Current Techniques of Carotid Artery Stenting

An overview of the access approaches, device selection, and medical management of CAS.

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Carotid artery stenting (CAS) is emerging as an alternative therapy to surgical carotid endarterectomy (CEA) for the treatment of extracranial carotid stenosis.[1-3] The common goal of both procedures is the prevention of stroke, and the efficacy depends highly on the periprocedural complication rates. The endovascular stent procedure offers a less-invasive approach to achieving this goal by avoiding some of the perioperative complications associated with surgical treatment. The randomized trial of carotid angioplasty (CAVATAS) showed that despite the use of suboptimal interventional techniques, the early and 3-year outcomes were equivalent.[2] Klaus Mathias, MD, who performed the first balloon angioplasty of the carotid artery in 1979, used techniques derived from his experience performing peripheral interventions.[4] Initially, .035-inch guidewires were used to directly cross the lesion, followed by treatment with a balloon and stent without direct angiographic visualization using the spinal column as an anatomic landmark.

Recently, there has been a rapid growth in this procedure's use due to the technological advances and the experience gained from performing coronary interventions. The technique of CAS was revolutionized when Gary Roubin, MD, started the use of long introducers advanced forward in the common carotid, allowing the visualization of the stenosis with contrast medium throughout the procedure, and started the use of low-profile guides and balloons for coronary interventions.[1]

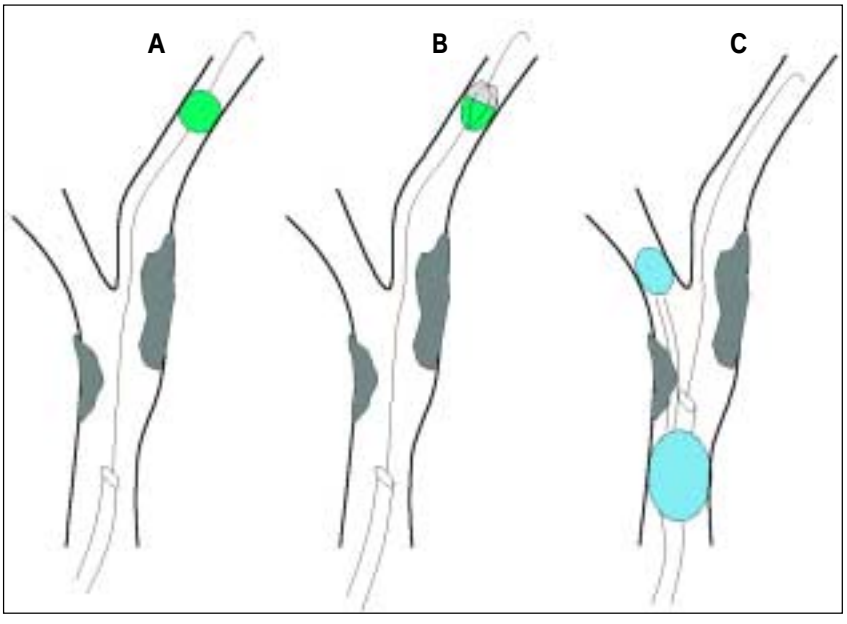


Figure 1. The three systems of cerebral protection: distal balloon occlusion (A), distal filter devices (B), and proximal balloon occlusion (C).

This article discusses the technical aspects of CAS and the different approaches to treatment that may reduce the risk of periprocedural complications.

