Journal of the American College of Cardiology
Vol. 37, No. 8, 2001
ISSN 0735-1097/01/$20.00
PII S0735-1097(01)01284-0
Published by Elsevier Science Inc.


# Emergency Stenting to Treat Neurological Complications Occurring After Carotid Endarterectomy

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**OBJECTIVES** The purpose of this study was to assess the efficacy of emergency stent implantation for the treatment of perioperative stroke after carotid endarterectomy (CEA).

**BACKGROUND** Carotid endarterectomy has been proven safe and effective in reducing the risk of stroke in symptomatic and asymptomatic patients with >60% carotid artery stenosis. However, perioperative stroke has been reported in 1.5% to 9% of CEA cases. The management of such a complication is challenging. Recently, percutaneous transluminal carotid angioplasty with stent deployment has emerged as a valuable and alternative strategy for the treatment of carotid artery disease.

**METHODS** Between April 1998 and February 2000, 18 of the 995 patients (1.8%) who had CEA in our institution experienced perioperative major or minor neurological complications. Of these, 13 patients underwent emergency carotid angiogram and eventual stent implantation, whereas the remaining five had surgery re-exploration.

**RESULTS** Carotid angiogram was performed within 20 ± 10 min and revealed vessel flow-limiting dissection (five cases) or thrombosis (eight cases). Percutaneous transluminal carotid angioplasty with direct stenting (self-expandable stent) was performed in all 13 cases. Angiographic success was 100%. Complete remission of neurological symptoms occurred in 11 of the 13 patients treated by stent implantation and in one of the five patients treated by surgical re-exploration ($p = 0.024$).

**CONCLUSIONS** Stent implantation seems to be a safe and effective strategy in the treatment of perioperative stroke complicating CEA, especially when carotid dissection represents the main anatomic problem. (J Am Coll Cardiol 2001;37:2074–9) © 2001 by the American College of Cardiology

Carotid artery occlusive disease is responsible for 20% to 30% of stroke cases (1). Carotid endarterectomy (CEA) has been proven safe and effective in reducing the risk of stroke in symptomatic and asymptomatic patients with >60% carotid artery stenosis (2,3). However, perioperative stroke has been reported in 1.5% to 9% of CEA cases (4). Several early reports describe poor neurological results after surgery for acute carotid artery thrombosis (5–7). Other reports give more satisfactory results when acute thrombosis occurs in the immediate postoperative period and the patient is re-explored immediately (8–10).

Recently, percutaneous transluminal carotid angioplasty (PTA) with stent deployment has emerged as an alternative strategy for the elective treatment of carotid artery disease (11,12). In this study, we report the results of emergency stent implantation for the treatment of perioperative stroke after CEA.

## METHODS

From April 1998 to February 2000, 995 patients underwent CEA of the extracranial carotid artery in our institution. Eighteen patients (1.8%) sustained a perioperative stroke. Thirteen of these patients had emergency angiography with subsequent stent implantation on the culprit carotid artery. The remaining five patients underwent surgical re-exploration of the carotid artery because the catheterization laboratory was not available.

**Clinical examination.** "Perioperative stroke" was defined as a stroke occurring intraoperatively (for patients treated under local anesthesia) or in the immediate postoperative period. Stroke was defined as an acute disturbance of focal neurological function with symptoms that were presumably caused by cerebral ischemia (13). A neurologist performed a complete neurological examination, including the National Institutes of Health (NIH) stroke scale, preoperatively, at the time of stroke occurrence, after PTA and during follow-up (i.e., before hospital discharge, at one and at six months). Stroke was classified in terms of the following definitions:

1) *Category 1 minor stroke*—a new neurological deficit that changed the NIH stroke scale by 1 point and persisted for >24 h but completely resolved or returned to baseline within seven days.
2) *Category 2 minor stroke*—a new neurological deficit that either completely resolved or returned to baseline within 30 days or that changed the NIH stroke scale by 2 or 3 points. By definition, both categories of minor stroke are nondisabling neurological events.

