotid bifurcation</li> <li>▪ Calcification of the aortic arch</li> <li>▪ Pronounced (especially circumferential) plaque calcification</li> <li>▪ Long-segment stenosis (&gt;10 mm)</li> <li>▪ Free-floating thrombus</li> </ul>	↑	2b

## 8.6 What is important for optimal peri-interventional management?

### 8.6.1 Recommendations

Recommendations	Grade*	LoE°
<b>UNCHANGED:</b> CAS should be preceded by dual platelet inhibition with aspirin (100 mg) and clopidogrel (75 mg)	↑	3
<b>NEW:</b> Treatment with clopidogrel should be initiated at least 3 days before the intervention at 75 mg/day or on the day before the intervention at 300 mg/day		EC
<b>UNCHANGED:</b> The dual platelet inhibition should continue for at least 1 month		EC
<b>NEW:</b> For detection and medical therapy of cardiovascular responses with bradycardia and hypotension or blood pressure increases, peri- and postinterventional monitoring should be performed in CAS interventions		EC

<p><b>NEW:</b> The following measures should be applied:</p> <ul style="list-style-type: none"> <li>▪ Bradycardia prophylaxis with atropine administration before stent deployment and postdilatation</li> <li>▪ Administration of circulation-activating drugs for hypotension</li> <li>▪ Establishment of normal blood pressure to prevent reperfusion injury</li> </ul>	EC
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## 8.7 How are peri-interventional complications optimally managed?

### 8.7.1 Recommendations

Recommendations	Grade	LoE
<p><b>NEW:</b> Whenever intraprocedural cerebral ischemia is suspected, angiography of the carotid artery and dependent intracranial arteries should be performed immediately</p>	↑↑	1
<p><b>UNCHANGED:</b> Angiography of the intracranial arteries should be performed after completion of CAS</p>	EC	
<p><b>NEW:</b> In the presence of a neurological deficit in the early postinterventional period, cerebral and vascular imaging should be performed immediately</p>	EC	
<p><b>NEW:</b> In the presence of an intraprocedural intracranial embolism, medical therapy with bolus administration of a GP IIb/IIIa inhibitor or, provided there are no contraindications, thrombolysis with rTPA may be considered</p>	EC	
<p><b>NEW:</b> In the case of peri-interventional thromboembolism with occlusion of a functionally relevant intracranial main branch, catheter-based thrombectomy should be performed immediately</p>	↑↑	1
<p><b>UNCHANGED:</b> Whenever postinterventional hyperperfusion syndrome (HPS) and/or cerebral hemorrhage is suspected, neurological examination and cranial CT (CCT) or MRI of the brain should be performed immediately</p>	↑↑	3
<p><b>NEW:</b> Due to the risk of bleeding or vascular injury at the arterial puncture site (e.g., groin hematoma, pseudoaneurysm), CAS patients should be monitored postinterventionally and in the case of relevant findings treatment with compression or, if required, surgery is recommended.</p>	EC	
<p><b>UNCHANGED:</b> Cardiovascular, pulmonary, and other general complications after CAS should be treated according to internal and intensive medicine standards and guidelines and involve specialists in these fields. The staff and technical equipment required to treat complications should be available</p>	EC	

## 9 Care structure, continuing education, and case numbers

### 9.1 Main aspects in brief

- CEA and CAS should be performed on an inpatient basis, since approximately 30% of all complications (stroke, MI, delayed bleeding) do not occur on the day of treatment.
- CEA should always be performed by specialized vascular surgeons.
- CAS should be conducted by clinically and technically qualified physicians with extensive experience in angiographic diagnostics and recanalization procedures in brain-supplying arteries.
- CEA should be performed exclusively in hospitals with caseloads of at least 20 CEA/year. For CAS, performance of at least 10 elective procedures/year is recommended.