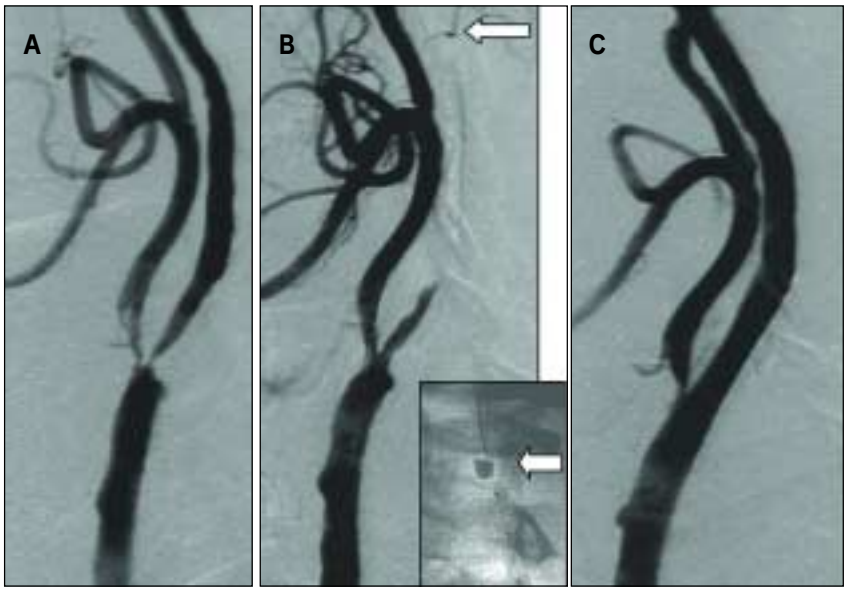


Figure 2. Stenting of a severe, ostial lesion of the internal carotid artery. Baseline angiography (A). Occlusion of the distal artery with a Guardwire balloon (Medtronic, Santa Rosa, CA) (B). Final angiographic result (C).

THE CAS PROCEDURE

Patient Monitoring

Continuous ECG monitoring is mandatory to control eventual bradycardia, and direct pressure monitoring through the guiding catheter or through the introducer sheath is highly recommended to observe the hemodynamics of the patient. Generally, patients are not sedated. Continuous contact with the patient is essential to monitor eventual neurological complications.

Vascular Access

Access from the femoral artery, which allows an easy cannulation of the common carotid arteries, is preferred. Only if the femoral arteries are occluded, or if the access of the common carotid artery from the femoral artery is unsuccessful, is brachial access used. In this case, we used the brachial right artery for treatment of the left carotid artery, and the brachial left artery for treatment of the right carotid artery. In the case of a radial approach, 6-F armed introducers (external diameter >7 F) are not recommended because of the possibility of prolonged arterial spasm; therefore, guide catheters of 7 F are preferable.

Diagnostic Catheters

Selective cannulation of the common carotid artery by a diagnostic catheter is necessary both to obtain adequate angiographic images and to advance the support guides. Usually, right curve-type Judkins catheters are used. Possible alternatives are the right-type Amplatz in the case of origin from an acute angle of the left common carotid artery, and the internal mammary catheter for the brachial or radial access. For the beginning of a correct diagnostic and interventional program related to the carotid arteries, some specific catheters are necessary, even if rarely used. There are several types of suitable catheters that allow, after a short time of operator training, stable cannulation of the anatomically difficult carotid arteries due to their curve positioned in the ascendant aorta. The dimensions of the diagnostic catheters range from 4 F to 6 F. Also, with use of a 4-F catheter selectively positioned in the carotid artery, it is possible to obtain a good-quality carotid angiogram. Furthermore, these catheters are thinner, softer, and less traumatic. With the exception of very simple cases, it is preferable to move the catheter forward on .035-inch wires. We typically use hydrophilic wires that are very soft and cause little trauma. However, these guidewires must not move forward beyond the carotid bifurcation. Carotid angiography is an integrated element of the CAS intervention and care should be taken to reduce the incidence of thromboembolic complications to a minimum. Moreover, it has been shown that using magnetic resonance imaging, cerebral focal lesions have been demonstrated in more than 25% of diagnostic cerebral angiographies.[5] These lesions, usually asymptomatic, are likely due to a dislocation of plaque fragments from the aortic arch and the ostia of the carotid arteries. We suggest performing intracranial angiography through the carotid artery to be treated in the anteroposterior and lateral projection. In this way, it is possible to collect information regarding possible intracranial stenotic lesions and a baseline image of the intracranial vascularization that may be very useful in solving embolic complications.