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Manuscript received December 5, 2000; revised manuscript received February 20, 2001, accepted March 1, 2001.

**Abbreviation and Acronyms**

CEA = carotid endarterectomy
CI = confidence interval
NIH = National Institutes of Health
PTA = percutaneous transluminal carotid angioplasty
TIA = transient ischemic attack

3) *Major stroke*—a new neurological deficit that persisted after 30 days and changed the NIH stroke scale by ≥4 points.

During the surgical procedure, electroencephalogram with simple contro-lateral hand-gripping maneuvers was used to monitor the patient's neurostatus. Computed tomography of the head was performed in all patients before CEA and after perioperative stroke occurrence.

**Angiographic examination and stent implantation procedure.** After the diagnosis of the complication, 13 of the 18 patients were immediately moved from the recovery room to the cardiac catheterization laboratory, and a diagnostic angiographic examination was performed. A 6F sheath was positioned in the right femoral artery, and a 6F right Amplatz 1 diagnostic catheter (Cordis, Johnson & Johnson Company, Miami, Florida) was advanced in the aortic arch on a 0.035-inch guidewire, and the common carotid artery was cannulated.

After the diagnostic angiogram, all 13 patients underwent PTA with stent implantation. Acetylsalicylic acid (250 mg intravenously) and unfractionated heparin (70/IU/kg) were administered. The 6F right Amplatz 1 diagnostic catheter was advanced into the external carotid artery over a 0.035-in., 175-cm-long high torque guidewire (Storque supersoft, Cordis, Johnson & Johnson Company). The guidewire was then exchanged with a 0.035-in. Amplatz super stiff guidewire (Boston Scientific, Watertown, Massachusetts). This guidewire facilitates the advancement of the 8F 80-cm kink resistant introducer sheath (Arrow, Reading, Pennsylvania) just before the carotid bifurcation.

The GuardWire Temporary Occlusion & Aspiration System (PercuSurge Inc., Santa Rosa, California) (a catheter system designed to contain and retrieve particulate material and prevent distal embolization) was used (14). This system was advanced through the lesion in the distal segment of the carotid artery, and the balloon was inflated in order to occlude the vessel. The occlusive balloon was promptly deflated if vessel occlusion was not tolerated. After stent implantation, the Export Aspiration Catheter (PercuSurge Inc.) was advanced throughout the guidewire to the occlusive balloon for the removal of debris and thrombus accumulated in the vessel during the intervention. Stent implantation was performed utilizing a self-expanding Easy Wallstent (Boston Scientific). Stent deployment was done in all lesions with the intent to cover the entire dissection or the region of haziness. Angiographic success was defined as achievement of a final stenosis ≤20%, with normal flow.

**Postprocedure management.** No further heparin was given after the procedure. Sheaths were removed when the activated clotted time was <160 s. At discharge, oral aspirin 325 mg/day was advised to be continued indefinitely and ticlopidine, 250 mg twice a day, for four weeks. Follow-up was obtained by a neurological evaluation at one and six months.

**Statistical analysis.** Continuous variables are presented as mean ± 1 standard deviation. Differences between groups were assessed by chi-square analysis for categorical variables and Student *t* test for continuous variables. Probability values <0.05 were considered significant. Data were analyzed with SPSS 8.0 for Windows (SPSS Inc., Chicago, Illinois).

## RESULTS

**Clinical and angiographic characteristics.** Baseline characteristics and procedural details of the 18 patients are summarized in Table 1.

STENT GROUP (13 PATIENTS). Mean age of our population was 65 ± 5 (range 59 to 77) years. All patients had a history of transient ischemic attack (TIA). Neurological symptoms developed in all patients within 1 h (range 5 to 60 min) after the surgical procedure. Angiographic examination was performed within 19 ± 8 min (range 8 to 35) after onset of symptoms. The angiogram revealed a flow-limiting dissection in five (39%) patients (Fig. 1) and definite or possible thrombus in eight cases (61%) (Fig. 2) at the site of the previous endarterectomy.

