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Latest Recommendations on the Anesthetic Management of the Symptomatic Carotid Artery Disease

Laia Pazó-Sayós[1], Ana Arnalich-Montiel[1], Dayana Flórez-Palacio[2], Begoña Quintana-Villamandos[1]*

[1]Department of Anesthesiology, Hospital Universitario Gregorio Marañón, Spain

[2]Department of Anesthesiology, Hospital General Universitario Ciudad Real, Spain

***Corresponding author:** Begoña Quintana-Villamandos, Department Anesthesiology, Hospital Universitario Gregorio Marañón, 28007, Madrid, Spain, Tel: +34 915868367, Email: begoquinti@gmail.com

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ABSTRACT

Symptomatic carotid artery stenosis is a source of major disability. Optimal treatment may halt the ischemic insult and ensure the best possible recovery. Revascularization is performed by a multidisciplinary team, and may be done via carotid endarterectomy (CEA) or carotid artery stenting (CAS). The anesthesia provider faces the challenge of trying to preserve the neurological status of the patient during the procedure. Patients' outcomes depend greatly on choosing wisely the most appropriate approach, optimal intraoperative anesthetic care and the development or not of post-procedural complications. The purpose of this chapter is to clarify when CEA or CAS must be performed, how to offer our patients the best medical intraoperative care and which possible complications may arise during the peri-procedural period.

Keywords: Vascular anesthesia; Carotid artery stenting; Carotid endarterectomy.

INTRODUCTION

Stroke is a relatively frequent event and one of the major causes of important disability. Carotid arterial stenosis is a common cause of stroke. Prompt treatment of symptomatic carotid artery stenosis is therefore of the utmost importance to enhance the possibility of a full recovery and to avoid the ongoing ischemia of the cerebral tissue. Numerous clinical trials have addressed this problem and analyzed the outcomes after each of the available treatments: best medical treatment alone, carotid endarterectomy (CEA) or carotid artery stenting (CAS). CEA or CAS must be performed by a multidisciplinary group of professionals, among which the anesthesiologist is the responsible for ensuring the wellbeing of the patient and trying to prevent the worsening of ischemia while the procedure is performed.

In this chapter we are going to develop the preoperative considerations that must be taken into account to optimally treat our patients, as well as analyze the numerous factors that we must keep in mind while providing anesthesia care in this setting. Lastly, we will review the different complications that may halt the recovery of such a potentially disabling disease.

PREOPERATIVE CONSIDERATIONS

The term symptomatic carotid artery stenosis disease refers to those patients having suffered symptoms related to the carotid artery territory in the last 6 months, being these transient or persistent [1,2]. However, there is at least one guideline (the Carotid Artery Stenting: Second Consensus Document of the ICCS/ISO-SPREAD Joint Committee [3]) that challenges this 6-months period and proposes a 3-months period instead based on the significant reduction of the risk of recurrence in symptomatic patients just after a few weeks of the event [4,5].

Symptoms of carotid artery disease include [1-3]:

- Symptoms related to retinal ischemia such as ipsilateral amaurosis fugax.
- Symptoms related to hemispheric ischemia such as sensory impairment of hemi- face/arm/leg, motor deficits of the same territory, aphasia/dysphasia…

When Should we Treat Symptomatic Carotid Artery Disease?

There have been numerous trials that have examined this issue. The two largest randomized controlled trials to date have been the European Carotid Surgery Trial (ECST, 1998) [6] and the North American Symptomatic Carotid Endarterectomy Trial (NASCET, 1991) [7]. Although most guidelines base their recommendations on these trials, they were conducted before the generalized used of statins. Therefore, to compare outcomes after the updated best medical treatment (BMT) to surgical treatment + BMT, there is a second European Carotid Surgery Trial currently under way (ECST2).

Table 1: Recommendations on surgical treatment issued by the 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS). Table adapted from these guidelines.

	Class	Level
Carotid endarterectomy is indicated in patients having carotid artery related symptoms the preceding 6 months and with documented 70-99% carotid stenosis, if the estimated procedural death/stroke rate is <6%.	I	A
Carotid endareterectomy is recommended in patients having carotid artery related symptoms the preceding 6 months and with documented 50-69% carotid stenosis, if the estimated procedural death/stroke rate is <6%.	IIa	A
Carotid revascularization might be considered in symptomatic patients with <50% carotid stenosis and repeated symptoms despite best medical treatment.	IIb	C
Carotid revascularization should not be considered in patients with a chronic internal carotid near-occlusion, unless having repeated symptomatic events despite optimal medical treatment.	III	C

The 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS) [1] issued the following recommendations [Table 1]. These recommendations do not contradict the 2011 American Heart Association / American Stroke Association (AHA/ASA) guidelines on the Management of Patients With Extra cranial Carotid and Vertebral Artery Disease [2] and a 2017 Cochrane Review [8]:

Which Surgical Approach should be Considered?

ESCT and NASCET were conducted in the 1990's and didn't provide useful data regarding which revascularization technique to use: CEA or CAS. Therefore, other trials were developed to properly address this question:

- The Carotid Revascularization Endarterectomy versus Stenting Trial (CREST) [9,10] was a large randomized trial in which 53% of the patients had symptomatic carotid artery disease. They found similar results of both techniques in the long term (10 years follow-up [10]) but a significantly higher proportion of stroke and death rate in the 30 days follow-up for the stenting group, as well as an increased number of adverse events for patients older than 70 years [9]. However, CEA group showed higher proportion of myocardial infarction in the peri-procedural period than CAS group [9].

- The International Carotid Stenting Study (ICSS) [11,12] trial randomly assigned 1700 symptomatic adults (>40 years old) to either CAS or CEA. Similar results to those in CREST were found for the risk of stroke at 30 days, favoring CEA versus CAS. In the long-term analysis, there was a higher risk for non-disabling stroke for CAS patients.