Access Into the Common Carotid Artery

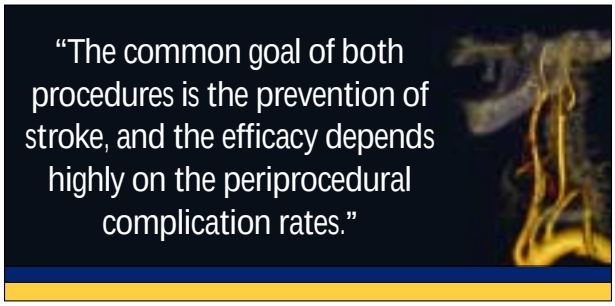
The most important factor in achieving technical success in a CAS procedure consists of the ability to gain access to the common carotid artery through a long

introducer or a guide catheter. The principal reason for procedural failure is the inability to advance an introducer or a guide catheter in the common carotid artery due to a difficult take-off from the brachiocephalic trunk or from the aortic arch, or due to significant kinking or coiling of the common carotid itself. Baseline images of the arch obtained angiographically or with MRI are very helpful to select the best approach.

A long introducer of 6 F or 7 F is the preferred instrument to achieve cannulation of the common carotid artery by using Roubin's approach. This involves positioning of a diagnostic catheter relatively distally in the common carotid artery. To move the catheter forward into the vessel, a technique incorporating very slow "push and pull" of the catheter on the .035-inch floppy, hydrophilic wire can be used. The floppy wire is then retracted and a long (220- to 260-cm), high-support, floppy-tip, .035-inch wire (eg, Supra Core, Guidant Corporation, Indianapolis, IN) is positioned in the external carotid artery through the diagnostic catheter. The angiographic application of the road mapping is useful to facilitate the crossing of the wire into the external carotid artery, which helps avoid crossing the lesion of the internal carotid artery with the wire, which may lead to possible dislocation of material.

Once the guidewire has been positioned into the external carotid artery, the diagnostic catheter is removed and the introducer (with its inner dilator) is advanced in the common carotid artery. We suggest observing this passage under fluoroscopy. Partial retention of the dilator on the inside of the introducer may be useful to cross very angled curves. The introducer is advanced close to the bifurcation and the dilator and the guide are then removed. Armed introducers (80-cm to 100-cm long) are used, which provide both acceptable flexibility and sufficient stability so that they do not bend or kink after removal of the dilator.

Alternatively, some operators prefer to use the coaxial technique to position the sheath (in contrast to the previously described sequential technique). In this case, a long (>120 cm), 4- to 5-F diagnostic catheter is preloaded into a long sheath. Using the hydrophilic wire, the common carotid artery is engaged with the diagnostic catheter. Subsequently, the sheath is advanced on the wire and the diagnostic catheter into the common carotid artery. Only in rare cases is a support wire needed to advance the sheath into the common carotid artery.



Another system that can be used to access the common carotid artery is 8-F guiding catheters. Coronary catheters, such as the right Judkins-type for both carotid arteries, the multipurpose type for the right carotid artery, and the hockey-stick type or a mammary artery catheter for the left carotid artery may be used. Usually, the guide catheters are rotated in the aortic arch to directly engage the common carotid artery. The coronary guide catheters are positioned in the aortic arch because deep intubation into the common carotid artery is impossible due to the quite rigid preshaped curves (especially the Amplatz or hockey-stick curves). Despite this fact, they usually give a sufficient support