SURGICAL GROUP (FIVE PATIENTS). Mean age was 64 ± 5 (range 57 to 71) years (p = 0.55 vs. stent group). All patients had a history of TIA. Neurological symptoms developed in all patients within 1 h (range 15 to 60 min) after the surgical procedure (p = 0.77 vs. stent group). Surgical re-exploration was performed within 23 ± 12 (range 10 to 40) min after onset of symptoms (p = 0.17 vs. stent group). A flow-limiting dissection occurred in three (60%) patients and thrombus in two patients (40%) at the site of the previous endarterectomy (p = 0.41 vs. stent group).

**Procedural characteristics.** STENT GROUP. Interval between onset of neurological symptoms and stent implantation was 46 ± 11 (30 to 70) min. Angiographic success was obtained in all patients. The self-expanding Easy Wallstent was implanted in all cases without predilation. A post-balloon dilation was not performed in any patient. In all cases, vessel occlusion by the PercuSurge GuardWire system was not tolerated. In fact, in all cases we observed a deterioration of neurological status after balloon inflation. Therefore, we immediately deflated the balloon and performed the procedure without distal protection in all cases.

SURGICAL GROUP. The interval between onset of neurological symptoms and surgical treatment of the complication was 50 ± 15 (range 35 to 75) min (p = 0.77 vs. stent

**Table 1.** Baseline Characteristics and Procedural Details

| Pt | Age | Gender | Vessel | Intervention | Treatment | Angiographic Appearance | DS (%) Pre | DS (%) Post | Neurological Deficit | Clinical Outcome |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 63 | M | RICA | Eversion CEA | Stent | Dissection | 85 | 0 | Minor | Recovery |
| 2 | 65 | F | LICA | Eversion CEA | Stent | Thr | 90 | 0 | Major | No recovery |
| 3 | 63 | M | RICA | Eversion CEA | Stent | Dissection | 90 | 10 | Minor | Recovery |
| 4 | 64 | M | LICA | Eversion CEA | Stent | Thr | 75 | 20 | Minor | Recovery |
| 5 | 63 | M | RICA | Eversion CEA | Stent | Dissection | 80 | 0 | Minor | Recovery |
| 6 | 62 | M | LICA | Eversion CEA | Stent | Thr | 75 | 20 | Minor | Recovery |
| 7 | 65 | M | RICA | Standard CEA | Stent | Thr | 85 | 0 | Minor | Recovery |
| 8 | 60 | F | RICA | Eversion CEA | Stent | Dissection | 80 | 20 | Minor | Recovery |
| 9 | 77 | M | LICA | Eversion CEA | Stent | Thr | 90 | 0 | Major | Death |
| 10 | 66 | M | RICA | Eversion CEA | Stent | Thr | 90 | 15 | Minor | Recovery |
| 11 | 68 | M | RICA | Eversion CEA | Stent | Thr | 80 | 0 | Minor | Recovery |
| 12 | 59 | M | LICA | Eversion CEA | Stent | Thr | 90 | 10 | Minor | Recovery |
| 13 | 66 | F | LICA | Eversion CEA | Stent | Dissection | 95 | 10 | Minor | Recovery |
| 14 | 71 | M | LICA | Eversion CEA | Surgery | Thr | | | Minor | Recovery |
| 15 | 65 | M | LICA | Eversion CEA | Surgery | Thr | | | Major | No recovery |
| 16 | 68 | F | RICA | Eversion CEA | Surgery | Thr + Dissection | | | Minor | No recovery |
| 17 | 57 | F | RICA | Eversion CEA | Surgery | Thr + Dissection | | | Minor | No recovery |
| 18 | 61 | M | RICA | Standard CEA | Surgery | Thr + Dissection | | | Major | No recovery |

CEA = carotid endarterectomy; DS = diameter stenosis; LICA = left internal carotid artery; Pt = patient; RICA = right internal carotid artery; Thr = thrombus.

group). Thrombectomy was performed in all cases. Patch implantation was necessary in the three cases where vessel dissection occurred.

