Ref: Ro J Neurol. 2022;21(4)
DOI: 10.37897/RJN.2022.4.10

Carotid stenting technique and review of literature – What every resident should know

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ABSTRACT

Carotid artery stenosis is a prevalent and substantial cause of ischemic stroke; however, in patients who have significant symptomatic stenosis, carotid revascularization can lower their chances of having an ischemic stroke. Carotid endarterectomy (CEA) continues to remain the gold standard treatment modality for lowering the likelihood of carotid artery stenosis. Carotid artery stenting (CAS) is an alternative to CEA. In the last few years, carotid stenting use has increased with improved clinical outcomes. This article discusses the technique of carotid stenting with a review of literature.

Keywords: carotid artery stenting, stroke, carotid stenosis

INTRODUCTION

Cerebrovascular disease is responsible for 10% of deaths, worldwide [1]. Carotid artery stenosis (CAS) secondary to atherosclerotic disease, is one of the leading causes of death and is responsible for almost 20-30% of these strokes [2]. Amongst all cerebrovascular diseases, ischemic strokes have always been the most prominent. Of these ischemic strokes, almost 15-20% occur secondary to atherosclerotic carotid artery stenosis, especially of the internal artery [3]. A considerable amount of carotid artery stenosis is noted in 0.5% people between the ages of 60-79 years and in about 10% people 80 years and older, respectively [4]. While many patients are generally asymptomatic, symptomatic carotid artery stenosis usually presents with neurological dysfunction. Patients who experience neurological disturbances like transient ischemic attacks, amaurosis fugax and stroke are at an increased risk of cerebrovascular events.

Clinically, carotid stenosis is generally classified into mild, moderate and severe. Nearly 3.1% of people suffer from severe asymptomatic carotid stenosis [5]. There are several options to treat carotid stenosis, for example, medical, surgical and endovascular treatment. Several studies were published to find out the best possible management of carotid stenosis. However, controversy regarding the best possible management of symptomatic carotid stenosis still remains.

Carotid endarterectomy was considered the gold standard of treatment for symptomatic carotid artery stenosis. In fact, the advantages of carotid endarterectomy (CEA) have been established over best medical therapy (BMT) in older research. However, in the past few years, carotid stenting has emerged as a viable alternative to CEA. The aim of this article is to review the carotid stenting procedure and the literature surrounding it.

Carotid stenosis can cause ipsilateral monocular blindness, contralateral weakness/paralysis, dysphagia, dysarthria, contralateral homonymous hemianopia. Several well designed randomized clinical trials demonstrated, that the risk of ipsilateral stroke directly correlates with degree of carotid stenosis. This direct correlation was demonstrated and reported by NASCET and ECST [6,7]. Hypertension is the most prevalent modifiable risk factor for stroke. Other risk factors are diabetes, heavy alcohol consumption and cigarettes smoking.

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Article history:
Received: 13 August 2022
Accepted: 30 August 2022

TECHNIQUES

Indications of Carotid Artery Stenting (CAS)

CAS is currently approved for patients with carotid stenosis exceeding 70% and patients considered to have high-risk conditions (Table 1) [8].

TABLE 1. High-risk features for carotid endarterectomy

ANATOMIC
Re-stenosis after carotid endarterectomy
Bilateral stenosis
Contralateral carotid occlusion or laryngeal nerve palsy
Previous radiation treatment or surgery of the neck
Lesion inaccessible by surgery
Neck immobility
Tracheostomy or tracheostoma
Severe intracranial stenosis
COMORBID CONDITIONS
Unstable angina
Left ventricular ejection fraction of <30%
Congestive heart failure
Planned coronary artery bypass or valve replacement
Renal failure
Chronic obstructive pulmonary disease
Coronary artery disease with ≥70% stenosis
Planned peripheral vascular surgery
Myocardial infarction within 6 weeks of the procedure
Age older than 80 years

European Society for Vascular Surgery, 2017 Guidelines for Carotid Stenosis [9]

If the recorded procedural death/stroke rate is less than 6%, CAS should be considered in recently symptomatic individuals with a 50% – 99% stenosis who in addition also present with unfavorable anatomical feature and/or medical comorbidities that are thought to put them at "high risk for CEA".

CAS should be taken into account as an alternative to surgery when revascularization is indicated in "average surgical risk" patients with symptomatic carotid disease, provided the recorded procedural death/stroke rate is less than 6%. When opted for, it is usually suggested that revascularization of symptomatic 50% – 99% carotid stenosis be performed at the earliest and preferably within the first 14 days of the onset of symptoms.