### 9.1.1 Recommendations

Recommendations	Grade	LoE <sup>o</sup>
<b>UNCHANGED:</b> Surgical and endovascular treatment of an extracranial carotid stenosis should not be performed as an outpatient procedure, because neurological symptoms or delayed bleeding may occur up to more than 24 h later		EC
<b>Recommendations for CEA</b>		
<b>UNCHANGED:</b> CEA should always be performed by specialized vascular surgeons because the postoperative results are then better	↑↑	2a
<p><b>The following structural stipulations should be met for CEA:</b></p> <ul style="list-style-type: none"> <li>• Availability of intraoperative (including intracerebral) angiography and/or duplex ultrasonography</li> <li>• <b>MODIFIED:</b> 24-h availability of a specialist in vascular surgery</li> <li>• 24-h availability of duplex ultrasonography, computed tomography, or MRI</li> <li>• 24-h availability of a neurologist/vascular medicine specialist experienced in the treatment of cerebral ischemia</li> <li>• 24-h availability of an endovascular intervention service</li> <li>• Potential for monitoring (intermediate care, intensive care unit, stroke unit)</li> <li>• <b>NEW:</b> 24-h availability of treatment for a complication-related intracranial mass</li> </ul>		EC
<b>NEW:</b> Because the perioperative stroke/death rate is lower in hospitals with high annual caseloads, CEA should be performed exclusively in hospitals with caseloads of > 20 CEA/year.	↑↑	2a
<b>Recommendations for CAS</b>		
<b>MODIFIED:</b> CAS should be conducted by a clinically and technically qualified physician with extensive experience of recanalization procedures in brain-supplying arteries. As prerequisite for elective CAS procedures the operator should have performed at least 10 interventional treatments for carotid stenosis under supervision.		EC
<p><b>The following structural stipulations should be met for CAS:</b></p> <ul style="list-style-type: none"> <li>• 24-h availability of a neurointerventional service that can perform selective intracranial angiography (selective microcatheter navigation) and, if needed, endovascular therapy (local thrombolysis, mechanical recanalization)</li> <li>• 24-h availability of duplex ultrasonography, computed tomography, or MRI</li> <li>• 24-h availability of a neurologist/vascular medicine specialist experienced in the treatment of cerebral ischemia</li> <li>• Potential for monitoring (intermediate care, intensive care unit, stroke unit)</li> <li>• <b>NEW:</b> 24-h availability of treatment for a complication-related intracranial hemorrhage</li> <li>• <b>NEW:</b> 24-h availability of a specialist in vascular surgery</li> </ul>		EC
<b>MODIFIED:</b> Because the perioperative stroke/death rate is lower in hospitals with high annual caseload, elective CAS should be performed exclusively in hospitals with a caseload of >10 elective CAS/year.	↑↑	2a

## 10 Aftercare, treatment of recurrence, and quality of life

### 10.1 Main aspects in brief

- After uncomplicated vascular interventions on the carotid artery (CEA, CAS), early mobilization is indicated during the hospital stay. Medical rehabilitation is only indicated after postoperative/postinterventional deficits with functional impairment. For geriatric patients, the indication for early geriatric rehabilitation should be determined as part of a geriatric assessment. Under consideration of geriatric multimorbidity, biological age has precedence over chronological age.
- After carotid reconstruction, guideline-conform monitoring and treatment of vascular risk factors (RF) should be performed in all patients. This includes long-term platelet inhibition. After CAS, dual platelet inhibition with aspirin (81–325 mg) and clopidogrel (75 mg) is recommended for 4 weeks. Additionally, in the presence of corresponding RF, blood pressure control with target range <140/90 mmHg, therapy of diabetes, and treatment of hyperlipidemia (preferably with statins) are recommended. Nicotine abstention, weight loss, and regular exercise are the cornerstones of nonmedical therapy. These treatment principles also apply for geriatric patients.
- After carotid reconstruction, duplex ultrasonography (DUS) should be performed intraoperatively or prior to hospital discharge. DUS should be repeated after 6 months to rule out early recurrence of stenosis. In the absence of recurrent stenosis, annual DUS follow-up is recommended thereafter.
- In the presence of a  $\geq 50\%$  ipsilateral recurrent stenosis or a  $\geq 50\%$  contralateral stenosis and in patients with an elevated risk of recurrence (diabetes, women, smoker, dyslipidemia), DUS should be repeated at 6-month intervals. As soon as two successive examinations show the same findings, the interval can be increased to 12 months.
- Recurrent stenosis is defined as  $\geq 50\%$  stenosis with and without clinical symptoms. Whenever there is sonographic suspicion of recurrent stenosis, an additional imaging modality (preferably CTA) should be performed. Upon detection of a symptomatic 50–99% recurrent stenosis, renewed carotid reconstruction is indicated. Upon detection of a high-grade asymptomatic recurrent stenosis, renewed reconstruction may be considered after interdisciplinary consultation. Special criteria apply to ultrasonographic diagnosis of recurrence of stenosis after CAS.
- Mortality after CEA or CAS is 2–5% during the first year. There are no differences in long-term mortality between CEA and CAS.