- The Stent-Supported Percutaneous Angioplasty of the Carotid Artery versus Endarterectomy (SPACE) trial failed to prove non-inferiority of CAS versus CEA for the peri-procedural complication rate [13]. At 2 years [14], the rate of ipsilateral recurrent stroke was similar for both groups, whereas the rate of restenosis was higher for CAS.

- The Endarterectomy Versus Angioplasty in Patients with Symptomatic Severe Carotid Stenosis

(EVA-3S) trial [15] showed again a higher incidence of stroke or death at 30 days for CAS. In fact, it was prematurely stopped due to the excessive death rate in the CAS group. As limitations though, the heterogeneity of the use of cerebral protection devices, stent types or operator experience were highlighted.

Taking into account the former trials, ESVS guidelines [1] issued the following recommendations [Table 2]:

Table 2: Recommendations on revascularization approach issued by the 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS). Table adapted from these guidelines.

	Class	Level
It is recommended that patients who have had carotid stenosis symptoms the preceding 6 months and are >70 years old, would undergo carotid endarterectomy rather than carotid stenting.	I	A
In symptomatic patients in the last 6 months and <70 years old, carotid stenting might be considered if the peri-procedural death/stroke rate is <6%.	IIb	A

AHA/ASA guidelines [2] recommendations do not differ from the previously stated.

Which is the Recommended Timing for CAS/CAE After The Onset of Symptoms?

Evidence derived from randomized control trials [16,17] suggests that CEA should be performed <14 days after the first symptomatic episode, but it shouldn't be performed during the first 48h. In the case of CAS, a metaanalysis performed by the Carotid Stenosis Trialist's Collaboration (CSTC) [18] and which included CREST [9], ICSS [11,12], SPACE [13] and EVA-3S [15], led to the conclusion that CEA was a better alternative than CAS if the revascularization took place in the first 7 days of the onset of symptoms.

There are some special situations that should be addressed separately:

→ In patients with a severely disabling stroke chances of hemorrhagic transformation are higher [19].

→ Patients with an evolving stroke and an affected area <1/3 could be considered for an urgent CEA (during the first 48h) [20].

→ In those patients who have received intravenous thrombolysis, revascularization can be performed during the first 14 days if they meet certain criteria [Table 3] [21].

Thus, ESVS [1] recommendations are as follows [Table 3]:

Table 3: Recommendations on timing of revascularization issued by the 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS). Table adapted from these guidelines.

	Class	Level
In symptomatic carotid stenosis of 50-99%, if revascularization is indicated, it should be performed within the first 14 days of onset	I	A
If revascularization is indicated during the first 14 days, carotid endarterectomy should be performed rather than carotid stenting.	I	A
Patients with a disabling stroke (modified Rankin score of 3 or more), with an infarction area greater than one third or with altered mental status, should not undergo an early revascularization.	I	C
Patients with 50-99% stenosis and an evolving stroke could be considered for an urgent endareterectomy (<24h).	IIa	C
Early endarterectomy could be considered after intravenous thrombolysis in patients with good neurological recovery (Rankin 0-2), infarction area < 1/3, with a recanalised middle cerebral artery, 50-99% carotid stenosis and no hemorrhage conversion or no significant cerebral edema.	IIa	C
In former patients, intravenous heparin or antiplatelet therapy must be stopped during the first 24h after intravenous thrombolysis. But antiplatelet therapy should be reinitiated before carotid revascularization. Postoperative hypertension has to be aggressively treated to avoid parenchymal hemorrhage.	I	C

AHA/ASA guidelines [2] do not contradict the previously stated.

How Must we Optimize Patients Before Carotid Revascularization?

Numerous guidelines include recommendations about the best medical treatment for this kind of patients. The American Heart Association (AHA) guideline on perioperative cardiovascular evaluation and management of patients undergoing non-cardiac surgery [22] and the European Society of Cardiology (ESC) and the European Society of Anaesthesiology (ESA) guidelines on non-cardiac surgery [23] developed recommendations on best preoperative management for non-cardiac surgery. More specific guidelines are the AHA/ASA guidelines on the Management of Patients With Extracranial Carotid and Vertebral Artery Disease [2] and the European Society for Vascular Surgery practical guidelines [1] on the same matter (mentioned elsewhere).

For practical purposes, we are going to show the recommendations of ESVS guidelines [1] and discuss the differences with the AHA/ASA guidelines [2], as previously done.

Antiplatelet therapy

Table 4: Recommendations on antiplatelet treatment issued by the 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS). Table adapted from these guidelines.

	Class	Level
Patients with symptomatic 50-99% carotid stenosis not undergoing revascularization should initiate antiplatelet therapy. First choice treatment: clopidogrel 75mg/daily or aspiring 75mg/daily + dipiridamol 200mg/twice a day	I	A
All patients receiving carotid endarterectomy should receive treatment with low doses of aspirin (75-325mg daily) throughout the perioperative period.	I	B
If carotid stenting is to be performed, patients should receive dual antiplatelet therapy with clopidogrel (75mg) and aspirin (75-325mg).	I	B
It is not necessary to maintain a long-term dual antiplatelet therapy after either CEA or CAS, unless indicated for cardiac pathology.	III	C

AHA/ASA guidelines [2] differ from the previously exposed in that they do recommend long-term dual antiplatelet as well as single antiplatelet therapy after CEA or CAS (IB). Dosages slightly differ from ESVS guidelines.

Other medical recommendations

→ Patients with symptomatic carotid artery disease should be treated with statins to prevent stroke or other cardiovascular events (IA). Statins must be initiated before carotid revascularization and should not be discontinued afterwards (IB) [1,2].

→ Hypertension should be controlled with antihypertensive drugs (IA), but we must be cautious with aggressive treatment immediately after carotid revascularization (IIa C) [1,2].

