Characteristics of Cerebral Microembolism During Carotid Stenting and Angioplasty Alone

Giovanni Orlandi, MD; Simona Fanucchi, MD; Cristina Fioretti, MD; Giovanni Acerbi, MD; Michele Puglioli, MD; Riccardo Padolecchia, MD; Ferdinando Sartucci, MD; Luigi Murri, MD

Background: Cerebral microembolism has often been documented by transcranial Doppler imaging during carotid angioplasty and stenting. However, few data are available about its characteristics during the 2 different kinds of procedure.

Objectives: To compare the incidence of microemboli occurring during angioplasty alone with that during stenting in the different phases of the procedures and to relate it to periprocedural cerebrovascular complications.

Patients and Methods: Thirty-eight patients underwent 41 procedures (15 angioplasty alone and 26 stenting) for symptomatic carotid stenoses of 70% or more. Transcranial Doppler monitoring was performed to detect microemboli in the middle cerebral artery during 3 phases of the procedure: (1) guidewire crossing, (2) first dilatation in case of angioplasty alone or stent release with predilatation if performed, and (3) further dilatation.

Results: Microemboli occurred in all cases in phase 1 of the procedure but less frequently in the arteries treated with stenting when compared with those treated with angioplasty alone in phase 2 and particularly (P<.02) in phase 3. The mean number of microemboli was highest in phase 2, predominant (P<.05) during angioplasty alone, and particularly reduced (P<.02) in phase 3 during the stenting procedures. During 2 (5%) of the 41 procedures, cerebrovascular complications occurred in phase 1, with the number of microemboli being higher than mean values.

Conclusions: Cerebral microembolism is a very common event, especially during guidewire crossing and angioplasty alone compared with stenting. Further studies concerning the prognostic significance of this are advisable.

Arch Neurol. 2001;58:1410-1413

PERCUTANEOUS transluminal angioplasty and stenting of carotid arteries represent a promising alternative to endarterectomy for patients with symptomatic stenosis of 70% or more and a simultaneous high perioperative risk, although there is no strong evidence from clinical trials to show that these procedures are more beneficial than other surgical or medical treatments. Moreover, many periprocedural complications may occur, such as ischemic neurological deficits due to distal embolization and hemodynamic impairment. Silent brain embolism has also been frequently documented on magnetic resonance images obtained before and after neurointerventional procedures.

Transcranial Doppler imaging is an useful tool for monitoring and detecting microemboli in the middle cerebral artery and can reveal a high incidence of asymptomatic embolization during both carotid angioplasty alone and stenting procedures, with more than 8 times the rate of microemboli observed during carotid endarterectomy, despite low levels of hemodynamic impairment.

Nevertheless, few data are available regarding differences between periprocedural microemboli occurring during angioplasty alone and those arising during stenting, moreover, the role of plaque morphology, which may be associated with differences both in emboli production and in ischemic brain damage, is not often considered.

The aim of this study was to compare a group of patients who underwent carotid stenting with another group of patients who underwent angioplasty alone with regard to the occurrence of cerebral microemboli during the different phases of the 2 procedures and to the relationship between the detection of microemboli and periprocedural cerebrovascular complications.

RESULTS

Microemboli occurred in all cases in phase 1 of the procedure. On the contrary, arteries treated with stenting showed a lower...
PATIENTS AND METHODS

Thirty-eight patients (25 men and 13 women; mean age, 67.8 years; age range, 54-79 years) recruited between February 1998 and July 2000 underwent 41 procedures for symptomatic internal carotid stenoses (bilateral in 3 cases) of 70% or more proven by selective angiography and evaluated according to the criteria of the North American Symptomatic Carotid Endarterectomy Trial. All patients presented a high risk (cardiological in 21 cases and pulmonary in 17) for anesthesia, with contraindications for endarterectomy, and gave their written informed consent to endovascular treatment. Fifteen arteries were treated with angioplasty alone and 26 with stent placement. The aim to obtain 2 groups as homogeneous as possible in plaque morphology and degree of stenosis determined whether arteries were to be selected for angioplasty alone or for the stenting procedure. The morphological features of plaque were determined using a duplex-scanner device (AU5; ESAOTE Biomedica, Florence, Italy) according to qualitative criteria concerning plaque echogenicity (hypoechoic, isoechoic, or hyperechoic), plaque texture (homogeneous, heterogeneous, or calcified), and plaque surface (smooth, irregular, or ulcerated). The Table shows the similar distribution of ultrasonographic plaque features and angiographic mean degree of stenosis in the 2 groups of arteries selected for angioplasty alone or for stenting.