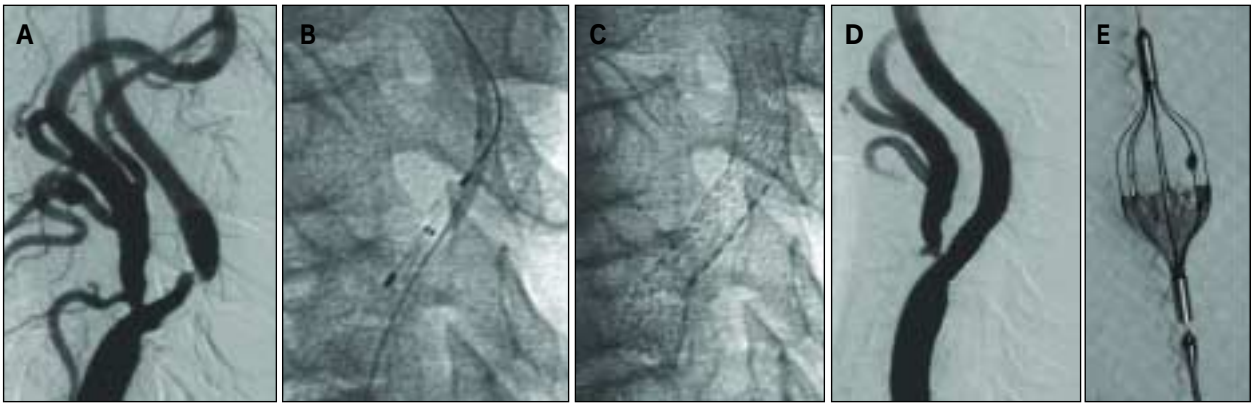


Figure 3. Filter-protected CAS. Angiography of a subocclusive stenosis of the internal carotid artery (A). Lesion crossing with a closed filter device (Angioguard, Cordis Corporation, a Johnson & Johnson company, Miami, FL) is possible only after positioning a .014-inch "buddy wire" in the tortuous internal carotid artery (B). The expanded nitinol stent (Precise, Cordis) conforms well to the vessel tortuosity (C). Final angiographic result (D). The used filter with evidence of captured debris (E).

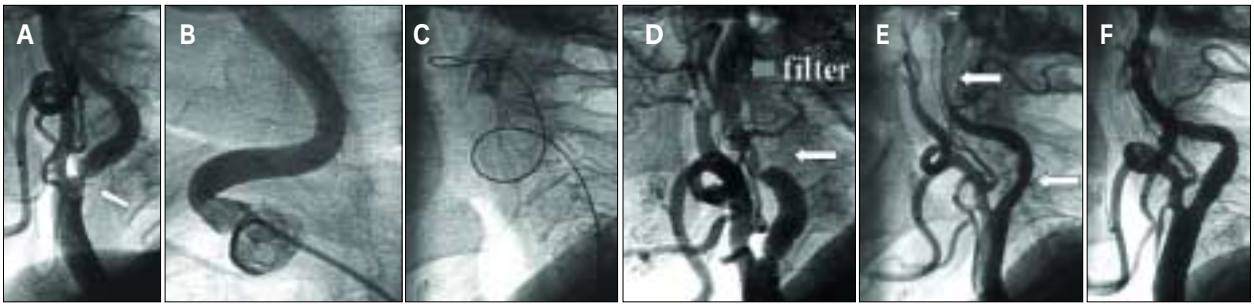


Figure 4. Possible difficulties during CAS in a single patient. Baseline angiography of a focal stenosis of the right internal carotid artery (A). Significant tortuosity of the common carotid artery (B). Support wire (.035 inch) positioned in the external carotid artery to provide necessary support to advance the long sheath into the common carotid artery (C). Spasm (arrow) of the internal carotid artery after opening of the distal filter (D). Slow flow after stent implantation and postdilatation (the arrow indicates the filter) (E). Final result with normal flow after removal of the filter (F).

to perform the angioplasty with low-profile stents and protection devices. Specific guide catheters have a very soft tip and a distal segment of 5 cm and allow for more distal advancement of the catheter into the common carotid artery. These catheters (Guider, Boston Scientific Corporation, Natick, MA) are available only with multipurpose curves and a 40º curve.