In 1980, Mathias and associates carried out the first known angioplasty of a carotid bifurcation. While the majority of initial indications included nonatherosclerotic diseases such as radiation-induced or inflammatory stenosis, a further look into atherosclerotic diseases found an increased risk of distal embolic complications. To overcome these problems distal embolic protection devices were used. They first used simple distal occlusion by balloon, which was followed by aspiration of debris. Theron et al. were the first to describe distal balloon occlusion. In today's scenario, both proximal and distal embolic protection devices are the most frequently used embolic protection devices.

TABLE 2. Trials/studies and their results

TRIAL/STUDIES	RESULTS
Jansen et al. [10]	EPD provides no protection
Macdonald et al. [11]	No difference in filter protected vs unprotected carotid artery stenting
Zahn et al. [12]	Patients treated with EPD had lower rates of ipsilateral stroke [1.7% vs 4.1%]
Wholey et al. [13]	Less chances of periprocedural strokes after EPD use [2.23% vs 5.29%]

A systemic analysis of 2357 patients showed lower rates of periprocedural strokes in patients who received embolic protection devices [14].

Stents

Self-expanding stents replaced the older ones. They are of two types, open and closed cell stents. Closed-cell stents often straighten the vessel after deployment. In addition to it, they also help in preventing the plaque material from extruding through the tines. This makes them suitable for symptomatic lesions which may contain more unstable plaque and exposed debris. However, a decrease in conformability of these stents have been noticed due to their rigidity which can lead to worsening of the post-stent kinking of the native blood vessel. Open-cell stents on the other hand, are less rigid and adapt better to native blood vessels. This feature occurs at the expense of tine density and pore size, which results in the potential for a worse "cheese-grating" effect with resultant release of embolic material, particularly in symptomatic unstable plaques [15]. Of all the closed-cell stents currently approved by the FDA, the Wallstent (Boston Scientific, Marlborough, MA) has the smallest cell size, followed by the Xact stent (Abbott Vascular). The Nex- Stent (Boston Scientific), Acculink, Protégé (ev3/Covidien, Irvine, CA), and Precise (Cordis Corporation) are some of the other FDA-approved open-cell designs.

Guidelines for Administration of Dual Antiplatelet Therapy Pre and Post Procedure CAS

European Society of Vascular Surgery, 2017 [16]: Start DAPT with Aspirin 300 mg initially for up to 14 days f/w, 75 mg/day if not already taking aspirin and clopidogrel [75 mg/day] three days prior to CAS. Aspirin and clopidogrel should be continued for at least 1 month, followed by clopidogrel, unless the physician opts for an alternative platelet regimen.

CAS TECHNIQUE

Patient Preparation

Informed consent should be taken without fail.

Either oral antiplatelet therapy consisting of clopidogrel should be started 5 days before surgery, or a loading dosage of 300 mg clopidogrel should be administered 4-5 hours before procedure.

A baseline neurological exam should be carried out and recorded.

For access, inguinal regions of both sides should be sterilely prepped.

CAS is better accessed via the right common femoral artery (CFA).

Other alternative sites are left common femoral artery and brachial artery.

A short 5-F vascular sheath should be installed and set once access has been established so as to provide a continuous infusion of heparinized saline.

FIGURE 1. Making stab incision at femoral artery puncture site

FIGURE 2. Introduction of guide wire by Seldinger Technique

Since the choice of catheter for the common carotid artery (CCA) catheterization will rely on the aortic arch morphology, cervical arch aortography performed at roughly 30-35° left anterior oblique projection should profile the origins of the great vessels. Sometimes it is very difficult to go through the aortic vessels. On the basis of the origin of the great vessels, in reference to convexity of the aortic arch, it is classified into three types:

- Type I – great vessel origins are level with upper convexity
- Type II – great vessel origins are between the upper and lower convexity
- Type III – great vessel origins are caudal to lower convexity

Type III is the most difficult anatomy to deal with for which we require special catheters like Simmon 2 or 3 catheter.

After selecting the CCA, the antero-posterior and lateral projections of the cervical carotid artery are acquired.

To optimally detect and visualize stenosis, oblique projections are also recommended.

To reduce the incidence of embolus, careful attention to flushing is advised.

The North American Symptomatic Carotid Endarterectomy Trial (NASCET) technique is typically recommended for stenosis analysis; viz. the narrowest region of the stenosis is measured in relation to the most normal diameter that is just cephalad of the stenosis rather than below it.

A baseline ipsilateral cerebral angiography is carried out if a stenosis is found to exist.

