Carotid Intervention 2: Technical Considerations

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ABSTRACT

Carotid angioplasty and stenting (CAS) is an evolving technique for treating patients with carotid occlusive disease. However, technical and clinical outcomes are closely related to the knowledge and experience of the interventionalist, and procedural mistakes often lead to serious neurological complications. This article discusses the preinterventional workup of a patient selected for CAS, the different steps of a CAS procedure, the potential complications, how to avoid them, and once they occur how to intervene. Finally, a short overview of the follow-up is given.

KEYWORDS: Carotid, angioplasty, stent, interventional procedure

Objectives: Upon completion of this article, the reader should understand the preinterventional workup, the different steps, and the potential complications of a carotid artery stent procedure.

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Atherosclerotic stenosis of the internal carotid artery is an important cause of stroke. A complete neurology history and examination performed by a neurologist is required before starting a carotid angioplasty and stenting (CAS) procedure. Besides clinical evaluation, the patient also needs radiological examination of both the brain parenchyma and the extra- and intracranial supra-aortic vessels. Baseline magnetic resonance (MR) imaging with special attention to diffusion-weighted imaging may be performed to document preexisting ischemic lesions and to exclude other, non-ischemic brain lesions. Additionally, evaluation of the degree of the carotid artery stenosis by noninvasive imaging is mandatory. Duplex ultrasound of both carotid bifurcations, preferentially performed by an experi-

enced ultrasonographer, is the most inexpensive and easiest diagnostic tool, but in case of doubt or suboptimal evaluation, computed tomography (CT) angiography or MR angiography are very helpful adjunctive tools. Additionally, these imaging modalities have the advantage of evaluating the aortic arch, the supra-aortic vessels, and the intracranial arterial vasculature with regard to the degree of stenosis, the amount of calcified atherosclerotic plaque, and the anatomical configuration of the carotid bifurcation. Based on the clinical and radiological findings described in the previous article, a decision to treat the patient's carotid artery stenosis by endovascular technique can be made. Finally, discussion of the pros and cons of CAS with the patient is vital, and the patient has to give complete informed consent.

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DIFFERENT STEPS OF A CAS PROCEDURE

Every interventionalist should perform CAS in a standardized way with an experienced team who all know their job. Every step of the procedure should be well known and fluently performed without hesitation because the longer a CAS procedure takes, the more mistakes and complications occur. These steps can be summarized as follows: (1) medical pretreatment, (2) vascular catheterization of the common carotid artery, (3) insertion of a cerebral-protection device (CPD), (4) lesion predilation, (5)stent placement, (6) postdilation of the stented segment, (7) removal of the protection device, (8) closure of the vascular access site, and (9) immediate postprocedural care.

Pretreatment

It is mandatory to obtain baseline laboratory values, including hemoglobin, serum creatinine, electrolyte levels, and clotting screen, as well as an electrocardiogram (ECG). If renal insufficiency is present, intravenous hydration must be started 1 day before the procedure and the use of iso-osmolar contrast agents or possibly gadolinium for angiographic imaging considered.¹ Patients receiving long-term anticoagulation, should discontinue Coumadin at least 3 days before the procedure and converted to low-molecular-weight heparin. In contrast to other peripheral vascular interventions, antiplatelet therapy should be started 3 days before the procedure, consisting of acetylsalicylic acid, 160 mg,

and clopidogrel, 75 mg daily.² It is important to understand that the antiplatelet effect of clopidogrel is vital to the early success of this procedure, and it takes a minimum of 48 hours for clopidogrel to affect the platelets. In patients > 80 years of age this effect may take longer, and 7 days pretreatment is recommended.

Optimal imaging during a CAS procedure is crucial for a good technical and clinical outcome; therefore carotid artery stenting should be performed in a dedicated angio suite, with a state-of-the-art C-arm, digital subtraction angiography, and a road-map module.

Noninvasive blood pressure measuring, heart rate and ECG monitoring are required during the procedure. Typically, CAS has to be performed by a physician, an assistant physician, and a scrub nurse, all of them familiar with all devices and all steps of the procedure.