It is not easy to choose which is the better technique between the long introducer and the guide catheter. The introducer technique, which comprises a diagnostic catheter, the cannulation of the external carotid artery with a support guide switch-type, and the introducer itself is surely more complex and more expensive. The most important advantage is advancement of the introducer in a very controlled manner from the aorta into the common carotid artery using the introducer tip tapered by the dilator or by the diagnostic catheter, reducing the risk of dislocation of the plaque and possible embolization to the brain. Furthermore, the introducer positioned into the common carotid artery ensures high support to complete the stenting procedure.

The technique of the guide catheter is simpler and less expensive, but bears a theoretical increase of embolization risk in cases of aortic arch with severely diseased vessel wall. In case of a very angled origin of the common carotid artery (type II or III arches or bovine arch), the hockey stick guiding catheter is our first choice.

If the access to the common carotid artery is difficult, we suggest ceasing attempts after 30 minutes and recommend surgical therapy because, in the experience of many centers, major complications may occur after prolonged maneuvers with catheters in the aortic arch.

PROTECTION SYSTEMS

Studies using transcranial Doppler have demonstrated that carotid stenting is associated with a higher incidence of embolization of fragments in comparison to surgical endarterectomy.[6] To reduce the possibility of this embolization causing periprocedural neurological complications, various systems of cerebral protection have been proposed. The first system, a balloon for the distal occlusion, was developed and used by Theron in 1990.[7] Actually, three different approaches for cerebral protection are used: two systems of distal protection such as distal occlusive balloons and filters, and proximal protection using the occlusion of the common and external carotid arteries (Figure 1). Histopathologic analysis of the debris collected using the various systems of protection has demonstrated that they are fragments of the atheromatous plaque dislodged during carotid stenting.[8,9]

Distal Occlusive Balloons

Distal occlusive balloons constitute the first system of protection used on a large scale.[8,9] They consist of a .014-inch guide with a balloon on the distal portion that may be inflated and deflated through a very small channel contained in the guide itself (Percusurge/Guardwire, Medtronic Vascular, Santa Rosa, CA) (Figure 2). The lesion is crossed with the guide, thereby positioning the balloon distally to the stenosis where it is inflated until the blood flow in the internal carotid artery is blocked. Angioplasty and stenting are then performed. On completion of the procedure, a catheter is advanced up to the distal balloon and the column of blood contained in the occluded internal carotid artery is aspirated. In this way, debris dislodged during the stent procedure is eliminated. The balloon is then deflated and the guide is removed.

The advantages of distal occlusive balloons are their small diameter (2.2 F) and the good maneuverability and flexibility of the system. Possible disadvantages are that

the occlusion is not tolerated by 6% to 10% of patients,[8,9] and it is not possible to image the vessel with contrast medium during the inflation.

Distal Filter System

Protection filters consist of a metallic structure (or skeleton) coated by a membrane of polyethylene or a net of nitinol wires that contain 80-mm to 200-mm-diameter holes (Figure 3).[10,11] The filters are usually positioned at the distal portion of a .014-inch guide. During the procedure, the filters are enveloped into a delivery catheter in which they are advanced distally to the stenosis. After the lesion is crossed, the filter is opened by removing the delivery sheath. At the end of the stenting procedure, the filter is closed with use of a retrieval catheter, and the filter is removed from the carotid artery.

In the presence of sharp stenoses from calcific or very fibrous plaques, passage of the closed filter may be impossible. After use of a .014-inch buddy wire or careful predilatation with 2-mm to 2.5-mm-diameter balloons, it becomes possible to cross the stenosis with the filter. Possible complications of the filter are vasospasm or no-flow due to occlusion of the pores by material embolized into the filter (Figure 4). Both complications generally resolve after the removal of the filter device.

