Carotid artery stenting in a vascular surgery practice

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Purpose: We tested the clinical applicability, technical results, and morbidity of carotid angioplasty-stenting (CAS) in the treatment of severe stenosis of the internal carotid artery (ICA) in patients deemed to be high-risk candidates for carotid endarterectomy (CEA).

Method: After an initial series (1994-1997) of 52 interventions, we adopted the use of a transfemoral access technique and self-expanding stents in late 1997. From Dec 1, 1997, to Mar 31, 2001, 135 CAS procedures were performed on 132 patients with more than 70% (symptomatic) or more than 80% (asymptomatic) stenoses of the ICA. Sixty percent of the patients had no symptoms, and 40% of patients had symptoms. The interventional technique was standardized with the use of a 7F long interventional sheath, balloon pre-dilatation of the stenotic lesion, placement of a self-expanding stent (Wallstent in 12 patients and a SMART stent in 120 patients), and post-balloon dilatation when necessary. Brain protection devices were not used. Patients were given clopidogrel and aspirin before and after the procedure and heparin during the intervention.

Results: All procedures except two were completed as planned, with access failure in three patients (2.2%). Residual in-stent stenosis of less than 20% was detected in 14 of 132 stented vessels (11%) and accepted as a satisfactory angiographic outcome. Neurologic complications included one patient with a single-episode transient ischemic attack (TIA; motor-sensory deficit of the hand) occurring 2 hours after CAS. One patient sustained a major stroke after thrombosis of the stented ICA, which occurred 3 days after the CAS procedure and 24 hours after open-heart surgery. A third patient sustained a minor stroke that began intraprocedurally after post-balloon dilatation of the stent, and a fourth patient had another minor stroke with transient aphasia (beginning during the procedure and resolving after 4 hours) and monoparesis of the hand, which resolved after 1 week. All stented vessels remained patent during the follow-up period (range, 2-41 months; mean, 16 ± 9 months), with four instances of hemodynamically significant in-stent restenosis. Re-intervention with balloon angioplasty was undertaken successfully at 4 months in one patient with restenosis. The periprocedural mortality rate was 0.

Conclusion: Carotid stenting can be performed with acceptable safety on carefully selected patients by using meticulous, standardized interventional techniques. It may offer a possibly superior therapeutic alternative for non-CEA candidates. Evolving technological improvements and brain protection devices are likely to enhance its role in the treatment of carotid artery disease in the future. Surgical endarterectomy remains the standard of care for most patients at the present time. (J Vasc Surg 2002;35:430-4.)

Carotid angioplasty-stenting (CAS) has been proposed as an alternative to carotid endarterectomy (CEA) in the treatment of severe stenosis of the internal carotid artery (ICA).1,2 The procedure is being performed in clinical practice, propelled by the growing view that it may be an attractive therapeutic option for patients with local anatomical factors that make CEA difficult or riskier (ie, restenosis after earlier surgery, “hostile neck” after radical surgery and/or radiation therapy, and distal ICA lesions).3,4 It has also been proposed as a treatment modality competitive with CEA. Two randomized trials comparing CAS with CEA have been published. The Carotid and Vertebral Artery Transluminal Angioplasty Study (CAVATAS) study6 demonstrated comparable safety and efficacy, with a trend toward fewer minor complications for CAS when compared with surgery. The Leicester Stopped Trial7 was discontinued by the safety committee because of an inordinate number of strokes, occurring in five of the first seven patients who underwent carotid intervention. This study and its significance have been questioned because of flawed design, lack of appropriate safeguards, and the apparent inadequacies in endovascular skills and experience.8 Several other clinical studies are underway or in the planning stages, including the large randomized Carotid Revascularization Endarterectomy Versus Stent Trial that is likely to provide the most definitive information on the subject. CEA remains the standard of care at present.

Our clinical experience with endovascular intervention for treatment of carotid artery disease dates back to April 1994,3 when CAS began to be offered to carefully selected patients who had been deemed “inoperable” because of anatomical contraindications to CEA. Procedural strategy during this initial series included a direct cervical approach to the common carotid artery (CCA) and the use of balloon-expandable stents. A standardized transfemoral tech-
nique and self-expanding stents were adopted in December 1997, when a high-risk protocol for treatment of “non-CEA candidates” was developed and approved by the Institutional Review Board (IRB). The purpose of this report was to review the role of CAS in the treatment of carotid artery disease during our second-phase clinical experience by using a standardized transfemoral interventional approach, with emphasis on applicability, technical results, and neurologic morbidity.