The procedure itself is performed under local anesthesia and without sedation. This allows continuous neurological monitoring of the patient during and immediately after the procedure. Occasionally conscious sedation or general anesthesia may be required if the patient is not cooperative.

Vascular Catheterization of the Common Carotid Artery

Typically, the right common femoral artery is punctured under local anesthesia for access. After insertion of a 5F sheath and administration of 5000 IU of heparin, a pigtail catheter is advanced into the ascending thoracic

Figure 1 Carotid stent procedure. (A) Arch angiography shows a rather proximal implantation of the brachiocephalic trunk (arrow) with subsequently a sharp angle between the aortic arch and the proximal brachiocephalic trunk, making catheterization and placement of a guiding catheter into the right common carotid artery more difficult. (B) Despite tortuosity, fluoroscopic image shows guiding catheter (arrowheads) placed correctly.

aorta to perform an arch angiogram. The left anterior oblique view is preferred to evaluate the origin of all supra-aortic vessels, their patency, and their anatomical configuration. Additionally, confirmation of the degree of the carotid stenosis can be obtained as well as the anatomical configuration of the entire extracranial segment of the internal carotid artery. Based on these findings, the interventionalist has to decide if safe catheterization of the common carotid artery and subsequently the internal carotid artery is feasible (Fig. 1A,B). If not, the procedure has to be aborted for technical reasons at this stage.

Selective catheterization of the common carotid artery can be performed by a variety of guidewires and diagnostic catheters, but it is advisable to be familiar with a few of them. In our practice we routinely use a hydrophilic guidewire (Glidewire; Terumo, Leuven, Belgium) and have available a vertebral and Simmons I or II catheters, although other types of catheters, like a Vitek catheter (Cook, Bloomington, IN), H1, or a JB3, have been used successfully by other radiologists.³ Once the catheter is in place, a road map is performed to image and allow catheterization of the external carotid artery. The diagnostic catheter is advanced into an external carotid branch vessel and then exchanged for a stiff guidewire, like an Amplatz (Boston Scientific, Natick, MA) guidewire (Fig. 2A,B). Over this stiff guidewire, a 6F long sheath or an 8F long guiding catheter is advanced 2 cm proximal to the carotid bifurcation.

Insertion of a Cerebral-Protection Device

The evidence for the use of CPDs and discussion about them is dealt with in the next article. Currently, the most popular CPDs are distal filter devices. Briefly they consist of a floppy-tipped 0.014-inch guidewire and an umbrella made of polyurethane with a nitinol skeleton. The polyurethane fabric has multiple pores with diameters depending on the type of filter, providing continuous antegrade flow.⁴

Before introducing the distal protection device, a correct view on the tip of the guiding catheter, the carotid bifurcation, the carotid stenosis, and the filter landing zone, at least 2 cm above the arterial segment to be covered by the stent, has to be determined. In the majority of cases, a lateral view or an ipsilateral oblique view of the carotid artery bifurcation is the best working position. A road map in this optimal working position is made, and subsequently the carotid stenosis is crossed directly by the filter device, still collapsed in a 5.5F dedicated peel-away catheter. After removing the peel-away catheter, the filter is deployed. This should be in a straight segment instead of in a tortuous segment because the latter potentially can lead to a suboptimal apposition of filter to arterial wall and subsequent poor function. An alternative technique, where tortuosity or degree of stenosis makes advancement of the filter wire difficult, is the use of an adjunctive 0.014-inch floppy-tipped coronary guidewire, frequently termed "buddy wire." The carotid stenosis

Figure 2 Carotid stent procedure. (A) Global arch digital subtraction angiography reveals a tortuous aspect of the left common carotid artery (arrowheads). Note also the high-grade stenosis (arrow) of the left internal carotid artery. (B) Fluoroscopic image shows a stiff guidewire (arrowheads) straightening the left common carotid artery, making placement of a guiding catheter and subsequent stent placement possible.