A number of second- and third-generation protection filters exist. The technical characteristics of a good protection filter consist of a low profile (<3 F), an adequate torqueability to cross tortuous vessels, and, when open, adequate apposition to the wall to ensure the best possible protection. Filter systems with a free wire that allow positioning of the wire followed by the advancement of the filter itself are now available and may be useful in patients with internal carotid arteries with significant tortuosity.

Proximal Protection Systems

The distal protection devices (occlusive balloons or filters) have the disadvantage that they must cross the lesion before they are inflated or opened,[12] which carries the risk of embolization during this unprotected step of the procedure. Proximal protection systems, in contrast, provide cerebral protection before the passage of any type of device through the stenosis. These systems consist of a long introducer sheath with a balloon that is inflated in the common carotid artery. A second balloon, inflated in the external carotid artery, ensures the total blockade of the antegrade blood flow in the internal carotid artery. Proximal protection systems use the cerebral vascular connections of the circle of Willis. After occlusion of the common and external carotid artery, the collateral flow through the circle of Willis will create so-called back-pressure, which will prevent antegrade flow in the internal carotid artery. After stent positioning, and before the deflation of the balloons in the common and external carotid artery, the blood present in the internal carotid artery—possibly containing dislodged debris—is aspirated and removed.

The advantage of the proximal protection system is the fact that the entire procedure is carried out under protection and, if it is correctly applied, it should completely avoid any type of embolization. The disadvantages of the proximal protection system are that it is not tolerated by all patients and that the two systems actually available (Parodi ArteriA, ArteriA Medical Science Inc., El Presidio, CA; Mo.Ma, Invatec, Roncadelle, Italy) require the use of a 10-F introducer sheath.

STENT IMPLANTATION

With the exception of the treatment of the in-stent restenoses, actually every carotid angioplasty procedure implies elective stent implantation. Use of the stent results in excellent, immediate, and long-term results—better than those obtained by the use of simple balloon angioplasty. From an initial strategy with predilatation followed by stent implantation, we now perform direct stenting in the majority of lesions. Only in cases of very severe (>90%) or calcified lesions that may cause a difficult passage or a difficult stent expansion is predilatation using coronary balloons (diameter, 3.5-4 mm) performed. Typically, 6-mm to 9-mm diameter stents are used, and the diameter of the distal common carotid artery is used as a reference. In the more rare cases in which the stent is positioned only into the internal carotid artery without covering the bifurcation, the dimensions of the stent are selected in accordance to the diameter of the internal carotid artery. Relatively long stents that allow coverage of the entire lesion are used. The stent length ranges from 30 mm to 40 mm and, on the contrary to what was demonstrated for coronary stenting, there are no data showing a relationship between the length of the stent and the incidence of in-stent restenosis. The stent is positioned as less distally as possible, ensuring, however, the complete coverage of the stenosis. In the majority of cases, the stent is positioned so that it covers the bifurcation with the origin of the external carotid. We have seen rare cases of occlusion of the external carotid that have remained clinically silent.

Self-expandable stents are used in the carotid artery almost exclusively because of their lower risk of deformation or fracture in cases of sharp movements or neck trauma compared to balloon-expandable stents. There

are two different kinds of self-expanding stents. Mesh wire stents consist of braided alloy wires, which open like a spring adapting to the vessel diameter (Carotid Wallstent; Boston Scientific Corporation, Natick, MA). Advantages of this stent are its very low profile (5.5 F) and flexible shaft. It also has a rapid exchange that allows the use of short guides and excellent stent deliverability. The possibility to re-close a stent half released allows for exact positioning of the stent in the distal extremity. Possible drawbacks are significant foreshortening at stent release, and vessel straightening leading to possible distal kinking. More recently, self-expandable nitinol stents have been introduced that are characterized by higher radial strength and higher adaptability to tortuous vessels and to the differences of diameter between the internal and the common carotid. These stents open to a given diameter because of their thermal memory. Some nitinol stents are made to be cone-shaped (tapered stents) and have a lower diameter at the distal portion to be positioned in the internal carotid, and a larger diameter at the proximal portion to be positioned in the common carotid artery. At present, it cannot be determined which design and which stent material achieve the best results in the long-term because comparative studies between the different types of stents are not available.