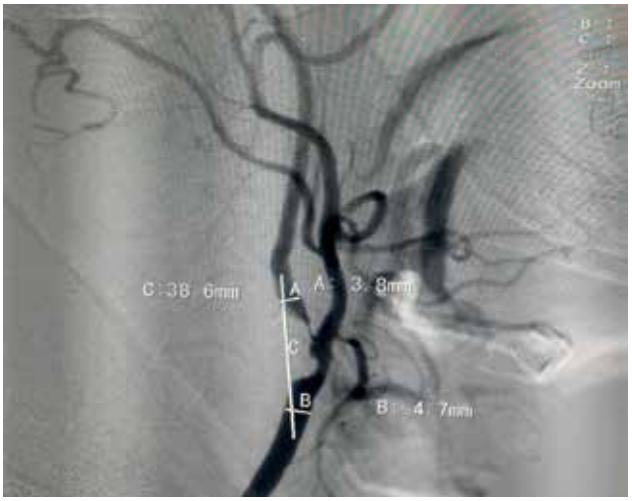

FIGURE 3. Measuring length of stenotic segment and planning for size of stent

Carotid Artery Stenting

A guide-wire with an exchange length is inserted with its tip either in the external carotid artery or the distal CCA.

Any accidental contact of the wire with the stenosis should be avoided.

A sheath of adequate length and diameter is positioned (commonly a 90 cm 8Fr sheath).

It is necessary to use intravenous anticoagulation, and most surgeons prefer unfractionated heparin.

A 100 unit/kg bolus dose is given and adjusted until the activated clotting time (ACT) is between 250 to 300 seconds.

Heparin can be replaced with bivalirudin, which is a direct thrombin inhibitor. Bivalirudin is administered as a 1mg/kg bolus dose followed by a 0.2 mg/kg infusion.

Embolic Protection Device Placement

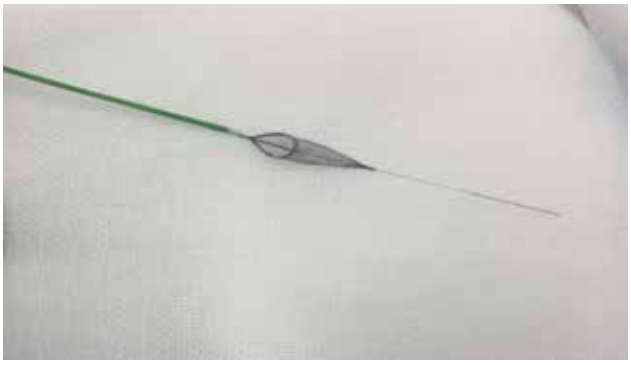

FIGURE 4. Distal embolic protection device (SpiderFX)

The three common types of EPD include distal occlusion balloon, distal filter device and proximal flow diversion.

An EPD of a suitable size (i.e. slightly larger than the diameter of the internal carotid artery) should be chosen and positioned with the help of the reference marker.

To allow stent delivery with sufficient space, the EPD needs to be placed in the cervical carotid artery's straight terminal portion at a suitable distance from the stenosis.

Angiography must be used to confirm adequate apposition to the carotid arterial walls.

While a smaller device may not be able to effectively capture emboli, a larger EPD may either end up causing injury to the artery or induce vasospasm. So, after deployment of embolic protection devices, angiography should be done.

The main drawback of the distal protection devices is the absence of protection when the stenosis first engages the EPD delivery system before the deployment of EPD. When placing the EPD, the roadmap technique proves beneficial in preventing blind probing of the stenosis.

A distal filter type, such as the SpiderFx Embolic Protection Device, can be used once the wire has successfully passed the stenosis.

The benefit of proximal protection devices like the Mo.Ma Ultra Proximal Cerebral Protection Device (Medtronic, Inc., MN) or the Gore Flow Reversal (Gore & Associates, Flagstaff, AZ) is, that none of these devices cross the stenosis before protection is engaged, thereby protecting the entire procedure. The need for a larger 9F sheath and venous access however, is additionally present.

Predilation

The purpose of predilation is to induce stent through the stenosis. Controversy surrounds predilation of the stenosis following the placement of the EPD and prior to stent deployment.

Disadvantages include the potential of distal embolization, possibility of plaque rupture without stent protection, and added time demands.

A 2.5 mm or 3 mm diameter balloon should be used if predilation is desired.

Prior to predilation, 0.5 to 1 mg of atropine should be kept ready for administration in case bradycardia occurs.

STENT PLACEMENT

Nitinol or Elgiloy-based self-expanding stents are available which are commonly used for CAS.

The length of the stent should be sufficient to completely cover the stenosis, which should typically extend from the CCA to the ICA.