→ Diabetic patients with symptomatic carotid artery disease must undergo strict glycemic control (IC), with target pressure levels < 140/85 (IB) [1,2].

→ Smoking cessation should be encourage (IB) [1,2].

INTRAOPERATIVE ANESTHETIC MANAGEMENT

In the following section we are going to develop the optimal anesthetic management for CEA and CAS, specifying the differences between both procedures when needed.

Choice of anesthesia

The decision of the anesthetic technique remains at the discretion of the surgeon and anesthesiologist and also the patient's peculiarities and preferences. In general terms, CEA is performed under general or regional anesthesia while CAS is carried out with sedation.

General Anesthesia

There are not conclusive data that demonstrate one technique, general or local/regional anesthesia is superior to another. The data from The American College of Surgeons National Surgical Quality Improvement Program were utilized by two large, retrospective, observational studies. Leichtle et al. analyzed data on 26.070 patients who underwent CEA and concluded

that general anesthesia is an independent risk factor for postoperative myocardial infarction compared with regional anesthesia [24]. Additionally, Schechter et al. evaluated data on 24.716 patients who underwent CEA and found that anesthetic technique does not influence outcomes after CEA, but may impact overall cost of care [25].

Usually, during general anesthesia agents that provide a suitable hemodynamic control are preferred in order to avoid disarrangements in brain perfusion and minimize myocardial stress. Besides that, anesthetic drugs should provide fast emergence, thus allowing early neurological examination. Sevofluorane and Desfluorane seem to have a good anesthetic profile as they result in quicker extubation and recovery times. Regarding Nitrous Oxide, a subgroup analysis from GALA trial showed that this agent is not related to increase vascular risk when it is compared with local anesthesia for carotid surgery; however, it continues to be a point in question [26]. Regarding intravenous agents, Propofol is a good alternative for carotid surgery due to its neuroprotective profile.Finally, there are other agents such as Remifentanil which has some interesting features such us smoother and faster emergence and predictable offset [27], what makes it advantageous in this kind of procedures.

Sedation

Sedatives are useful in both CEA and CAS to supplement regional anesthesia. Different sedatives are used in order to decrease anxiety and, at the same time, preserve mental alertness and communication with the patient. For instance, Dexmedetomidine has a proper profile since it provides patient sedation and analgesia without respiratory depression. Nevertheless, the anesthesiologist should take into account that this agent could produce hypotension and bradycardia. Propofol and Remifentanil are also suitable options in sedation for carotid revascularization since they are related to low myocardial ischemia rate.

Regional Anesthesia

Regional anesthesia for carotid surgery can be carried out by cervical plexus block or cervical epidural.

Cervical Plexus: Cervical plexus is formed by the first four anterior rami of the cervical spinal nerves, after their emergence from the vertebral column and is divided in superficial and deep branches. The first cervical spinal nerve gives motor innervation and is of little interest to locorregional anesthesia. The superficial cervical plexus supplies sensitive innervation to the skin and superficial structures of the neck, head and shoulder, while deep cervical plexus provides motor innervation to deeper structures such us muscles of the anterior neck and diaphragm.

Traditionally, cervical plexus blocks have been placed using landmarks. However, ultrasound is becoming a safer and more usual technique. On the other hand, despite of an appropriate block, more than half of patients require additional local anesthetic administration by the surgeon.

a) Landmark technique

Deep cervical plexus block: a line is drawn over the posterior border of sternocleidomastoid muscle between the mastoid process and the transverse process of the sixth cervical vertebra (Chassaignac tubercle), that can be palpated just below the cricoid cartilage. C2, C3 y C4 are located at 2 cm, 4 cm and 6 cm from to the mastoid process, respectively. The needle is inserted a little caudally and posteriorly until it contacts the posterior tubercle of the transverses process. At each level 3-5 ml of local anesthetic are administered, although it is possible to perform a single injection at C3. This block is more frequently related to serious complications due to its proximity to spinal nerves and vascular structures (Figure 1).

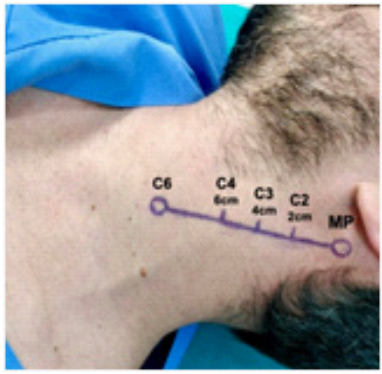

Figure 1: Deep cervical plexus landmarks. Image provided by the author MP: Mastoid Process.

Superficial cervical plexus block: the needle is inserted in the midpoint of the line described above, in the posterior border of sternocleidomastoid muscle and then redirected cephalad and caudally. Approximately 20-30 ml of local anesthetic are injected subcutaneously.

b) Ultrasound technique

Nowadays, regional anesthesia guided by ultrasound is more common due to its safety and quality. Spreading of the local anesthetic can be visualized needing less local anesthetic.

Deep cervical plexus: The neck is scanned in pursuit of the posterior transverse processes of C2, C3 and C4, which appear as hyperechoic images with acoustic shadowing. Like in the landmark technique, the needle is advanced until it contacts with the vertebral process and 3-5 ml of local anesthetic are administered at each level (Figure 2). The vertebral artery can be visualized by ultrasound, thus decreasing the risk of a vascular complication.

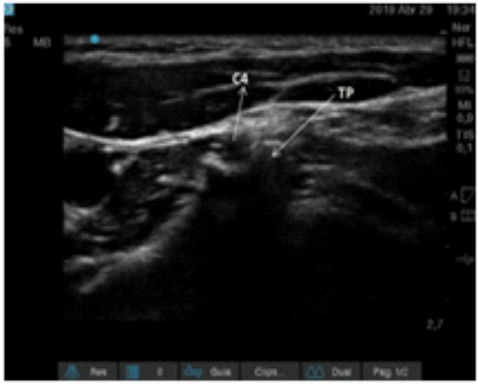

Figure 2: Deep cervical plexus. TP: Transverse process. Image provided by the author.

