Emergent Stenting to Treat Patients With Carotid Artery Dissection
Clinically and Radiologically Directed Therapeutic Decision Making
José E. Cohen, MD; Ronen R. Leker, MD; Marc Gotkine, MBBS; Moshe Gomori, MD; Tamir Ben-Hur, MD, PhD

Background and Purpose—Carotid artery dissection (CAD) is a common cause of stroke in young patients. Clots formed at the low-flow zone in the false arterial lumen may give rise to distal emboli, and the mural hematoma may eventually occlude the artery. Anticoagulation is currently the accepted treatment, but it is unknown which patients will improve spontaneously, which will respond to anticoagulation, and which will have an exacerbation of ischemic symptoms despite therapy. Endovascular treatment of CAD may be an attractive alternative to anticoagulation, and methods of identifying patients who stand to benefit from such therapy need to be established.

Methods—We present here 3 cases of spontaneous symptomatic CAD in which endovascular stenting procedures were performed on the basis of a paradigm aimed at identifying potentially salvageable but at-risk brain tissue by combining clinical with MRI (diffusion and perfusion) and angiographic data.

Results—Diffusion-perfusion MRI mismatches and/or evidence of cerebral ischemia on angiographic parenchymography were identified in all patients. They did not respond to anticoagulation, were therefore treated with endovascular stents, and had excellent outcomes.

Conclusions—Endovascular stent placement may be an immediate, effective, and safe method of restoring vessel lumen integrity. It may be considered for selected patients who are clinically symptomatic despite anticoagulant treatment and in whom neuroimaging methods suggest that the neurological signs originate from a viable, hypoperfused, ischemic penumbra. (Stroke. 2003;34:e254-e257.)

Key Words: endovascular therapy ■ magnetic resonance imaging, diffusion-weighted ■ magnetic resonance imaging, perfusion-weighted ■ penumbra

Carotid artery dissection (CAD) may occur spontaneously in apparently healthy vessels, in vessels weakened by a primary arteriopathy, or more commonly after trauma.1 Well-characterized inherited connective-tissue disorders have been associated with an increased risk of spontaneous CAD in a small number of patients, but less well-defined collagen abnormalities have been identified in most patients with CAD.2 Although carotid and vertebral artery dissections account for only a small minority of stroke patients, they are a particularly common cause of stroke in young patients.1

The natural history of CAD is not fully understood, and it is generally believed that, despite the frequent involvement of proximal cervical segments of the extracranial arteries, strokes secondary to CAD may be surprisingly benign in some cases.3-5 However, CAD may lead to ischemic (embolic or hemodynamic) or hemorrhagic stroke, resulting in significant disabilities.6

Although controlled studies of the treatment of cervical artery dissections have not been performed, anticoagulant therapy is used in most institutions.7,8 This recommendation is based on the view that the most common mechanism of stroke complicating cervical artery dissection is embolization of thrombi that develop on the intimal flap.9 Another mechanism of stroke is hemodynamic insufficiency by critical stenosis of the true arterial lumen. Recently, endovascular stent placement has been proposed as an alternative to the traditional use of anticoagulants in patients with CAD.9-11 Stenting restores the vessel caliber and normal circulation and covers the arterial defect, preventing formation of emboli. Follow-up series found that the recurrent stroke rate in patients after the acute phase of CAD was <1% per year.5,12 This finding raised a question regarding the necessity of anticoagulation or endovascular treatment. However, in symptomatic dissections, once stroke has started to evolve,
the prognosis is usually poor, and heparin has not been shown to change its course. Therefore, stenting may be especially appropriate as a means of altering the clinical course during the acute, clinically dynamic phase of dissection. No parameters have been identified yet for predicting the clinical course in CAD and which patients should therefore be treated with anticoagulation or stenting. Here, we performed emergent stenting on patients with acute symptomatic cervical artery dissections who were refractory to medical treatment and in whom neuroradiological investigation indicated the existence of significant hypoperfusion or a large penumbra. The stenting procedure altered the clinical course in these patients toward a favorable outcome. We discuss the clinical and radiological criteria for selection of patients who may benefit from this procedure.