**In-hospital and late outcome.** In the surgical group, only one (20%) of the five patients had complete recovery, whereas the remaining four patients did not have any neurological recovery (Table 1). In contrast, in the stent group, complete remission of neurological symptoms occurred in 11 (84.6%) patients. One patient died three days after the procedure; the other patient had permanent neurological deficit (p = 0.024 vs. stent group; odds ratio = 0.045, 95% confidence interval [CI] = 0.003 to 0.649).

By logistic regression analysis, the only predictor of the outcome was the treatment with stent implantation. In fact, such a strategy improved the outcome of these patients compared with surgical re-exploration (relative risk = 0.045; 95% CI = 0.003 to 0.649; p = 0.023). In order to better understand the potential mechanism of this result, we separately analyzed the patients where the complication was due to a flow-limiting dissection or to a thrombus at the site of endarterectomy (Table 2). The outcome was better with stent implantation only in the subgroup with a flow-limiting dissection. In contrast, there was no difference in the outcome in the subgroup with thrombus at the endarterectomy site.

## DISCUSSION

**CEA and perioperative stroke.** Carotid endarterectomy has been proven safe and effective in reducing the risk of stroke in symptomatic and asymptomatic patients with severe carotid artery stenosis (2,3). However, perioperative stroke has been reported in 1.5% to 9% of CEA (4). Thrombosis after CEA is the most common cause of perioperative stroke, accounting for up to 75% of cases (8,15,16). Distal intimal flap, furthermore, represents another important cause of such a complication (17,18). The results of our study confirm the prevalent role of thrombosis (56% of cases) and underline the importance of a flow-limiting dissection (44% of cases) as the cause of the perioperative stroke. The eversion endarterectomy technique is faster and more effective in reducing restenosis than conventional technique. However, one of the major drawbacks associated with eversion endarterectomy is a distal intimal flap that may develop after flow restoration (19).

Identification of vessel dissection is very accurate by angiographic examination. However, it has been reported that angiography requires at least 1 h to perform. This additional time required to reach a diagnosis is justified if the diagnostic procedure (carotid angiography) has a therapeutic counterpart.

**Treatment of perioperative stroke.** The main finding of this study was that stent implantation seems to be more effective than surgical re-exploration in the treatment of perioperative stroke, especially when the problem is due to vessel dissection. This result confirms data of previous studies by our group (17) as well as other (18) investigators, suggesting that stent implantation is an expeditious technique to treat carotid dissection occurring after eversion CEA.

The relevant role of distal dissection after CEA may also explain why surgical re-exploration has a variable, and sometimes poor, result (5–10). Immediate re-exploration includes thrombectomy or patch implantation (20). The poor results that have been experienced with re-exploration for thrombosis have partially been explained by Kwann et al. (21) who pointed out the critical role of time for recovering from neurological insult. More satisfactory results have been achieved when acute thrombosis occurs in the immediate postoperative period and the patient is immediately re-explored (8–10). Immediate thrombectomy of the throm-