Superficial cervical plexus: A linear transducer is place transversely at the midpoint of sternocleidomastoid muscle. The superficial cervical plexus is visualized, in the posterior border of this muscle, as a small collection of hypoechoic nodules underneath the prevertebral fascia and immediately above of the scalene groove (Figure 3). Either in-plane or out-of-plane approach can be used and 10-15 ml of local anesthetic are distributed in this plane [28].

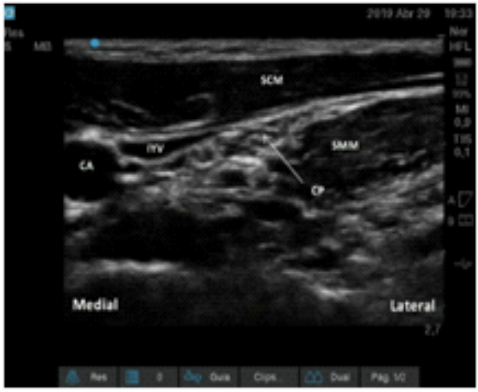

Figure 3: Superficial cervical plexusCP: Cervical plexus, SMM: Scalenus medius muscle. SCM: Sternocleidomastoid muscle. IYV: Internal jugular vein, CA: Carotid artery. Image provided by the author.

Nonetheless, cervical plexus block has transient adverse effects such us recurrent laryngeal nerve block (hoarseness), Horner's syndrome, cough, facial palsy and dysphagia [29].

Additional to the cervical plexus, cervical epidural may be useful for carotid surgery. The catheter is placed at C6-C7. This neuroaxial block is related with block failures and risky complications such us hypotension, bradycardia, respiratory depression, dural tap, spinal cord damage, among others. This makes cervical plexus block the preferred modality [28, 30].

Monitoring

Patients who undergo carotid revascularization are monitored following the standard American Society of Anesthesiologists (ASA) recommendations, confirmed by both the AHA guidelines on perioperative cardiovascular evaluation and management of patients undergoing non-cardiac surgery [22] and the ESC/ESA guidelines on non-cardiac surgery [23]):

1. EKG identifies myocardial ischemia
2. Invasive arterial pressure allows for hemodynamic control.
3. If general anesthesia is needed, we must ensure proper mechanical ventilation that provides normocapnia and therefore a normal cerebral perfusion.
4. Normothermia should be maintained considering that both hypothermia and hyperthermia are related with poor outcomes.

Patients with depressed ventricular function require a more advanced monitoring.

Neuromonitoring

Carotid clamping during CEA and balloon inflation during CAS can cause a decrease in cerebral blood flow. Hence, continuous assessment of the neurologic state in carotid surgery is essential in order to preserve a normal brain blood supply. Modifications in the neuro-monitor suggest the necessity of an intervention, either increasing blood pressure, establishing a shunt or even with a cross-clamp release.

Cerebral perfusion may be evaluated using different monitoring techniques. However, it is unclear which method is the best and does not exist homogeneous criteria to determine brain ischemia. Monitoring devices include:

→ *Transcranial Doppler Sonography* analyzes the blood flow velocity in the middle cerebral artery; it is useful not only for detection of cerebral hypoperfusion but also in detecting embolism.

→ *Stump pressure measurement* reflects the perfusion pressure transmitted to the Circle of Willis. Although there is not unanimity, pressures above 50 mmHg are considered appropriate.

→ *Near Infrared Spectroscopy* (NIRS) measures cerebral regional oxygenation non-invasively and continuously. A saturation decrease of 12% means low cerebral flow.

→ *Electroencephalography* (EEG) assesses electrical activity of cortical brain areas. Normal pattern changes rapidly during ischemic periods. This is the most used monitor to detect ischemia, but its accuracy could be affected by anesthetic drugs and hypothermia.

→ *Somatosensory Evoked Potentials* (SSEPs) evaluate the cerebral electrical activity after peripheral stimulation. An alteration in the cerebral waves, such as decreased amplitude

or increased latency, indicates a deficient perfusion. Thus, unlike EEG, SSEPs can detect subcortical ischemia [27, 31].

All the previous neuro-monitoring methods are applied when the patient is under general anesthesia. The use of regional anesthesia allows for a continuous evaluation of the neurological state of the awake patient and provides an early detection of hypoperfusion [31]. Nevertheless, not all patients are candidates to perform this technique, as it requires patient cooperation. Confusion, agitation, seizures, unconsciousness or contralateral motor weakness will be detected if an inadequate perfusion occurs.

Thus, the decision of which monitor to choose depends on the availability, surgical team experience with a specific monitor and patient's characteristics.

Hemodynamic management

Under general anesthesia relative hypotension is seen intraoperatively, while hypertension is common in the postoperative period. Conversely, when regional anesthesia is performed hypertension is more frequent during cross-clamping period, whereas hypotension is more frequent afterwards [32, 33].

In CEA, cross-clamping is associated to ischemic risk. Therefore, systolic blood pressure should be maintained normal or 20% above patient's baseline to enhance collateral blood flow [27]. This measure has been related to a lower risk of early postoperative cognitive dysfunction [34]. However, it can be associated with cardiac complications. After flow reestablishment, blood pressure should be maintained normal or mildly low to prevent hypoperfusion syndrome.

Short acting vasoactive drugs are useful to treat blood pressure disorders. Hemodynamic alterations may suggest complications such as hypoperfusion, embolism and artery dissection. Bradycardia and hypotension are seen during direct carotid sinus manipulation in CEA or balloon inflation in CAS and they are usually treated with atropine.