The stent diameter should match that of the CCA in order to achieve adequate wall apposition in all carotid segments. Before deployment, the stent should be about 1-2 mm beyond desired location distal to the stenosis, which should then be retracted to minimize any redundant forces that may cause the stent to move further.

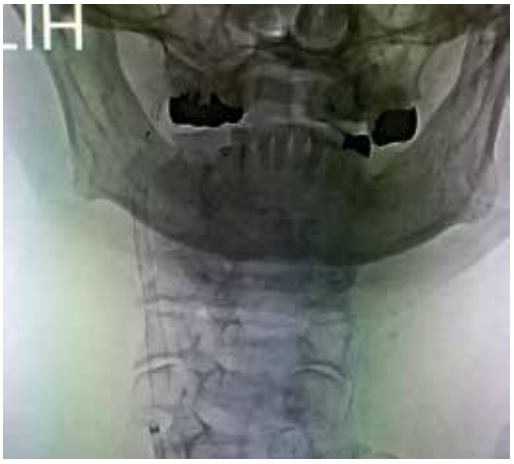

FIGURE 5. Fluoroscopic image showing guiding catheter, deployed stent (pre-dilatation) and distal embolic protection device

A second stent may be required in cases where the stenosis is not adequately covered by the first one.

In the event that bradycardia occurs, atropine should be available to administer immediately.

Postdilation

In cases where the stent is not sufficiently inflated before placement, postdilation may be necessary.

Avoid postdilation if it's not absolutely necessary, as it can cause an embolic phenomenon.

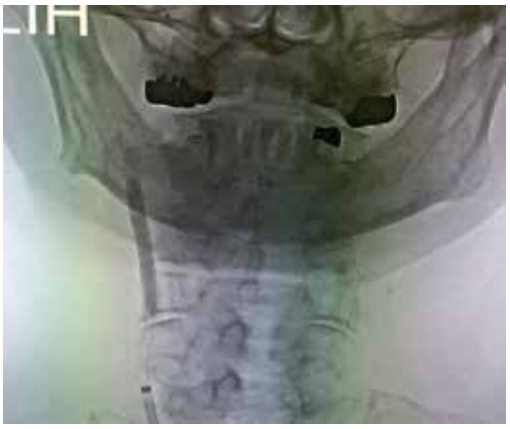

FIGURE 6. Fluoroscopic image showing dilatation of stent using balloon filled with contrast

Postdilation if required, can be done by utilizing a 5 mm balloon to gently dilate the stenosis. Atropine should also be kept ready should bradycardia ensue.

EPD Removal and Completion Angiogram

After completing the stent placement and postdilation (if required), the EPD should be examined for any trapped embolic material before its retrieval. On detection of a substantial embolic load, an aspiration catheter should be used to clear any lodged debris.

Mostly the embolic load will be minimal and the EPD can be collapsed safely with the appropriate catheter. Removal should be done under fluoroscopic observation as the stent margins may get engaged withdrawing it through the stent.

Removal may be facilitated by turning the head of the patient, asking them to cough or by performing the Valsalva maneuver.

In case the EPD is on a monorail system, a 5F catheter will also have to be converted to a monorail from over the wire system by making a hole close to the leading end of the catheter.

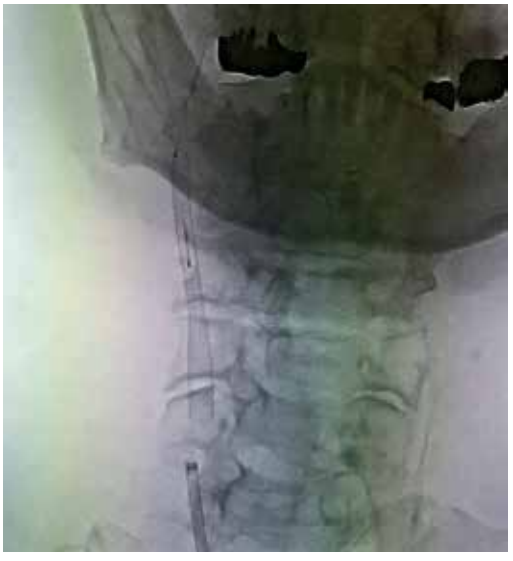

FIGURE 7. Fluoroscopic image showing retrieval of distal embolic protection device

A completion angiogram is done including both the cervical ICA and the intracranial circulation after successful removal of the EPD, to check for any residual stenosis, rule out vasospasm or dissection, and to assess intracranial blood flow. This should be evaluated in comparison with the pre-procedure angiogram to rule out distal emboli which can occur subtly.