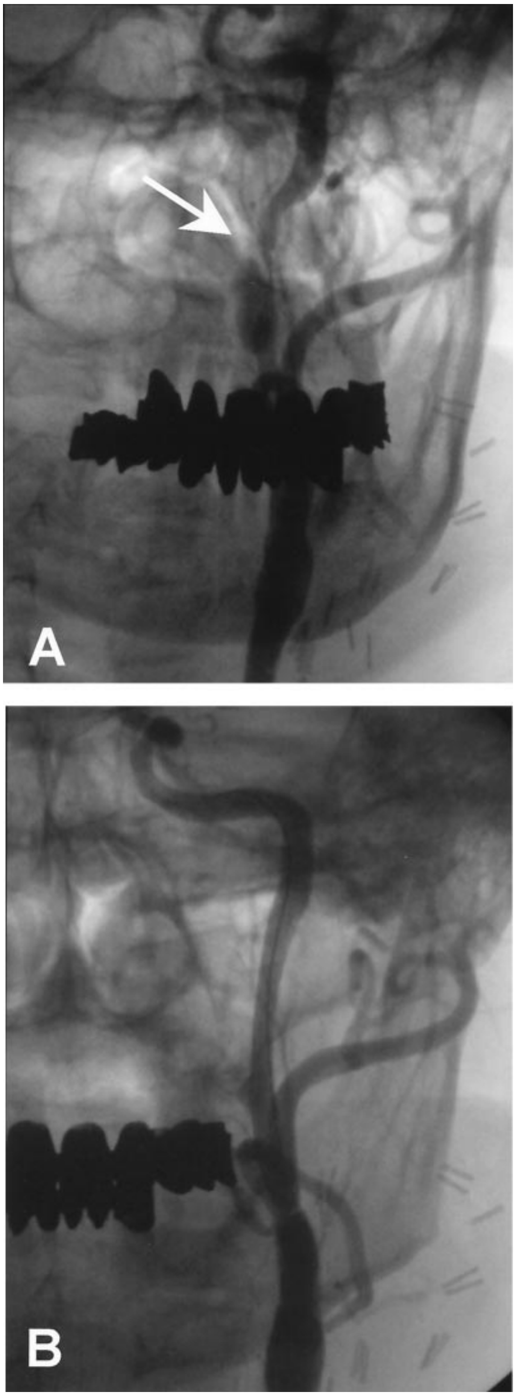


**Figure 1.** **(A)** Left internal carotid artery after eversion carotid endarterectomy. The **arrow** indicates a flow-limiting dissection in the proximal segment of the internal carotid artery. **(B)** Final angiographic result after placement of an auto-expandable Easy Wallstent.

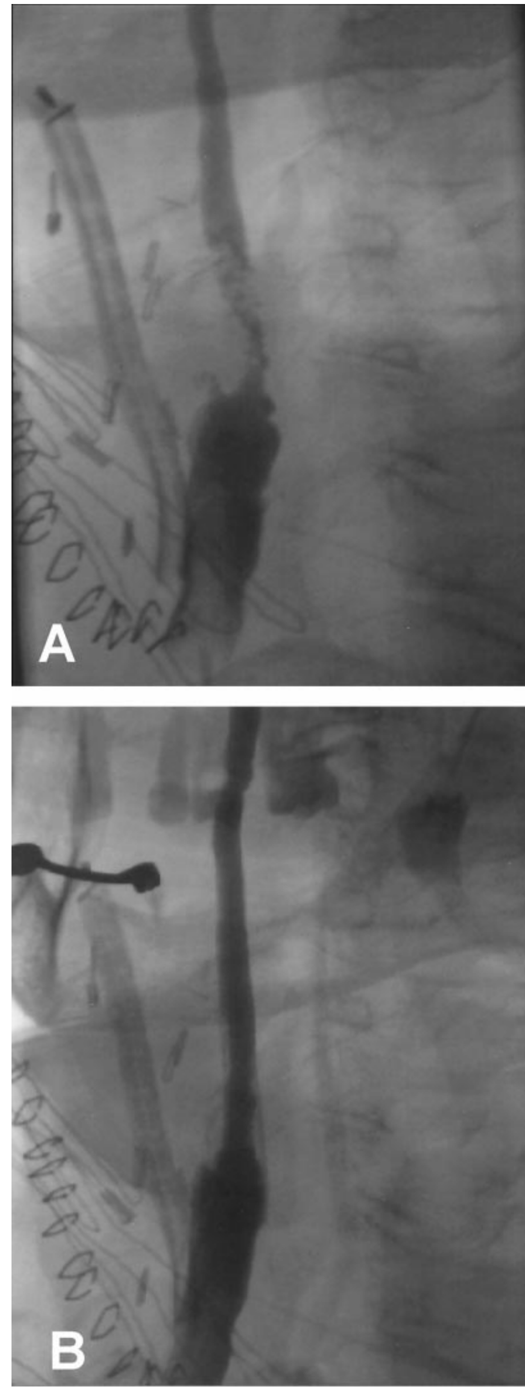


**Figure 2.** **(A)** Left internal carotid artery after eversion carotid endarterectomy. The angiogram shows a large thrombus in the proximal segment of the internal carotid artery. **(B)** Final angiographic result after placement of an auto-expandable Easy Wallstent.