Anticoagulation

With the purpose of decreasing thromboembolic complications, unfractionated heparin is administered before the establishment of cross-clamping in CEA and before balloon angioplasty and stenting in CAS. Either, fixed doses of 5000 units or weight-based doses of 1mg/kg [35] are used to achieve an ACT of approximately twice the baseline value (250 - 300 s). Protamine may be used to completely or partially reverse the anticoagulation, if needed.

PERIPROCEDURAL COMPLICATIONS OF CAROTID ARTERY REVASCULARIZATION

Complications related to techniques of carotid revascularization (CEA and CAS) have significantly declined over the years because of the advances in intraoperative management

and postoperative care [36]. Multiple factors can influence in the occurrence of perioperative complications, such as the surgeon´s experience, the type of technique and the patient´s comorbidities. In this section, we will describe the potential complications observed after carotid revascularization.

Stroke

The incidence of this complication is higher in patients undergoing CAS (with a 30-day range of 6 to 9% in symptomatic patients; 2 to 4% in asymptomatic ones) [37-39] compared to those undergoing CEA (less than 5% of strokes in symptomatic patients; 0.25 to 3% in asymptomatic ones) [40,41]. Still, perioperative stroke represents the second most common cause of death following CEA [36].

Factors which conditionate poor cerebral perfusion will contribute to perioperative stroke; such as hypotension, vasospasm, thrombosis, intimal flap, plaque, air or platelet emboli. Besides, intraoperative use of intraluminal shunt can produce arterial damage and therefore it increases the risk of stroke after CEA [36].

Neurologic changes in the postoperative period may be the anteroom of ictus and should be evaluate immediately. Either a Doppler US or direct intraoperative inspection will be performed to assess if there is an adequate flow through the carotid vascular bed. In addition, a subsequent CT may be useful to detect intracranial hemorrhage. If there is no hemorrhage, selected patients will undergo intra-arterial thrombolytic therapy with acteplase or CAS procedure. However, there are no controlled trials to justify the use of intra-arterial thrombolytic therapy in patients who develop stroke after CEA. Intravenous alteplase is an independent risk factor for subarachnoid hemorrhage after CEA [36].

Myocardial infarction (MI)

Several randomized trials have demonstrated that the risk of MI after CEA (0 to 2%) is higher than after CAS [42,43] This complication is directly associated with several risk factors, such as previous history of coronary artery disease or peripheral artery disease, advanced age, and carotid re-stenosis.

Hyperperfusion syndrome

It is an uncommon complication of CEA, with an incidence from 1 to 3% [44]. However, it represents the first cause of postoperative bleeding and seizures within the 2 first weeks after CEA [36]. Usually, hyperperfusion syndrome is associated with revascularization of lesions over 80% of stenosis as well as an inadequate perioperative blood pressure control [45].

The mechanism of this complication is associated with a compensatory vasodilatation of small distal vessels to compensate the reduction of cerebral vascular bed blood flow due to carotid artery stenosis. Once the normal blood flow is restored after carotid revascularization, these

vessels are unable to vasoconstrict as they have lost their blood flow auto-regulation, resulting in elevated postoperative cerebral perfusion pressures.

Clinically, hyperperfusion syndrome typically presents with ipsilateral headache, which improves on upright posture; and when it associates cerebral edema and hemorrhage, it can produce focal motor seizures and neurologic changes. Once suspected, a strict blood pressure control (targeting a SBP <150 mm Hg) and immediate performance of imaging tests (Doppler US, TAC, MRI) are required. Antithrombotics should also be discontinued [36].

Carotid restenosis

It is one of the most frequent complications after CEA (2.6 to 10% of patients after 5 years of surgery), with lower rates found when CAS is performed (0.5% to 5%) [46-48]. Thankfully, most of these patients are asymptomatic and they will be identified during follow-up carotid imaging.

The incidence of this complication can be reduced by acting over several risk factors, such as smoking, hypertension, hyperglycemia, hyperlipidemia and elevated creatinine [49]. In addition, female sex has also been associated to carotid restenosis, probably due to the smaller size of this vessel in this group of population [48].

Time of presentation of carotid restenosis following CEA is related to the mechanisms that produce this complication [50], dividing the patients into two different groups:

→ Those presenting with an early carotid restenosis (within two or three years after CEA), explained by an intimal hyperplasia. It is rarely associated with cardiovascular embolism.

→ Patients presenting with a late restenosis (more than two or three years after CEA), due to the progression of vascular atherosclerosis. It is frequently associated with plaque source embolism.

Re-intervention is only necessary in high-grade restenosis, with a decrease of 80% or higher of carotid blood distal flow, as well as patients who associate neurologic symptoms. There is not enough evidence to support CEA or CAS as the recommended therapy for postoperative carotid restenosis. A systematic review which evaluated 4399 patients who underwent carotid intervention for treatment of restenosis after CEA, showed no significant differences in 30-day mortality, stroke or transient ischemic attack between patients who underwent CEA and those who underwent CAS [51]. However, the incidence of cranial nerve injury after CEA was significantly higher than after CAS, although most of the cases where self-limited and solved within the first 3 months after surgery.

Cervical hematoma

This complication is associated with patients undergoing CEA. In severe cases, it can lead to an acute airway obstruction, which may be life threating and requires an immediate re-exploration of the neck wound in the operating room. Patients receiving anticoagulant or antiplatelet therapy

and those with uncontrolled postoperative hypertension have higher risk of developing this complication [52].

Cervical infection

It is an unusual complication after CEA, and can be manifested as surgical site infection or a parotitis.

Wound infections are usually superficial and normally respond well to antibiotic therapy. Surgical site closure with prosthetic patch has been associated with an increased risk of wound infection in several reports [53], justifying the use of prophylactic preoperative use of antibiotics in these patients.

