Restenosis After Carotid Surgery
The Importance of Clinical Presentation and Preoperative Timing

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Background and Purpose—Carotid endarterectomy (CEA) of stable atherosclerotic plaques is associated with an increased risk for restenosis. Patients with transient ischemic attack and patients with stroke have relatively unstable atherosclerotic plaques. However, carotid plaques stabilize over time after a cerebrovascular event due to plaque repair after rupture. These findings raised 2 questions: (1) Is preoperative clinical presentation related to restenosis after CEA? (2) Does delayed revascularization result in a higher risk for restenosis compared with CEA in the short term after a cerebrovascular event?

Methods—Between 2002 and 2009, 1203 patients undergoing CEA were included. The impact of clinical presentation on the occurrence of restenosis 1 year after CEA was investigated and corrected for cardiovascular risk factors, medication use, and type of arteriotomy closure. Patency was assessed with standardized duplex ultrasound imaging at 1 year after CEA. Restenosis was defined as recurrent luminal narrowing ≥50% at the endarterectomy site.

Results—At 1 year of follow-up, restenosis was observed more frequently in asymptomatic patients than in patients with transient ischemic attack and patients with stroke. The adjusted odds ratio (95% CI) for restenosis was 0.56 (0.35 to 0.89) for patients with transient ischemic attack and 0.49 (0.27 to 0.87) for patients with stroke compared with asymptomatic patients. Subgroup analysis showed an increased risk for restenosis if CEA was performed >30 days after stroke (adjusted OR, 2.23; 1.02 to 5.73).

Conclusions—Asymptomatic patients have an increased risk for restenosis at 1 year after CEA compared with patients with transient ischemic stroke and patients with stroke. CEA within 30 days after stroke is associated with a decreased risk of restenosis, which supports the current strategy for early surgical intervention after stroke. (Stroke. 2011;42:965-971.)

Key Words: asymptomatic carotid stenosis ■ carotid endarterectomy ■ restenosis ■ stroke risk factors ■ timing of surgery ■ transient ischemic attack

Carotid endarterectomy (CEA) is the gold standard for the treatment of patients with a symptomatic internal carotid artery stenosis and for selected subgroups of patients with an asymptomatic stenosis.1–5 Restenosis at the site of surgery is a drawback of CEA that can eventually lead to relapse or de novo cerebrovascular events, thereby limiting the long-term benefit of revascularization in the prevention of stroke. Restenosis resulting in a >50% diameter reduction, as detected on duplex ultrasound, has been reported to occur in 6% to 36% during long-term follow-up.6–7 The risk for restenosis has been described to be the highest in the first 2 years after surgery.8 Smoking, age, diabetes mellitus, female sex, and a history of ipsilateral carotid surgery have been reported as clinical risk factors for restenosis.9–12 In addition, stable atherosclerotic plaque characteristics with low macrophage content and small lipid core size are associated with an increased incidence of restenosis compared with unstable inflammatory lesions.13 Carotid plaques from patients who have had a stroke or transient ischemic attack (TIA) contain more unstable inflammatory properties and a larger lipid core than plaques from asymptomatic patients who are considered eligible for carotid surgery.14 Combining these observations, the question arises whether asymptomatic patients with relatively stable carotid plaques are more at risk for restenosis after CEA than patients with TIA and patients with stroke.

Plaques from patients operated on after a relatively long interval between their ischemic event and CEA revealed more smooth muscle cells, less macrophages, and a decrease in...
local carotid plaque inflammation, suggesting that carotid atherosclerotic plaques stabilize over time after a cerebrovascular event. Therefore, we consecutively hypothesized that early surgical intervention after an ischemic cerebral event could be associated with a decreased restenosis rate. The timing of carotid surgery in symptomatic patients is an ongoing subject of discussion but mainly focuses on the incidence of secondary events due to delayed surgery versus a believed higher operative risk due to early surgery. For clinical perspectives, the outcome of the current study could be helpful in the identification of patients who are at increased risk for restenosis 1 year after surgery based on initial clinical presentation and supports the growing evidence in favor of early revascularization.

Methods

Athero-Express Biobank
Athero-Express is an ongoing translational carotid biobank with a longitudinal study design that has been reported previously. Carotid plaques from patients undergoing CEA were collected and subjected to histological examination. Patients are prospectively monitored for 3 consecutive years after surgery. All patients who underwent CEA in 1 of the participating hospitals were considered eligible for inclusion in this study. Medical ethics boards of both participating hospitals approved the study, and all included patients provided written informed consent.