METHODS

Patient population. Between Dec 1, 1997, and Mar 31, 2001, 135 CAS procedures were performed on 132 consecutive patients selected in accordance with a protocol that was approved by the IRB to study the feasibility and safety of CAS on patients deemed (by the vascular surgery team) to be at high risk for conventional CEA. During the same period, 191 patients underwent CEA, so the interventional cohort (N = 132) represents 41% of the overall patient population undergoing treatment for carotid artery disease. Every patient signed an informed consent form that disclosed the investigational nature of the procedure and its potential risks, especially stroke.

Eighty-six patients were men (65%), and 46 patients were women (35%), with a mean age of 68 ± 9 years; 11 patients (8%) were 80 years or older. Both symptomatic (> 70% stenosis) and asymptomatic (> 80% stenosis) ICA lesions were included in our study group; the former made up 40% of the group, whereas the latter comprised 60% of the group. Demographics and medical co-morbidities are summarized in Table I. Of the 132 patients treated with CAS, 92 (69%) were at “anatomical high risk” for CEA: post-CEA restenosis occurred in 52, distal ICA lesions (at or above the level of C2) occurred in 22, and a hostile neck situation occurred in 18. Necks were considered to be “hostile” in patients with a permanent tracheostomy, earlier radical neck surgery with resultant marked deformity, presumed radiation-induced ICA stenosis, and cases in which the cervical spine was very stiff and/or unstable, making endotracheal intubation unsafe or impossible. Forty patients (31%) did not have any local anatomical contraindication to CEA, but were found to have severe medical co-morbidities that would have (presumably) increased the risk of standard operation; 24 of the patients were classified as class III, and 16 patients were classified as class IV by using Goldman’s multifactorial index score.9

Diagnosis and patient treatment. Diagnosis of severe ICA stenosis (as defined) was made by means of duplex ultrasound scanning and was always confirmed by means of conventional catheter angiography. The latter was obtained as a stand-alone diagnostic procedure in 102 patients (77%) or during the initial phase of the CAS procedure in 30 patients (23%). Patients were examined before and within 24 hours of CAS by the vascular surgery team and, in some instances (28 patients, 21%), by an independent neurologist. Pre-discharge clinical evaluation and duplex scanning were obtained the morning after the procedure and then at 30 days, 6 and 12 months, and yearly thereafter.

Carotid angioplasty-stenting technique. Patients were given aspirin (325 mg/day) and clopidogrel (Plavix; 75 mg/day) beginning 2 to 3 days before the procedure. Clopidogrel was continued for 30 days, and aspirin therapy was continued indefinitely. The interventions were performed in a state-of-the-art (Multi-Star Siemens) angiostat, by using local anesthesia at the femoral puncture site supplemented with light intravenous sedation. A standardized endovascular approach was used, which included initial femoral entry with a 5F introducer sheath and power-injector aortic arch angiography in the left anterior oblique (LAO) projection. Systemic anticoagulation was induced with intravenous heparin, with a target activated clotting time of 250 to 300 seconds, which was maintained throughout the intervention. Selective catheterization of the target vessel was achieved by using a 5F diagnostic catheter (JB1, Uni-select, or JB2) with advancement of a 0.035-in Glidewire into the appropriate CCA. The catheter was then passed over the Glidewire to the distal CCA, to a point just proximal to the bifurcation. Angiography was used as a means of defining the anatomy of the external carotid artery (ECA), with subsequent “anchoring” of a support 0.035-in guidewire (Storq or Amplatz) in one of its branches. A 7F, 90-cm-long interventional sheath was introduced from the femoral puncture site to the mid or distal CCA over this guidewire. A high-quality digital angiogram of the carotid bifurcation was then obtained by administering radiocontrast through the sideport of the sheath. A 0.018-in SV-5 Cordis small-vessel guidewire was used to cross the ICA lesion, which was then pre-dilated with a 4- by 40-mm Savvy Cordis balloon angioplasty catheter. Stenting involved placement of a self-expanding device (Wallstent in 12 patients and a SMART nitinol stent in 120 patients) from the ICA across the bifurcation into the distal CCA (across the origin of the ECA). Post-balloon dilatation of the stent involved the use of a 4.5- by 20-mm or 5- by 20-mm Savvy balloon catheter. In 26 of the interventions (22%) in which a SMART stent was used, post-dilation proved unnecessary because of satisfactory angiographic appearance after stent deployment. Three patients underwent staged bilateral CAS carotid artery interventions; in seven patients, two (overlapping) stents were used for treatment of the