and the extracranial segment of the internal carotid artery are crossed by the buddy wire, straightening the internal carotid artery and making the passage of the filter protection device easier. The buddy wire can then be retrieved and the filter deployed. In rare cases the buddy wire cannot be advanced to the level of the distal internal carotid artery. Here the use of a coaxial microcatheter and a hydrophilic micro guidewire can be useful (Fig. 3A–G). Once the tip of the microcatheter

is positioned at the level of the skull base, it is exchanged for a 300-cm-long 0.014 coronary wire, which then acts as the buddy wire. Straightening a tortuous internal carotid artery and placement of a distal protection device can induce arterial spasm (Fig. 4A–D), but this is nearly always benign, disappearing spontaneously after retrieval of the wire and protection device. The administration of vasodilator drugs is only very rarely needed.

Figure 3 Carotid stent procedure using embolic protection. (A) Selective angiography of the right common carotid artery reveals a tight stenosis (arrow) of the origin of the right internal carotid artery. This tight stenosis could not be passed by a sheathed distal protection device or by a 0.014-inch coronary guidewire. (B) Fluoroscopic image shows catheterization of the stenosis and the distal internal carotid artery by a microcatheter and hydrophilic guidewire (Progreat 2.7; Terumo Europe, Leuven, Belgium) (arrowhead). Note also the calcifications at the level of the stenosis (white arrow). (C) Fluoroscopic image shows a 300-cm-long 0.014-inch guidewire (arrow) positioned across lesion. (D) Fluoroscopic image shows 3 × 20 mm angioplasty balloon (arrowheads) placement for predilation of the calcified tight stenosis (arrow).

Figure 3 (Continued) (E) Fluoroscopic image after predilation shows the 0.014-inch guidewire still in place. The lesion is now catheterized with the sheathed protection device (arrows). (F) Fluoroscopic image after retrieval of the 0.014-inch guidewire shows the distal protection device (arrows) is deployed. Stent placement and postdilatation can be performed under distal cerebral protection. (G) Completion angiography after stenting shows a normally patent internal carotid artery.

Lesion Predilation

The rationale in predilating the carotid stenosis is to create a small channel to cross the lesion safely with the stent catheter and to avoid unwanted migration of the stent during deployment. After intravenous administration of 0.6 mg atropine, the predilation is

performed using a 2 cm × 3 mm diameter monorail balloon catheter and only takes a few seconds. The positioning of the balloon catheter across the lesion also allows a better estimate of the length of the carotid stent to be introduced as the next step in the CAS procedure.

Figure 4 Common carotid angiogram through the guiding catheter in frontal (A) and lateral (B) projections, with the distal protection device in place, shows multiple spasms in the internal carotid artery, partially due to straightening (B, arrows) of the carotid artery and partially due to deployment of the distal protection device (B, arrowheads). (C) Carotid angiogram after stent placement and without administration of any vasoactive drug shows several minor spasms (arrows). Just proximal to the filter device, a residual major spasm (arrowhead) is shown. (D) Completion angiogram after filter retrieval shows patent internal carotid artery and residual minor spasm (arrowhead) at the level of the protection device deployment.

Stent Placement

Further imaging should not be necessary after predilation because diameter and length measurements were taken during earlier angiography. The carotid stent should have a diameter 1 mm larger than the nominal diameter of the largest vessel segment to be stented. In most of the bifurcation stenosis it will be the diameter of the distal common carotid artery. By preference the stent should cover the entire stenosis and the vessel segments at least 5 mm above and below the stenosis. If not, a second stent should be placed (Fig. 5A–C).