Deep wound infections are much less common and usually present with neck swelling and infected drainage in early stage. If it is a late complication can show up with a pulsatile neck mass due to pseudoaneurysm or a draining sinus tract.

Cervical infections are initially managed with empiric antibiotic therapy directed to gram positives, until definitive culture results and antibiotic sensitivities are obtained. For refractory patients, carotid artery ligation, arterial reconstruction with autogenous vein or bypass may be indicated [53].

Cranial nerve injuries

Surgical manipulation, accidental section or compression caused by local edema, hematoma or inflammation can result in nerve injury after CEA procedures. Nerve injuries are mostly transient and can occurred in approximately 5% after CEA [54]. Urgent or long (>2 hours) surgery and perioperative stroke may increase the risk of suffering this complication.

Among the potential nerve injuries, the hypoglossal nerve is the most frequently involved (2.7%), followed by the facial nerve (1,9%), the vagus nerve (0.7%) and the glossopharyngeal nerve (0.7%) [50]. Horner syndrome (miosis, ptosis and anhidrosis) is rarely observed following CEA. Besides, the “first bite syndrome” is a documented complication of CEA due to surgical sympathetic denervation of the parotid gland and it is clinically manifested by ipsilateral pain in the parotid region after first bite of the meal. It can be treated with botulinum toxin injection [55].

Specific complications following CAS

Among the specific complications of patient who undergo CAS, access-related complications (infection, bleeding, pseudoaneurysm, athero-embolization of lower limbs) are one of the most common ones. The incidence of femoral pseudoaneurysm is approximately 3% [56] and it is associated with an inadequate compression of the puncture site after the procedure, high body mass, peripheral arterial disease, age >65 and antiplatelet therapy during the intervention.

Furthermore, renal dysfunction after CAS is likely related to contrast administration or alternatively to renal thromboembolism. It is frequently associated with preoperative renal dysfunction or diabetes.

Stent fracture can also be observed after CAS, but its clinical significance is unknown. In a recent prospective study with 1021 patients treated with CAS, stent fracture was not associated with in-stent re-stenosis or increase in serious adverse clinical outcomes (death, stroke, MI) [57]. The risk of developing this complication is higher in patients with presence of intra-arterial calcification in the place where the stent was inserted [58].

CONCLUSIONS

Symptomatic artery stenosis is a potentially serious disabling disease. Current Guidelines favor CEA over CAS in the majority of patients, though there are some clinical trials that have yet to be concluded. The anesthesiologist must know all the possible peri-procedural complications in order to provide the best care. However, further research would be beneficial in order to improve patients' outcomes.

References

1. Naylor AR, Ricco JB, de Borst GJ, Debus S, de Haro J, et al. Editor's Choice - Management of Atherosclerotic Carotid and Vertebral Artery Disease: 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS). Eur J Vasc Endovasc Surg. 2018; 55: 3-81.
2. Brott TG, Halperin JL, Abbara S, Bacharach JM, Barr JD, et al. 2011 ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS guideline on the management of patients with extracranial carotid and vertebral artery disease: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, and the American Stroke Association, American Association of Neuroscience Nurses, American Association of Neurological Surgeons, American College of Radiology, American Society of Neuroradiology, Congress of Neurological Surgeons, Society of Atherosclerosis Imaging and Prevention, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of NeuroInterventional Surgery, Society for Vascular Medicine, and Society for Vascular Surgery. Developed in collaboration with the American Academy of Neurology and Society of Cardiovascular Computed Tomography. Catheter Cardiovasc Interv. 2013; 81: 76-123.
3. Lanza G, Setacci C, Cremonesi A, Ricci S, Inzitari D, et al. Carotid artery stenting: second consensus document of the ICCS/ISO-SPREAD joint committee. Cerebrovasc Dis. 2014; 38: 77-93.
4. Rothwell PM, Eliasziw M, Gutnikov SA, Fox AJ, Taylor DW, et al. Analysis of pooled data from the randomised controlled trials of endarterectomy for symptomatic carotid stenosis. Lancet 2003; 361: 107-116.
5. Bond R, Rerkasem K, Rothwell PM. Systematic review of the risks of carotid endarterectomy in relation to the clinical indication for and timing of surgery. Stroke 2003; 34: 2290-2301.
6. European Carotid Surgery Trialists' Collaborative Group. MRC European Carotid Surgery Trial: interim results for symptomatic patients with severe (70-99%) or with mild (0-29%) carotid stenosis. Lancet. 1991; 337: 1235-1243.
7. North American Symptomatic Carotid Endarterectomy Trial Collaborators, Barnett HJM, Taylor DW, Haynes RB, Sackett DL, et al. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. N Engl J Med. 1991; 325: 445-453.
8. Orrapin S, Rerkasem K. Carotid endarterectomy for symptomatic carotid stenosis. Cochrane Database Syst Rev. 2017; 6: 1-50.
9. Brott TG, Howard G, Roubin GS, Meschia JF, Mackey A, et al. Long-Term Results of Stenting versus Endarterectomy for Carotid-Artery Stenosis. N Engl J Med. 2016; 374: 1021-1031.
10. Mantese VA, Timaran CH, Chiu D, Begg RJ, Brott TG; CREST Investigators. The Carotid Revascularization Endarterectomy versus Stenting Trial (CREST): stenting versus carotid endarterectomy for carotid disease. Stroke. 2010; 41: S31-4.

11. Featherstone RL, Dobson J, Ederle J, Doig D, Bonati LH, et al. Carotid artery stenting compared with endarterectomy in patients with symptomatic carotid stenosis (International Carotid Stenting Study): a randomised controlled trial with cost-effectiveness analysis. Health Technol Assess. 2016; 20: 1-94.