Before access discontinuation, a basic neurological examination is conducted by asking the patient to answer simple questions or perform easy tasks. Manual compression or closure device can then be used to achieve hemostasis.

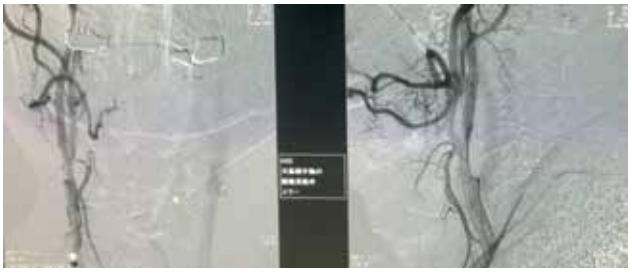

FIGURE 8. AP, lateral views showing post stenting carotid angiogram

Post-procedural Care

After completion of CAS, the patient is recovered from anesthesia and admitted for close observation.

Series of neurological exams are performed and documented in a systematic manner.

Access site is routinely evaluated in an appropriate manner.

Periodic hemodynamic monitoring is advised.

In case of postprocedural hypotension, volume resuscitation usually proves adequate.

If hypertension is present, then keep blood pressure below 150 mmHg systolic.

Majority of the patients are usually discharged the next day with a long-term follow up.

It is recommended that clopidogrel be continued for 45 days following surgery following which, the patient should be put on aspirin for life.

A follow-up ultrasound is advised every three months, six months and then yearly.

CONCLUSION

The CEA vs CAS debate continues to exist despite numerous randomized controlled trials. According to studies, periprocedural stroke rates are more likely to be linked to CAS then CEA. However, MI, CNIs and hematomas are more probable with CEA. Results over the medium- and long-term appear to favor neither CAS, nor CEA. Our current analysis suggests, that if performed in a high-volume center with skilled interventionalists, use of suitable equipment and under embolic protection devices, carotid

TABLE 3. Studies & trials on cas and cea and their result

TRIALS	RESULTS [CAS vs CEA]
CAVATAS(2002) [17]	Both symptomatic and asymptomatic patients included Periprocedural Disabling stroke/deaths similar b/w CAS and CEA-6.4% vs 5.9% Death: 10% vs 10% Cranial neuropathy: 0 vs 8.7% Neck/Groin hematoma: 1.2% vs 6.7% Re-stenosis at 1 year: No difference Restenosis at 3 years: 30.7% vs 10.5%
SAPPHIRE(2004) [18]	CAS non-inferior wrt death/stroke/MI within 30 days or death/ipsilateral stroke between 31 days & 1 year Rate of restenosis requiring intervention were also similar at 3 years
EVA 3S(2006) [19]	Symptomatic patients included and trial stopped prematurely due to high incidence of periprocedural stroke/death with CAS
SPACE(2006) [20]	Symptomatic patients included Failed to prove non-inferiority of carotid-artery stenting compared with carotid endarterectomy for the periprocedural complication rate [6.84% vs 6.34%] Recurrent restenosis more frequent with CAS
ICSS(2010) [21]	The incidence of stroke, death, or procedural myocardial infarction was 8.5% in the stenting group compared with 5.2% in the endarterectomy group Risks of any stroke, MI or deaths were higher in the stenting group Long-term restenosis rates similar
CREST(2010) [22]	Same rates of periprocedural stroke/death/MI Increased periprocedural strokes with CAS [4.1% vs 2.3%] Increased periprocedural MI/CN neuropathy in CEA No significant difference in stroke/death/MI rates at 10 years Similar rates of restenosis
ACT-1(2016) [23]	Asymptomatic patients were included Periprocedural stroke/deaths/MI with in 1 year: 3.8% vs 3.4% Post-procedure stroke /death rate similar up to 5 years 5 years stroke free survival similar between the groups

artery stenosis can be carried out with reasonable procedural safety along with high procedural success. If carried out by a skilled surgeon, it can be linked to high success rates and low cardiovascular complications in high-risk patients. Guidelines should be established for performing CAS, using instruments, embolic devices, use of dual or single antiplatelet therapy pre- and post-procedure along with use of open or closed stents, as they tend to have variations. In order to perform CAS for specific indications with use of specific instruments, high quality RCTs is needed. This procedure is not only less invasive, but is also well tolerated by patients, making it a better treatment option for carotid stenosis in the future. In comparison to CEA, CAS is also a safe and effective procedure for treating patients with carotid artery stenosis with additional surgical comorbidities. A rapid transition to CAS as the preferred treatment option is expected in the near future.

Conflict of interest: none declared
Financial support: none declared

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