**Patients**

**Case 1**
A 47-year-old man with a history of hyperlipidemia and smoking presented to the emergency room after an episode of left-hand paresthesia that lasted 3 hours. He had self-discharged from a different hospital a day previously, having been admitted after 4 episodes of profound left-sided weakness that occurred over 2 days and lasted several minutes each. At that time, a head CT was normal. Carotid duplex demonstrated high resistance to flow in the right internal carotid artery (RICA) with no extracranial stenosis. Subcutaneous low-molecular-weight heparin treatment was initiated. Diffusion and perfusion MRI studies performed while the patient was asymptomatic showed no evidence of infarction, with good perfusion maintained to both hemispheres. MR angiography (MRA) revealed dissection of the high cervical and petrous portion of the RICA with negligible distal flow past the stenotic segment. Angiography confirmed the findings (Figure 1A), and evidence for brain ischemia was noted on parenchymography (Figure 1B) while the patient was having a recurrence of symptoms. Because symptoms recurred despite anticoagulant therapy, endovascular stenting was performed. Because the RICA was occluded by angiography, low doses of urokinase and nimodipine were infused intra-arterially, resulting in negligible flow through the artery that was sufficient to pass the guide wire and to perform the stenting. Three balloon-expandable microstents (AVE inx, Medtronic AVE) were implanted in a telescoped fashion. After the procedure, repeated injection of contrast material revealed that RICA flow had been fully restored (Figure 1C) and there was no brain ischemia (Figure 1D). Neurological examination was normal, and the patient was discharged on antiplatelet therapy. No further episodes occurred, and the carotid was fully patent by duplex studies over a follow-up period of 1 year.

**Case 2**
A 55-year-old man presented to the emergency department with acute, progressive left-sided weakness and right-sided headache that had begun the previous day. Brain CT demonstrated an ischemic infarct in the right temporal lobe. The patient was heparinized rapidly with a bolus injection of 5000 U followed by a continuous drip of 20 000 U/d, but he continued to deteriorate over the next hours. T2-weighted MRI demonstrated 2 acute infarcts in the right hemisphere. Perfusion-diffusion MRI demonstrated considerable mismatch with loss of perfusion to most of the right cerebral hemisphere compared with the small infarcted area, indicating that an extensive penumbral region was present (Figure 2). MRA

---

**Figure 1.** Angiographic studies of patient 1. A, Selective angiography of the right common carotid artery (lateral view) showing a flamelike RICA occlusion indicative of a dissection. B, Capillary-phase angiographic view (parenchymography) after injection through the LICA revealed a large right frontoparietal hypoperfused area. C, After stenting, arterial caliber was restored with fully normalized flow through the RICA. D, Post-stenting parenchymography (injection through the repaired RICA) shows no perfusion defect.
Cohen et al  Emergent Stenting for Carotid Dissection

Figure 2. MRI of patient 2. A, Diffusion MRI showed a temporal and a small deep parietal hyperintense signal consistent with a small acute infarct. B, Perfusion MRI showed severely reduced perfusion to most of the hemisphere. This mismatch indicated the presence of a large penumbra that was at risk for imminent stroke.

demonstrated absence of flow in the intracranial RICA. Urgent angiography demonstrated a long “string sign” indicative of arterial dissection with >99% occlusion and no other evidence of cerebrovascular disease. Therefore, 2 balloon-expandable (AVE inx) followed by a proximal carotid wall stent were implanted. After stenting, the RICA flow was demonstrated to have been restored, which was paralleled with rapid clinical improvement of the patient. The left hemiparesis disappeared completely, and the patient remained with very mild hemihypoaesthesia. Follow-up MRI demonstrated that the penumbral region had been spared from infarct. The patient continued to be well, and follow-up transcranial Doppler studies indicated the patency of the arteries over the next year.

Case 3
A 47-year-old man was admitted with acute onset of motor aphasia and right hemiparesis. He had a 25-year history of multiple sclerosis but was fully functional except for severe loss of visual acuity in the right eye. He had fallen several times during the previous year, without sequela. Two days before his admission, he fell again and injured his neck, after which he suffered from left hemicranial headache. Diffusion MRI performed on arrival, while he was aphasic and hemiparetic, did not show ischemic changes. MRA showed lack of flow in the left ICA (LICA). Emergent angiography showed bilateral carotid dissections. On the left, there was >99% stenosis over a long segment, including the cervical and intracranial segments. At this stage, the dissection was considered inaccessible for stent placement. On the right, there was a long dissection with >80% stenosis. After 2 weeks of heparin treatment, the hemiparesis resolved completely and the aphasia improved significantly. However, there were fluctuations in his speech functions that were considered clinically to represent hemodynamic insufficiency. A repeated angiography showed that most of the LICA had opened but a distal critical 99% stenosis remained; consequently, perfusion to the left hemisphere was significantly reduced. Because of this persistent symptomatic stenosis, 2 balloon-expandable microstents (AVE inx) followed by 2 self-expandable carotid wall stents were implanted, covering the entire length of the LICA. Speech functions continued to improve without fluctuations. Because the dissected RICA was not stented, the decision was made to discharge the patient with oral anticoagulant and clopidogrel treatment. He continued to be well over the next 6 months.