bosed carotid artery leads to restoration of flow and reversal of ischemic changes before permanent neurological damage develops. Complete recovery usually occurs when delay is <1 h. However, even with immediate re-exploration, the result may be unsuccessful when dealing with carotid dissection. In particular, it may be especially troublesome when dissection arises above the Blaisdell's line (an imaginary line between the mastoid process and the angle of the mandible). The necessity for greater exposure often means that more time is needed for dissection or other maneuvers at a point of considerable inconvenience during the operation (18).

The appropriate means to treat distal intracranial dissection is still controversial. Intraoperative stent placement, accomplished through the use of endovascular technique or placement of a self-expanding stent under direct vision,

**Table 2.** Clinical Characteristics and Outcome in the Stent and Surgery Groups According to the Presence of a Thrombus or a Flow-Limiting Dissection at the Endoarterectomy Site

| | Stent Group | Surgery Group | p Value |
|---|---|---|---|
| Thrombus Group | 8 Patients | 2 Patients | |
| Age | 67 ± 5 | 68 ± 4 | 0.67 |
| Gender (male) | 7 (87.5%) | 2 (100%) | 0.60 |
| Time to treatment (min) | 51 ± 10 | 42 ± 10 | 0.84 |
| Outcome | | | 0.49 |
| Recovery | 6 (75%) | 1 (50%) | |
| No recovery | 2 (25%) | 1 (50%) | |
| Dissection Group | 5 Patients | 3 Patients | |
| Age | 61 ± 2 | 62 ± 6 | 0.10 |
| Gender (male) | 4 (80%) | 1 (33%) | 0.19 |
| Time to treatment (min) | 42 ± 8 | 55 ± 18 | 0.35 |
| Outcome | | | 0.005 |
| Recovery | 5 (100%) | 0 | |
| No recovery | 0 | 3 (100%) | |

represents an attractive expeditious method to treat dissection after CEA (17,18).

**Study limitations.** This retrospective, nonrandomized study represents a single-center experience with a relatively small sample size. We did not have any predetermined criteria for the selection of patients to be treated by carotid stenting or surgical re-exploration. In fact, all surgical re-exploration included in the study was performed because it was impossible to perform angioplasty. Cerebral protection devices are considered essential to prevent distal embolization during elective carotid angioplasty. We tried to use the PercuSurge GuideWire (the only protection device available at the time of the study), but it was not tolerated in all patients. This unexpected event may be due to: 1) lack of a "preconditioning-like" effect (22), and 2) cerebral autoregulatory dysfunction (23). The filters that trap debris during intervention, without occluding the artery, can now overcome the limitations of the balloon occlusion type device.

Recently, glycoprotein IIb/IIIa antagonists have been used in different thrombogenic settings, like acute myocardial infarction, with promising preliminary results (24,25). Although in eight of our 13 patients there was the angiographic evidence of thrombus, we did not use these drugs because of the risk of intracerebral hemorrhage (26,27).

**Conclusions and clinical implications.** This preliminary experience with primary stenting for the treatment of post-CEA stroke is encouraging and needs to be tested further in a larger sample size. This encouraging clinical result may be also explained by the fact that the interval between onset of neurological symptoms and stent implantation was 46 ± 11 (range 30 to 70) min. For this reason, we think that a meticulous neurological monitoring and a prompt availability of a catheterization laboratory emergency team are crucial for the efficacy of such a strategy for the treatment of perioperative stroke.

**Acknowledgments**
The authors are indebted to Raimondo Bellanca, RN, and Piero Vitale, RN, for their technical support.

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