All patients were treated with acetylsalicylic acid (100 mg/d) as a prevention against stroke recurrence. Mild sedation was achieved with promazine hydrochloride and intravenous heparin sodium (partial thromboplastin time, 80-100 seconds) was used during the procedure. Moreover, 1 mg of atropine sulfate was administered intravenously to prevent bradycardia due to carotid sinus stimulation during the balloon inflation phase. A guiding catheter was inserted into the common carotid artery, and the stenosis was crossed by a guidewire (0.014- to 0.020-in coronary guidewires) using road-mapping images. In the case of angioplasty, balloon catheters (OPTA 5 French or PowerFlex Plus; Cordis Corp, Miami, Fla) measuring, 5 to 6 mm in diameter were used, and 2 manual inflations lasting 20 to 30 seconds each were performed. When we used a stent (Wallstent; Boston Scientific Corp, La Garenne Colombes, France) (8 × 20, 8 × 30, 10 × 20, and 10 × 30 mm, fully open), care was taken to cover the entire lesion, and then the stent was submitted to a single dilatation by a balloon under high pressure. Predilatation with a 3-mm-diameter balloon catheter was performed before the stent release in the 3 cases showing the highest degree of stenosis.

A 2-MHz pulse-wave transcranial Doppler device (DWL Elektronische Systeme Multidop X-TCD7; Sipplingen, Germany) was used in all patients for long-term insonation of the middle cerebral artery, and monitoring was performed during the entire procedure. The Doppler probes had a diameter of 1.7 cm and were fixed to the skull with a head tape placed on the transtemporal acoustic window. The axial width of the sample volume was set at 10 mm, and the middle cerebral artery was insonated at a predetermined depth of 45 to 55 mm to obtain optimum insonation of the vessel. A high-pass filter was set at 100 Hz to eliminate low-frequency arterial wall vibrations. The ultrasonic power emitted at the probe surface was 50 to 100 mW/cm². Intensity was defined as the power measured in decibels contained in the Doppler spectrum. The algorithm for signal intensity measurements used the whole screen as a background, and the scale setting was between −100 and +150 cm/s, corresponding to a pulse repetition frequency of 6500 Hz. A 64-point fast-Fourier transform, with a length of 2 milliseconds and an overlap of 60%, was used. The above-mentioned parameters were chosen according to the recommendations of the International Consensus Group on Microembolus Detection. The transcranial Doppler device used an automated method for detecting high-intensity transient signals, which were identified as microemboli according to the criteria of the Ninth International Cerebral Hemodynamic Symposium: signal intensity at least 3 dB higher than that of the background blood flow signals lasting less than 300 milliseconds, unidirectional signal within the Doppler velocity spectrum, and association with a characteristic sound known as a chirp. To improve reproducibility of the data, an intensity detection threshold higher than 7 dB was chosen for this study.

Patient behavior and transcranial Doppler recording quality were continuously observed (on-line) by an investigator (S.F.) who recorded all the events that could be sources of artifacts. The high-intensity transient signals were recorded on stereo videotape and analyzed off-line by 2 independent observers (G.O. and C.F.) who were blind to the clinical data. The k index for interobserver agreement was 0.91.

Three phases of the procedure were taken into consideration: (1) guidewire crossing, (2) first dilatation in the case of angioplasty alone or stent release with predilatation if performed, and (3) further dilatation. The mean number and mean intensity of the microemboli were evaluated during each phase of the procedure in the angioplasty-alone group and in the stenting group. During the passage of the angiographic contrast medium, a wide and high increase in signal intensity, confusing microemboli detection, was always observed in the middle cerebral artery; hence, this phase of the procedure was excluded from data analysis. Moreover, the occurrence of amaurosis fugax, transient ischemic attack, or stroke was considered a peri-procedural cerebrovascular complication.

Data analysis was performed using 2-way $\chi^2$ analysis (the percentage of procedures with microemboli was compared between angioplasty alone and stenting) and the t test (the mean number and mean intensity of microemboli were compared between angioplasty alone and stenting). The level of significance was set at P<.05.