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<th>Table I. Clinical profile of the study group (N = 132)</th>
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<td>N</td>
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<td>Men</td>
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<tr>
<td>Women</td>
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<td>No symptoms (&gt; 80%)</td>
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<td>Symptoms (&gt; 70%)</td>
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<td>Hypertension</td>
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<td>Tobacco abuse</td>
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<td>Hypercholesterolemia</td>
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carotid artery lesion. On completion of the intervention, ipsilateral carotid and cerebral angiography (in multiple views) was obtained as a means of assessing procedural success and excluding distal embolization. Angiographic assessment of residual stenosis was determined by using the North American Symptomatic Carotid Endarterectomy Trial criteria of comparing the smallest diameter at the lesion with a reference diameter of the distal ICA in a segment with parallel walls. Minimum lumen diameter was measured by calibrating the imaging system with a known diameter (sheath or inflated balloon) within the field of fluoroscopic visualization. Femoral puncture closure devices were used in 92 (68%) of the interventions: Perclose (Closor) in 55, VasoSeal in 32, and a Duett device in 5.

RESULTS

Interventional outcome. Three procedures (2.2%) were considered access failures because of the inability to catheterize the target aortic arch branch. One of these patients underwent CEA and recovered uneventfully. The other two patients were considered to be “inoperable,” one because of severe cardiac co-morbidity and the other because of a very distal ICA lesion at the level of Cl; neither patient had a neurologic event during the follow-up period. Residual in-stent stenosis of less than 20% was identified by means of completion angiography in 14 of 132 stented carotids (11%) and was accepted as a satisfactory angiographic outcome. Additionally, in two of 52 interventions for treatment of restenosis (3.8%), the very hard-fibrotic nature of the lesion precluded full balloon expansion of the stent, resulting in a residual (persistent) narrowing of less than 50% with angiography. There were no instances of vessel wall dissection or rupture, and patency of the ECA was documented after stenting in every case except one (0.7%), in which the ECA became occluded. Post-procedural stent thrombosis occurred in one patient who underwent coronary artery bypass grafting 48 hours after CAS intervention. Carotid occlusion (and a major stroke) developed 24 hours after cardiac surgery; this was the only patient in the series who was not treated with clopidogrel. All other patients had a patent stented carotid artery on the pre-discharge duplex scan and also during follow-up (range, 2-41 months; mean, 16 ± 9 months).

Four instances of post-ICA stent restenosis (>50% on duplex scanning) were identified; only one required reintervention (balloon angioplasty), which was performed 4 months after the initial procedure. The two patients with persistent in-stent narrowing after treatment of restenosis continued to do well (at 14 and 18 months), without progression of the less than 50% residual stenosis on serial duplex scanning.

Neurologic outcome. None of the 102 patients undergoing diagnostic angiography as a stand-alone procedure had a neurologic event. Four patients (3%) had neurologic complications after CAS:

1. One patient sustained a single-episode transient ischemic attack (TIA), characterized by means of motor/sensory deficit of the hand, occurring 2 hours after CAS. He was treated with a 12-hour infusion of abciximab (ReoPro) and intravenous heparin. Recovery was complete (by the sixth hour), without sequelae or recurrences.

2. A second patient had a major hemispheric stroke caused by thrombosis of the stented ICA (as aforementioned) occurring 3 days after CAS and 24 hours after open-heart surgery. This was the only patient in the series who did not receive clopidogrel therapy because of the fear of bleeding complications during and after cardiac surgery.

3. The third patient had a minor stroke that began intraprocedurally 2 minutes after post-balloon dilatation of the carotid stent with a 5-mm balloon angioplasty catheter. The complication resulted in transient aphasia (lasting several hours) and monoparesis of the hand, which resolved after 2 weeks.

4. The fourth patient had transient aphasia (beginning at the end of the procedure and resolving after 4 hours) and monoparesis of the hand, which resolved completely after 1 week.

All four patients who sustained a neurologic event had symptomatic (stroke, TIA) ICA stenoses as the indication for CAS. Patients 2 and 3 had independent assessment by a neurologist before and after CAS. There were no deaths, either periprocedurally or during the follow-up period. Late strokes were observed in two patients (at 8 and 25 months), both affecting the cerebral hemisphere supplied by the contralateral (non-stented) carotid artery. One was fatal.

Femoral puncture site complications occurred in five cases: a large hematoma in three cases, femoral pseudoaneurysm in one case, and an arteriovenous fistula in one case. In all, the diagnosis was confirmed by means of duplex ultrasound scanning, and none required intervention. Hospitalization was prolonged by 2 days in one patient with a large hematoma.