Discussion
CAD is a dynamic process, and the radiographic and clinical findings may change dramatically within days or hours. Most dissections eventually resolve; about two thirds of occlusions recanalize and one third of resulting aneurysms decrease in size. The healing process may take 2 to 3 months after the dissection and occasionally longer. Imaging studies suggest that most brain infarcts secondary to CAD are thromboembolic in origin, and transcranial Doppler studies show a high frequency of intracranial microemboli. These observations led to the common practice of anticoagulation with a target international normalized ratio of 2.0 to 3.0 for 3 to 6 months after CAD. However, no randomized studies have been performed to assess the benefits and risks of anticoagulation in arterial dissection. Surgical treatment such as ligation of the carotid artery combined with an in situ or extracranial to intracranial bypass has been reserved for patients with persistent ischemic symptoms despite adequate anticoagulation. Because these procedures are technically demanding and are associated with a substantial morbidity rate, they have largely been abandoned.

Endovascular treatment by placement of metallic stents intuitively entails a lower risk than surgical treatment and, in most instances, has superseded surgery as the initial therapy of choice once medical therapy fails. Several advantages make stenting an attractive alternative to other forms of therapy: It allows the immediate recanalization of the artery and resolution of the dissection with immediate reperfusion of the ischemic brain; stenting eliminates the need for complicated and risky carotid reconstructive procedures; no routine anticoagulation is indicated after the procedure; and the patient is kept under antiplatelet agents only. Previous case series of patients treated with stents have generally shown a very low rate of complications. The major limitation of endovascular stenting in CAD is related to its specific technical difficulties: Selective microcatheterization of the true lumen of the artery often is especially difficult; the arterial segment that should be stented is usually long and frequently requires multiple and combined stents; a real superimposition of stents needs to be achieved (telescoping) to avoid interstent arterial dissections; and end-to-end stent implantation is discouraged.

Despite the relative advantages of endovascular stenting in CAD, no guidelines as to which patients may benefit from such a procedure currently exist. In previously reported series
using stenting for CAD, the decision to use stents was based mainly on the clinical impression of imminent infarction.\textsuperscript{7,11} The presence of objective evidence of cerebral ischemia and salvageable tissue on neuroimaging studies could help in the selection of the most appropriate patients for stenting. In the current series, we combined clinical and radiographic data in the decision-making process, leading to the selection of 3 patients for stenting of 8 patients with nontraumatic carotid dissections who were admitted during that period of time. Importantly, MRI and MRA were performed urgently on symptomatic patients to enable rational therapeutic decisions. In the 3 patients who were selected for stenting, we identified the presence of large ischemic but salvageable penumbral tissue by finding a diffusion-perfusion mismatch on MRI (with the perfusion deficit being larger than the diffusion deficit)\textsuperscript{19} or by finding delayed capillary filling (in areas known to be viable by diffusion MRI) on parenchymography during angiography.\textsuperscript{20,21} Because perfusion MRI and angiographic parenchymography are not entirely comparable, we performed both tests on our patients and regarded findings in either one of them as indicative for the presence of salvageable penumbra. The neurological deficits in our patients could be localized to the region of the ischemic penumbra. Their clinical course and radiological findings were suggestive of hypoperfusion as the primary cause of neurological symptoms. It has been suggested that penumbral tissue may survive longer than the classically viewed 6 hours.\textsuperscript{22} Therefore, the use of real-time diffusion MRI to verify that the at-risk brain tissue is still viable is especially important in some cases, enabling the selection of patients who are likely to benefit from stenting. The therapeutic value of this procedure in the selected patients with radiological evidence of ischemic yet viable brain tissue can be inferred from the prompt resolution of ischemic symptoms after stent insertion in all our patients. They did well on follow-up studies, and no periprocedural complications were observed.

In conclusion, this short-term study suggests that emergent endovascular stenting may be a feasible and effective treatment for symptomatic CAD patients with severe stenoses in the presence of radiographic evidence of a viable penumbra. The use of MRI (to detect diffusion-perfusion mismatch) and/or angiographic (parenchymography) data may be important for selection of patients with salvageable ischemic brain tissue and exclusion of those with irreversible ischemic changes. We propose a decision-making paradigm for selecting patients with CAD to undergo stenting. This procedure may be considered in patients who develop progressive neurological deficit or who continue to suffer recurrent neurological episodes (caused by emboli or to hemodynamic insufficiency) despite anticoagulant therapy. Stenting may be offered to those symptomatic patients who have radiographic evidence of a significant viable penumbral region that faces imminent evolution into irreversible stroke. We suggest that assessment of the benefits of stenting versus medical treatment of CAD patients in clinical studies should rely on such radiographic data.

References

Emergent Stenting to Treat Patients With Carotid Artery Dissection: Clinically and Radiologically Directed Therapeutic Decision Making
José E. Cohen, Ronen R. Leker, Marc Gotkine, Moshe Gomori and Tamir Ben-Hur

*Stroke*. 2003;34:e254-e257; originally published online November 6, 2003;
doi: 10.1161/01.STR.0000101915.11128.3D
*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2003 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/34/12/e254

**Permissions:** Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Stroke* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

**Reprints:** Information about reprints can be found online at:
http://www.lww.com/reprints

**Subscriptions:** Information about subscribing to *Stroke* is online at:
http://stroke.ahajournals.org//subscriptions/