12. Bonati LH, Dobson J, Featherstone RL, Ederle J, van der Worp HB, et al. Long-term outcomes after stenting versus endarterectomy for treatment of symptomatic carotid stenosis: the International Carotid Stenting Study (ICSS) randomised trial. Lancet. 2015; 385: 529-538.

13. SPACE Collaborative Group, Ringleb PA, Allenberg J, Brückmann H, Eckstein HH, et al. 30 day results from the SPACE trial of stent-protected angioplasty versus carotid endarterectomy in symptomatic patients: a randomised non-inferiority trial. Lancet. 2006; 368: 1239-1247.

14. Eckstein HH, Ringleb P, Allenberg JR, Berger J, Fraedrich G, et al. Results of the Stent-Protected Angioplasty versus Carotid Endarterectomy (SPACE) study to treat symptomatic stenoses at 2 years: a multinational, prospective, randomised trial. Lancet Neurol. 2008; 7: 893-902.

15. Mas JL, Trinquart L, Leys D, Albucher JF, Rousseau H, et al. Endarterectomy Versus Angioplasty in Patients with Symptomatic Severe Carotid Stenosis (EVA-3S) trial: results up to 4 years from a randomised, multicentre trial. Lancet Neurol. 2008; 7: 885-892.

16. Rothwell PM, Eliasziw M, Gutnikov SA, Warlow CP, Barnett HJ. Carotid Endarterectomy Trialists Collaboration. Endarterectomy for symptomatic carotid stenosis in relation to clinical subgroups and timing of surgery. Lancet 2004; 363: 915-924.

17. Rothwell PM, Gutnikov SA, Warlow CP. European Carotid Surgery Trialist's Collaboration. Sex differences in the effect of time from symptoms to surgery on benefit from carotid endarterectomy for transient ischaemic attack and non disabling stroke. Stroke 2004; 35: 2855-2861.

18. Rantner B, Kollertis B, Roubin GS, Ringleb PA, Jansen O, et al. Early endarterectomy carries a lower procedural risk than early stenting in patients with symptomatic stenosis of the internal carotid artery results from 4 randomized controlled trials. Stroke 2017; 48: 1580-1587.

19. Rantner B, Eckstein HH, Ringleb P, Woelfle KD, Bruijnen H, et al. American Society of Anesthesiology and Rankin as predictive parameters for the outcome of carotid endarterectomy within 28 days after an ischemic stroke. J Stroke Cerebrovasc Dis 2006; 15: 114-120.

20. Capoccia L, Sbarigia E, Speziale F, Toni D, Biello A, et al. The need for emergency surgical treatment in carotid-related stroke in evolution and crescendo transient ischemic attack. J Vasc Surg 2012; 55: 1611-1617.

21. Bartoli MA, Squarcioni C, Nicoli F, Magnan PE, Malikov S, et al. Early carotid endarterectomy after intravenous thrombolysis for acute ischaemic stroke. Eur J Vasc Endovasc Surg 2009; 37: 512-518.

22. Fleisher LA, Fleischmann KE, Auerbach AD, Barnason SA, Beckman JA, Bozkurt B, et al. 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: executive summary: a report of the American College of Cardiology / American Heart Association Task Force on practice guidelines. Develope in collaboration with the American College of Surgeons, American Society of Anesthesiologists, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Anesthesiologists, and Society of Vascular Medicine Endorsed by the Society of Hospital Medicine. J Nucl Cardiol. 2015; 22: 162-215.

23. Bøtker HE, Hert SD, Ford I, Gonzalez-Juanatey JR, Gorenek B, et al.2014 ESC/ESA Guidelines on non-cardiac surgery: cardiovascular assessment and management: The Joint Task Force on non-cardiac surgery: cardiovascular assessment and management of the European Society of Cardiology (ESC) and the European Society of Anaesthesiology (ESA). Eur Heart J. 2014; 35: 2383-2431.

24. Leichtle SW, Mouawad NJ, Welch K, Lampman R, Whitehouse Jr WM, et al. Outcomes of carotid endarterectomy under general and regional anesthesia from the American College of Surgeons' National Surgical Quality Improvement Program. J Vasc Surg. 2012; 56: 81-88.

25. Schechter MA, Shortell CK, Scarborough JE. Regional versus general anesthesia for carotid endarterectomy: the American College of Surgeons National Surgical Quality Improvement Program perspective. Surgery. 2012; 152: 309-314.

26. Sanders R, Graham C, Lewis S, Bodenham A, Gough M, et al. Nitrous oxide exposure does not seem to be associated with increased mortality, stroke, and myocardial infarction: a non-randomized subgroup analysis of the General Anaesthesia compared with Local Anaesthesia for carotid surgery (GALA) trial. British journal of anaesthesia. 2012; 109: 361-367.

27. Pong RP, Hanson NA. Carotid Artery Interventions and Anesthetic Technique: An Evidence-Based Review. Adv Anesth. 2012; 30: 29-46.

28. Stoneham M, Stamou D, Mason J. Regional anaesthesia for carotid endarterectomy. Br J Anaesth. 2014; 114: 372-383.

29. Erickson KM, Cole DJ. Anesthetic management of carotid endarterectomy. Curr Opin Anaesthesiol. 2013; 26: 523-528.

30. Hakl M, Michalek P, Ševčík P, Pavlíková J, Stern M. Regional anaesthesia for carotid endarterectomy: an audit over 10 years. Br J Anaesth. 2007; 99: 415-420.

31. Kim UR, Allain RM. Carotid artery stenosis: anesthetic considerations for open and endovascular management. Int Anaesthesiol Clin. 2016; 54: 33-51.