Currently, several dedicated carotid stents are commercially available on the market, all of them self-

expandable stents mounted on a rapid exchange catheter system. They are made of nitinol or stainless steel and some have an open cell or a closed cell design. All are more or less conformable to vessel tortuosity, avoiding straightening and subsequent kinking, and they present enough scaffolding to avoid late plaque migration through the stent struts. There is currently no scientific evidence that one stent is superior to another. Some authors speculate that carotid stents with closed cell design will result in fewer late neurological events due to migration of atherosclerotic plaque material through the interstices of the stent struts versus open cell design.⁵ Tapered stents are also available that conform better to

Figure 5 (A) Arch angiography reveals a high-grade stenosis of the right carotid bifurcation (arrow). (B) Fluoroscopic image shows the stent is placed too proximally and only partially covering the stenosis (arrowheads). Note the calcifications of the stenosis (arrow). (C) Fluoroscopic image shows placement of an additional stent (arrowheads) more distally to cover the stenosis (arrow) completely.

the diameter change between common and internal carotid arteries. No scientific evidence supports the use of these stents either. Balloon expandable stents should *not* be used because they are easily crushed in the neck.

Postdilation of the Stented Segment

Postdilation of the deployed stent is routinely performed to expand the stent to a diameter of $>70\%$ of the diameter of the internal carotid artery just above the stent; in other words, a residual stenosis of $<30\%$ is acceptable. Balloon size usually ranges from 4 to 6 mm diameter, and monorail systems are preferred. Like predilation, postdilation requires an intravenous injection

of 0.6 mg of atropine. We consider postdilation the most aggressive act during CAS, with significant changes in heart rate and blood pressure if atropine is not used. Also the patient will experience a sensation of pain in the neck region and may have a self-limiting seizure-like reaction during this phase.⁶

Removal of the Protection Device

Removal of the distal filter is performed by inserting a retrieval catheter over the wire through the stent, re-sheathing the filter and its potential embolic content entirely. If resistance is encountered when crossing the stent, the retrieval catheter can be reshaped, the patient's

head can be rotated, or light external compression can be applied at the level of the stent. If resistance is felt as the CPD is resheathed, it may indicate the filter is full of embolic material. Partial resheathing is recommended if this occurs. Once the entire system (recovery sheath and filter basket) is removed from the patient, a final angiogram of the cervical carotid artery is made. Some interventionalists routinely carry out ipsilateral intracranial angiography at this stage, but it is not clear that this additional imaging has clinical value in a patient who has not experienced any neurological complications during the procedure. If the patient has experienced any cerebral event during the procedure, intracerebral angiography is worthwhile because larger emboli can be snared and removed if occluding large intracerebral arteries. Intracerebral thrombolysis, despite its obvious dangers, may also be indicated.

Closure of the Vascular Access Site

Unlike many other percutaneous procedures, a closure device is routinely inserted after CAS. This allows the patient to ambulate earlier but, more importantly, these patients are quite aggressively anticoagulated post-procedure and are already on dual antiplatelet therapy. Hypotension due to hemorrhage at the puncture site should be avoided because it can lead to stent thrombosis and stroke.

In the immediate postprocedural period, the patient should be carefully monitored. Regular blood pressure and heart rate measurements are necessary to manage persistent bradycardia or reperfusion syndrome secondary to uncontrolled hypertension.

Continued dual antiplatelet therapy is more important than heparin in the periprocedural period⁷ and should be continued for a minimum of 30 days; after this, acetylsalicylic acid is prescribed for life.^{2,7}

COMPLICATIONS OF CAS

Complications related to CAS can be subdivided into non-neurological-adverse events and neurological-adverse events. According to Brott et al,⁸ neurological adverse events are categorized as TIA (transient ischemic attack), minor and major stroke. A TIA is a neurological deficit that resolves within 24 hours and leaves no

residual neurological damage; a minor stroke is a new neurological event that results in slight impairment of neurological function that either completely resolves within 7 days or causes a <4 points increase in the National Institutes of Health Stroke Scale (NIHSS); a major stroke is defined as a new neurological deficit that persists >7 days and increases the NIHSS score by >4 points. Depending on the time when the adverse event occurs, division into three stages is proposed by Wholey et al.⁹ Stage I complications occur during access to the common carotid artery; stage II complications occur during positioning of the distal filter device, and stage III complications during predilation, stent deployment, postdilation, and recovery of the filter.

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