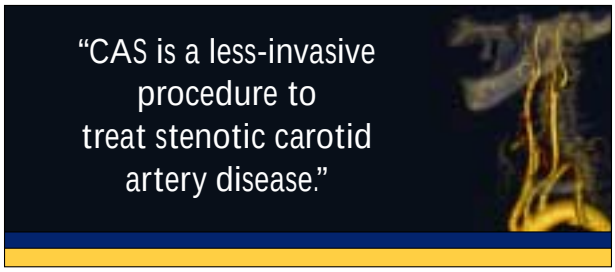
Therefore, the choice of stent depends on the ease of positioning with the lowest risk of acute complications.

Dilatation After Stent Placement

After stent implantation, in almost 100% of cases, dilatation using a balloon is necessary to get an acceptable angiographic result. Dilation after stent placement involves a significant risk of embolization. Use of transcranial echography has shown that the highest number of signals have been noticed during dilatation after stent placement. Because of the risk of embolization we recommend that, even if protection systems are used, the use of undersized diameter balloons with respect to the vessel diameter, and inflation pressures not higher than 10 atm. Unlike coronary stenting, it is not necessary during carotid stenting to obtain a residual stenosis close to 0%. We accept angiographic results showing a residual stenosis up to 50%, obtained without an excessive embolization risk, because they ensure very good clinical and echographic results at long-term. Furthermore, self-expandable stents may even increase their diameter over time.

PHARMACOLOGIC PROTOCOL

Before initiating CAS, we administer aspirin (100-325 mg) and ticlopidine (250 mg, two times a day, starting at least 3 days before the procedure) or clopidogrel (75 mg once a day if given 24 hours before the procedure, or 300 mg if administered immediately before the procedure). During the procedure, heparin (70-100 IU/kg) is administered, maintaining an ACT between 250 and 300 seconds. At the end of the procedure, it is advisable to repeat an ACT evaluation. In the case of values >250 seconds, we neutralize the heparin using protamine sulphate, to reduce the risk of intracranial hemorrhage. We suggest administering 1 mg of atropine intravenously just before the postdilatation to prevent or attenuate possible bradycardia or asystole. During the procedure, an infusion pump of dopamine is prepared and ready for use in case of prolonged hypotension.



After the procedure, aspirin therapy is continued indefinitely and ticlopidine or clopidogrel therapy is continued for 1 month. In cases in which CAS precedes aortocoronary bypass interventions (which is happening with increasing frequency), we have reduced the poststent antiplatelet therapy to only aspirin without problems. The use of glycoprotein IIb/IIIa is not recommended during CAS.[13,14]

FINAL CONSIDERATIONS

CAS is a less-invasive procedure to treat stenotic carotid artery disease. This endovascular treatment is performed in an increasing number of patients. Techniques, devices, and operator experience have rapidly improved and many operators from different clinical specialties are now able to perform CAS. The procedural success is high and the periprocedural 30-day complication rates are promising and are similar to results reported for surgical endarterectomy (see CAS Charts on page 78). In patients at high surgical risk, CAS appears favorable compared to surgery. Restenosis and mid-term results are also promising. Because CAS is a relatively new therapeutic approach, longer-term data are not yet available. Routine cerebral protection during CAS is technically feasible and clinically safe, and it may be prudent to consider it part of the procedure. Randomized trials to compare endarterectomy versus neuroprotected CAS are ongoing but are hampered by

slow enrollment, and results will only be available in several years. However, the less-invasive approach of CAS is increasingly performed, and similar to coronary angioplasty, it is likely that the endovascular approach will expand application before long-term results of a randomized confrontation with surgery are available. ■

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