Study Population
Between April 1, 2002, and May 1, 2009, 1251 consecutive patients underwent CEA at the University Medical Center Utrecht or the St Antonius Hospital Nieuwegein, The Netherlands. Criteria to perform CEA were based on recommendations by the Asymptomatic Carotid Atherosclerosis Study and Asymptomatic Carotid Surgery Trial for asymptomatic patients and the North American Symptomatic Carotid Endarterectomy Trial and the European Carotid Surgery Trial for symptomatic patients. All indications were reviewed in a multidisciplinary vascular team, and all patients were evaluated by a neurologist before CEA to assess their neurological status and document the preoperative symptoms.

To investigate the association between restenosis and clinical presentation, we stratified among asymptomatic patients, patients with TIA, and patients with stroke. Asymptomatic presentation was defined as no ipsilateral symptoms for at least 6 months before neurological assessment. TIA was defined as a brief episode of neurological dysfunction caused by focal brain ischemia with clinical symptoms typically lasting <24 hours and without evidence of acute infarction. Repetition of imaging at a later stage was left to the decision of the neurologist in charge. In case of multiple TIAs, the last event was used to calculate the time between symptoms and surgery. Amaurosis fugax was included in the TIA group and was defined as ipsilateral partial or complete visual field loss in 1 eye that was of ischemic origin and was followed by complete recovery. Stroke was defined as focal neurological dysfunction of sudden onset caused by brain ischemia lasting ≥24 hours confirmed by imaging.

Clinical studies have shown that the benefit from CEA is highest in the first 30 days after an event, especially in the first 14 days. Furthermore, histopathologic observations have shown a significant decrease in local plaque inflammation, especially 30 days after stroke. Combining these clinical and histopathologic findings, a cutoff of 30 days was chosen to differentiate between early and delayed surgery.

All CEAs were performed by an open, noneversion technique. A policy of selective patching was applied, preferably with venous patches. If no venous patch could be harvested, closure was performed with Dacron or bovine patches. Baseline characteristics and cardiovascular risk factors were gathered from questionnaires and patient medical records preopera-

Follow-Up
Patency of the ipsilateral carotid artery was assessed by means of duplex ultrasound (Philips Medical Systems, Eindhoven, The Netherlands) 1 year after CEA. Restenosis was defined as recurrent luminal narrowing of ≥50% at the site of the endarterectomy. The occurrence of ≥50% restenosis at the ipsilateral side was defined as a peak systolic velocity of at least 125 cm/s. If the end point of restenosis ≥50% was observed, 3-month duplex data were gathered to investigate whether residual stenosis could already be observed at that time. Duplex ultrasound measurements were performed by fully qualified and certified radiologists and clinical neurophysiologists. All investigators were blinded for data regarding the type of presentation and the time between the event and surgery. Patients who lacked complete 1-year duplex ultrasound follow-up data were excluded from this study (Figure 1).

To investigate the effect of preoperative timing in subgroups of symptomatic patients, 61 patients were excluded because the exact time between their last symptomatic event and CEA could not be obtained.

Patients were routinely examined by a neurologist after CEA, and cerebrovascular complications during hospitalization were registered by the neurologist in charge. A perioperative stroke was considered to have occurred if it manifested within 30 days of CEA and was defined as neurological dysfunction, as documented by a neurologist, caused by brain ischemia lasting ≥24 hours confirmed by imaging.
After discharge, a strict follow-up protocol was implemented for all patients with visits to the neurologist and vascular surgeon at 6 weeks, 3 months, and 1 year. The occurrence of stroke during follow-up was prospectively registered and defined identically as stated previously.

Statistical Analysis
For data analysis, SPSS 15.0 (SPSS Inc, Chicago, IL) was used. Univariate analysis was performed with nonparametric tests for continuous variables or the Pearson $\chi^2$ test for dichotomous variables, where appropriate. To test the influence and independent effect of clinical characteristics on restenosis, multiple correction through binary logistic regression was performed and outcome was reported in adjusted ORs with 95% CIs. All clinical factors that showed an association with restenosis in univariate logistic regression analyses with a probability value <0.20 were included in the multivariable model. For the 3 categories of clinical presentation, asymptomatic patients were chosen as the reference category. For different types of closure after endarterectomy, venous patch closure was considered as the reference category. A probability value <0.05 or a 95% CI not including 1 was considered statistically significant.

Results
 Patients
Between April 1, 2002, and May 1, 2009, 1251 patients underwent CEA at 1 of our institutions (Figure 1). Five patients were discharged from follow-up due to malignant disease and 1 patient due to residency abroad. Within the first year after CEA, 14 patients died of ischemic stroke (n=4), hemorrhagic stroke (n=5), myocardial infarction (n=2), or a noncardiovascular (n=3) cause. Another 28 patients (2.2%) lacked 1-year duplex ultrasound data and were considered lost to follow-up. The final cohort consisted of 1203 patients, 822 men (68.3%), mean age 68.1 ± 9.1 years. There were 180 asymptomatic patients (15.0%), 721 (60.1%) with TIA and 302 (25.1%) with stroke. Baseline characteristics are provided in Table 1.