## 10.2 Which patients profit from rehabilitation measures after carotid revascularization?

### 10.2.1 Recommendations

Recommendations	Grade*	LoE°
<b>MODIFIED:</b> After uncomplicated vascular interventions (including carotid surgery without complications), only the first phase of rehabilitation according to the WHO classification, i.e., early mobilization, should be performed during the hospital stay. In geriatric patients, the indication for early geriatric rehabilitation should be determined as part of a geriatric assessment		EC
<b>MODIFIED:</b> The indication for medical rehabilitation should be determined based on functional impairments, activities of daily living, and social participation, and be performed accordingly		EC

## 10.3 Which medical and nonmedical measures should be applied for how long for prophylaxis of recurrent cerebrovascular ischemia or a recurrent carotid stenosis and at which intervals are follow-up examinations indicated?

### 10.3.1 Recommendations

Recommendation	Grade*	LoE°
<b>MODIFIED:</b> Guideline-conform monitoring and treatment of vascular risk factors should be performed in all patients with extracranial carotid stenosis. This also applies to patients after surgical or endovascular treatment of a carotid stenosis		EC

## 10.4 At which intervals are follow-up examinations indicated?

### 10.4.1 Recommendations

Recommendations	Grade*	LoE°
<b>NEW:</b> After CEA and CAS, DUS should be performed before hospital discharge to document patency of the carotid artery and generate a DUS baseline for follow-up examinations		EC
<b>NEW:</b> If early DUS follow-up shows a good result, DUS should be repeated after 6 months to rule out early recurrence of stenosis		EC
<b>NEW:</b> DUS should be performed routinely at 12-month intervals after CEA and CAS, provided the findings could have therapeutic consequences		EC
<b>NEW:</b> In patients thought to be at an elevated risk of recurrent stenosis during follow-up (women, diabetes mellitus, dyslipidemia, nicotine abuse) DUS should be repeated at 6-month intervals after CEA and after CAS. As soon as two successive examinations show the same findings, the interval can be increased to 12 months.		EC

## 10.5 How is a recurrent carotid stenosis defined clinically and morphologically and which diagnostic and therapeutic steps must be taken?

### 10.5.1 Recommendations

Recommendations	Grade*	LoE°
<b>Unchanged:</b> A recurrent carotid stenosis is defined as $\geq 50\%$ (NASCET criteria) with and without clinical symptoms in the ipsilateral region of supply. Special criteria apply to diagnosis of recurrence of stenosis after CAS		EC
<b>NEW:</b> Whenever there is sonographic suspicion of a 70–99% recurrent carotid stenosis after CEA or CAS, an additional imaging modality (preferably CTA) should be performed for confirmation, provided therapeutic consequences can be anticipated		EC
<b>NEW:</b> In the presence of a symptomatic 50–99% recurrent carotid stenosis, renewed revascularization with CEA or CAS should be performed		EC
<b>NEW:</b> In the presence of a symptomatic $< 50\%$ recurrent carotid stenosis, no revascularization with CEA or CAS should be performed unless stenosis-associated symptoms reoccur despite best medical therapy		EC
<b>NEW:</b> In the case of a 70–99% asymptomatic recurrent carotid stenosis, renewed revascularization with CEA or CAS may be considered. This applies particularly whenever <ul style="list-style-type: none"> <li>▪ Imaging reveals insufficient collateral blood supply</li> <li>▪ clamping ischemia was clinically observed during the initial CEA</li> <li>▪ the ipsilateral flow velocity in the middle cerebral artery (TCD) was <math>&lt; 15\text{cm/s}</math> during clamping in the initial CEA</li> <li>▪ significant alternations were observed in neurophysiological monitoring during the initial CEA under general anesthesia</li> <li>▪ neurological symptoms occurred in the distal or proximal balloon occlusion test during the initial CAS</li> </ul>		EC
<b>NEW:</b> The indication for CEA or CAS of a recurrent carotid stenosis should be determined by an interdisciplinary team (neurology, vascular surgery, endovascular treatment, neuroradiology, radiology)		EC

## 10.6 Are there impairments to quality of life after surgical or endovascular treatment of carotid stenosis and how are these assessed?

No recommendations

## 10.7 At what frequency to serious cardiovascular adverse events occur during the first year after surgical or endovascular treatment of carotid stenosis?

No recommendations

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