32. Stoneham M, Thompson J. Arterial pressure management and carotid endarterectomy. Br J Anaesth. 2009; 102: 442-52.

33. Erickson K, Cole D. Carotid artery disease: stenting vs endarterectomy. Br J Anaesthe. 2010; 105: 34-49.

34. Heyer EJ, Mergeche JL, Anastasian ZH, Kim M, Mallon KA, et al. Arterial blood pressure management during carotid endarterectomy and early cognitive dysfunction. Neurosurgery. 2013; 74: 245-253.

35. Howell S. Carotid endarterectomy. Br J Anaesth. 2007; 99: 119-131.

36. Saha, SP, Subhajit Saha, MBBS, Krishna SV. Carotid endarterectomy: current concepts and practice patterns. Int J Angiol. 2015; 24: 223-235.

37. Halm EA, Tuhrim S, Wang JJ, Rockman C, Riles TS, et al. Risk factors of perioperative death and stroke after carotid endarterectomy: Results of New York Carotid Artery Surgery Study. Stroke. 2009; 40: 22-229.

38. Kim LK, Yang DC, Swaminathan RV, Minutello RM, Okin PM, et al. Comparison of trends and outcomes of carotid artery stenting and endarterectomy in the United States, 2001 to 2010. Circ Cardiovasc Interv. 2014; 7: 692-700.

39. Vincent S, Eberg M, Eisenberg MJ, Filion KB. Meta-analysis of randomized controlled trials comparing the long- term outcomes of carotid artery stenting versus endarterectomy. Circ Cardiovasc Qual Outcomes. 2015; 8: S99-108.

40. Hill MD, Brooks W, Mackey A, Clark WM, Meschia JF, et al. Stroke after carotid stenting and endarterectomy in the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST). Circulation 2012; 126: 3054-3061.

41. Faggioli G, Pini R, Mauro R, Gargiulo M, Freyrie A, et al. Perioperative outcome of carotid endarterectomy according to type and timing of neurologic symptoms and computed tomography findings. Ann Vasc Surg 2013; 27: 874-882.

42. Boulanger M, Camelière L, Felgueiras R, Berger L, Rerkasem K, et al. Periprocedural myocardial infarction after carotid endarterectomy and stenting; systematic review and meta-analysis. Stroke 2015; 46: 2843-2848.

43. International Carotid Stenting Study investigators, Ederle J, Dobson J, Featherstone RL, Bonati LH, et al. Carotid artery stenting compared with endarterectomy in patients with symptomatic carotid stenosis (International Carotid Stenting Study): an interim analysis of a randomised controlled trial. Lancet 2010; 375: 985-997.

44. Coutts SB, Hill MD, Hu WY. Hyperperfusion syndrome: toward a stricter definition. Neurosurgery 2003; 53: 1053-1058.

45. Naylor AR, Ruckley CV. The post-carotid endarterectomy hyperperfusion syndrome. Eur J Vasc Endovasc Surg 1995; 9: 365-367.

46. Goodney PP, Nolan BW, Eldrup-Jorgensen J, Likosky DS, Cronenwett JL, et al. Restenosis after carotid endarterectomy in a multicenter regional registry. J Vasc Surg 2010; 52: 897-904.

47. Dorigo W, Pulli R, Fargion A, Pratesi G, Angiletta D, et al. Comparison of open and endovascular treatments of post-carotid endarterectomy restenosis. EurJ Vasc Endovasc Surg 2013; 45: 437-442.

48. Chan RC, Chan YC, Cheung GC, Cheng SW. Predictors of restenosis after carotid endarterectomy: 17-year experience in a tertiary referral vascular center. Vasc Endovasc Surg 2014; 48: 201-206.

49. LaMuraglia GM, Stoner MC, Brewster DC, Watkins MT, Juhola KL, et al. Determinants of carotid endarterectomy anatomic durability: effects of serum lipids and lipid-lowering drugs. J Vasc Surg 2005; 41: 762-768.

50. Fokkema M, de Borst GJ, Nolan BW, Indes J, Buck DB, et al. Clinical relevance of cranial nerve injury following carotid endarterectomy. Eur J Vasc Endovasc Surg 2014; 47: 2-7.

51. Tu J, Wang S, Huo Z, Wu R, Yao C, et al. Repeated carotid endarterectomy versus carotid artery stenting for patients with carotid restenosis after carotid endarterectomy: systematic review and meta-analysis. Surgery 2015; 157: 1166-1173.

52. Morales Gisbert SM, Sala Almonacil VA, Zaragozá García JM, Genovés Gascó B, Gómez Palonés FJ, Ortiz Monzón E. Predictors of cervical bleeding after carotid endarterectomy. Ann Vas Surg 204; 28: 366-374.

53. Mann CD, McCarthy M, Nasim A, Bown M, Dennis M, et al. Management and outcome of prosthetic patch infection after carotid endarterectomy: a single-centre series and systematic review of the literature. Eur J Vasc Endovasc Surg 2012; 44: 20-26.

54. Cunningham EJ, Bond R, Mayberg MR, Warlow CP, Rothwell PM. Risk of persistent cranial nerve injury after carotid endarterectomy. J Neurosurg 2004; 101: 445-448.

55. Wang TK, Bhamidipaty V, MacCormick M. First bite syndrome following ipsilateral carotid endarterectomy. Vasc Endovasc Surg 2013; 47: 148-150.

56. Taha MM, Sakaida H, Asakura F, Maeda M, Toma N, et al. Access site complications with carotid angioplasty and stenting. Surg Neurol 2007; 68: 431-437.

57. Weinberg I, Beckman JA, Matsumura JS, Rosenfield K, Ansel GM, et al. 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 disease). Circulation 2018; 137: 49-56.

58. Ling AJ, Mwipatayi P, Gandhi T, Sieunarine K. Stenting for carotid artery stenosis: fractures, proposed etiology and need for surveillance. J Vasc Surg 2008; 47: 1220-1226.