The mean ± SD number of microemboli detected in phase 1 in arteries treated with angioplasty alone (13.5 ± 4.3) showed no difference from that seen in arteries treated with stenting (14.3 ± 5.2). On the contrary, the number of microemboli was highest in phase 2, with a significant (P<.05) prevalence in the arteries treated with angioplasty alone (22 ± 3.0) compared with those treated with stenting (19.1 ± 4.1). The number of microemboli decreased in phase 3 of the procedure and was particularly lower (P<.02) in the arteries treated with stenting.
(10.4±5.2) than in those treated with angioplasty alone (18.6±4.6) (Figure 1). There was no significant difference in the intensity of microemboli between angioplasty alone and stenting during all phases of the procedure.

During 2 (5%) of the 41 procedures performed, cerebrovascular periprocedural complications (transient ischemic attack in one case treated with angioplasty alone and stroke in another treated with stenting) arose in phase 1. Both cases demonstrated a number of microemboli that was much higher than the mean values for this parameter during the same phase of the procedure, whereas a similar distribution was observed regarding the intensity of microemboli (Figure 2). The occurrence of microemboli was asymptomatic in all other cases. During the dilatation, 3 patients who were treated with angioplasty alone developed minor periprocedural complications, consisting of transient bradycardia and sudden arterial hypotension. An angiographic control, performed at the end of the procedures, documented a residual degree of stenosis that was less than 30% in all cases.

**COMMENT**

The occurrence of microemboli appears to be a very common event during all phases of angioplasty and stenting procedures, especially in patients treated with angioplasty alone. Mechanical factors, such as trauma on the plaque surface when the guidewire crosses the stenosis and during the first dilatation, may account for the high incidence of microemboli detaching from the atherosclerotic lesion. On the contrary, the progressive decrease in the number of patients showing microemboli during further dilatation might be attributed to plaque squashing induced by stenosis dilatation, which makes the plaque surface less crumbly and also reduces friction by means of the blood flow velocity being restored to normal. Our findings agree with those of Markus et al., who observed multiple embolic signals immediately after balloon inflation in 9 of 10 patients treated with angioplasty alone. Likewise, McCleary et al. reported embolic signals in 9 of 9 patients during carotid stenting. Plaque entrapment by the stent after its release might also justify the fact that fewer patients in the group treated with stenting manifested microemboli during further dilatation than did the patients in the group treated with angioplasty alone. Similarly, Benichou and Bergeron reported a prevalence of periprocedural microemboli in 19 cases during angioplasty, compared with 13 cases detected during stenting. Plaque entrapment by the stent, likewise a close-mesh net, might also account for the mean number of microemboli observed both during and after stent release being lower than that detected during the dilatations in the angioplasty-alone group. Differences in the morphological features of plaque may be associated with differences in embolization rate; nevertheless, we selected the procedures so that the ultrasonographic plaque features would be similar in both the angioplasty group and the stenting group. Therefore, the incidence of microemboli cannot be attributed to differences in plaque features in the 2 groups, but rather to the 2 different procedures. With regard to the mean values of microemboli intensity, no substantial difference was observed between the angioplasty group and the stenting group. However, this parameter seems to have no clear significance, since it might depend both on the volume and on the nature of the microemboli, and the detection...
tion system used cannot supply this type of morphological characterization.

The occurrence of microemboli was found to be symptomatic in only 2 patients (5%) who had cerebrovascular complications related to carotid artery endovascular treatment, and both problems arose during guidewire crossing. This could be related to the high number of microemboli; however, other factors such as hemodynamic insufficiency accompanying the detachment of emboli may be involved in ischemic damage, probably because of a reduced microemboli clearance.22,23 In this respect, magnetic resonance studies have confirmed that brain embolization is more frequent than the apparent neurological complication rate.7 Moreover, Rapp et al24 observed recently that even small (<200 µm) plaque fragments may later cause neuronal ischemia, and neuropsychological sequelae have been reported as a consequence of cerebral microembolism during carotid angioplasty.25 Further studies are required to clarify whether a high number of microemboli may be the harbinger of cerebrovascular complications.

In view of these findings, it appears that stent placement is safer than angioplasty alone and that any attempt to avoid the production of microemboli or their consequences, such as the improvement of neurointerventional methods or the use of neuroprotective agents, might be advisable.

Accepted for publication April 23, 2001.

Corresponding author and reprints: Giovanni Orlandi, MD, Department of Neuroscience, Clinic of Neurology, Via Roma 67, 56100 Pisa, Italy (e-mail: g.orlandi@neuro.med.unipi.it).

REFERENCES


Figure 2. Number and intensity of microemboli during guidewire crossing in 2 cases with periprocedural cerebrovascular complications: comparison with mean values. TIA indicates transient ischemic attack.