DISCUSSION

CEA constitutes one of the best examples of evidence-based medicine as attested by means of published scientific proof of efficacy of the operation over best medical management alone for the treatment of symptomatic and asymptomatic severe stenoses of the ICA. However, patients with serious medical co-morbidities may not fare as well. In addition, local anatomical findings, such as restenosis after earlier CEA, distal ICA lesions, and anatomically disadvantaged necks from earlier radical surgery or radiation therapy, may also constitute impediments or high-risk factors for CEA. In fact, many, if not most, practicing vascular surgeons are reluctant to operate on such patients. Percutaneous CAS has emerged as an appealing therapeutic alternative in these cases, with the potential to achieve results equal or possibly superior to those of CEA in the same clinical setting. With this in mind, the senior author (F.J.C.) began to offer endovascular intervention to selected patients in 1994. This initial effort involved a direct cervical approach to the carotid artery and the use of balloon-expandable stents. Such ini-
tial experience demonstrated the feasibility of the approach, but also showed significant shortcomings related to the technique of carotid artery puncture in the neck. It limited interventional capabilities and was accompanied by serious threats of hemorrhagic complications at the puncture site from difficulties with external compression. The transfemoral approach constitutes, clearly, a more optimal access strategy, as does the use of self-expanding stents, which were adopted in late 1997. Refinements of technique led to a standardized approach, with critical assessment of angiographic arch anatomy and careful avoidance of CAS intervention in the face of unfavorable findings (Table II). The latter relate mainly to aortic arch and carotid artery anatomy and ICA lesion characteristics such as length, degree of calcification, and the possibility of associated clot or other intraluminal defects on angiography. These factors have been reported anecdotally to be associated with an increased risk of complications during CAS.

The potential for cerebral embolization and stroke are major concerns with catheter interventions in the cerebrovascular territory. Carotid artery plaques have been shown to release particles during transluminal manipulation. It is surprising that stroke does not occur more frequently after CAS and that the procedure can be performed relatively safely, without protection, on carefully selected patients. Such “low incidence” of stroke is likely related to a number of factors, including brain tolerance to emboli, under-diagnosis of lesser neuropsychologic changes that may go undetected, and the failure to evaluate patients with time. It could be argued that our neurologic complication rate (as reported) does not reflect all events because only a minority of patients (21%) underwent independent, systematic assessment by a neurologist. This may well be the case, but it would be difficult to understand how a major stroke could be missed in patients who were cared for by several physicians and nurses during the hospital stay. Brain protection technologies, currently being rapidly developed, will offer exciting new possibilities that are likely to enhance safety and promise to add considerable credibility to a procedure, the appropriateness of which continues to be considered suspect by many, if not most, vascular surgeons. They were not available for use during the period of the experience reported. The single major stroke in our experience was not related to embolization, but instead to stent thrombosis occurring after open-heart surgery in a patient who was not on clopidogrel antiplatelet therapy. There is consensus among leading carotid interventionists that this form of therapy is (probably) critically important, but it is an opinion without scientific validation at this time. Abciximab was used in only one patient for treatment of a TIA episode occurring 2 hours after CAS; we continue to reserve its use for such “rescue” indication only.

Careful case selection, impeccable technical execution, and “knowing when to quit” are some of the most important aspects of enhancing safety with CAS intervention. Restenotic carotid lesions have low embolic potential and are probably the safest to dilate and stent without protection. They should be looked on as the obvious indication target for beginner carotid interventionists. Restenoses, distal ICA lesions, and hostile neck situations should, in our view (and that of other authors), continue to be the prime indications for CAS currently. Expanding the indications to include “all comers” cannot be justified outside the setting of a controlled US Food and Drug Administration-sponsored clinical trial. Data in support of such an aggressive attitude are not likely to be forthcoming for several years, and, in the end, CAS may well be found to be a reasonable and possibly superior treatment alternative for non-CEA candidates only.

In conclusion, we have found CAS to be a valuable addition to our armamentarium. It is reserved largely for patients who are not ideal candidates for CEA. Further expansion of clinical indications is not yet recommended and should await further information on durability and efficacy to be generated by current and future clinical trials.

### Table II. When to avoid carotid angioplasty-stenting

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<td>Unfavorable aortic arch anatomy</td>
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<td>Severe tortuosity of the CCA</td>
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<tr>
<td>Heavily calcified carotid lesions</td>
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<td>Extensive stenoses (longer than 2 cm)</td>
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<tr>
<td>Intraluminal thrombus (angiographic defects)</td>
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<td>Extremely tight (99%) stenoses</td>
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CCA, Common carotid artery.

REFERENCES