Atherosclerotic Plaque Composition
Histological plaque characteristics are listed in Table 2. Carotid atherosclerotic plaques from asymptomatic patients contained relatively more smooth muscle cells compared with plaques from patients with TIA or patients with stroke: 2.13 (0 to 18.68) versus 1.58 (0 to 17.60) and 1.46 (0 to 20.85), respectively ($P=0.014$). A large lipid core, covering >40% of the plaque surface, was most frequently observed in the plaques from patients with stroke (35.9% [106 of 295]) and patients with TIA (30.5% [217 of 712]) than in the plaques of asymptomatic patients (23.6% [42 of 178]). Moderate or heavy calcifications were more frequently observed in asymptomatic patients (67.2% [199 of 291]) compared with patients with TIA (56.5% [402 of 712]) and patients with stroke (55.6% [164 of 295]; $P=0.023$). No differences were observed for amounts of macrophages or vessels or for collagen content.

Follow-Up: Restenosis 1 Year After CEA
Overall of 1203 patients, restenosis ≥50% developed in 178 (14.7%) after a mean follow-up of 365±80 days. Of all patients with restenosis ≥50% at 1 year after CEA, 159 (89.3%) did not have signs of residual stenoses at 3 months, 13 (7.3%) did show signs of residual stenosis, and for 6 patients (3.4%), no 3-month duplex imaging could be retrieved. There was no difference in clinical presentation between patients with and without residual stenosis. Of the 178 patients with restenosis ≥50%, 13 (7.3%) had a stroke during mean follow-up of 269 (±161) days. These 13 patients included 1 fatal stroke, 4 major invalidating strokes, and 8 strokes for which a secondary carotid revascularization was performed. In 15 patients (8.4%) with restenosis ≥50%, secondary ipsilateral carotid interventions were performed after a mean follow-up of 345 (±158) days. Secondary interventions in these 15 patients were performed in 8 patients because of stroke, in 4 patients because of TIA, and in 3 asymptomatic patients with rapidly increasing restenosis.

The incidence of restenosis was significantly higher among asymptomatic patients (23.3% [42 of 180]) compared with patients with TIA (13.7% [99 of 721]; adjusted $P=0.017$) and patients with stroke (12.3% [37 of 302]; adjusted $P=0.014$; Figure 2A). Adjusted ORs for restenosis ≥50% for patients

### Table 1. Baseline Characteristics of the Total Cohort of Patients That Underwent CEA

<table>
<thead>
<tr>
<th>Category</th>
<th>Total Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of patients</strong></td>
<td>1203</td>
</tr>
<tr>
<td><strong>Risk factors</strong></td>
<td></td>
</tr>
<tr>
<td>Age, mean±SD, years</td>
<td>68.1±9.1</td>
</tr>
<tr>
<td>Male gender</td>
<td>68.3% (822/1203)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>35.5% (393/1108)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>20.5% (219/1068)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>86.2% (941/1102)</td>
</tr>
<tr>
<td>Body mass index, mean±SD, kg/m²</td>
<td>26.4±3.7</td>
</tr>
<tr>
<td>History of coronary intervention</td>
<td>20.7% (249/1203)</td>
</tr>
<tr>
<td>History of peripheral intervention</td>
<td>17.2% (198/1150)</td>
</tr>
<tr>
<td>Days between surgery and duplex, mean±SD</td>
<td>365±80</td>
</tr>
<tr>
<td><strong>Symptoms</strong></td>
<td></td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>15.0% (180/1203)</td>
</tr>
<tr>
<td>TIA</td>
<td>59.9% (721/1203)</td>
</tr>
<tr>
<td>Stroke</td>
<td>25.1% (302/1203)</td>
</tr>
<tr>
<td><strong>Contralateral stenosis</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>56.5% (614/1087)</td>
</tr>
<tr>
<td>Stenosis 50%–99%</td>
<td>28.5% (310/1087)</td>
</tr>
<tr>
<td>Occlusion</td>
<td>15.0% (163/1087)</td>
</tr>
<tr>
<td><strong>Lesion</strong></td>
<td></td>
</tr>
<tr>
<td>De novo stenosis</td>
<td>96.1% (1129/1175)</td>
</tr>
<tr>
<td>Restenosis after CEA</td>
<td>3.9% (46/1157)</td>
</tr>
<tr>
<td><strong>Medication use</strong></td>
<td></td>
</tr>
<tr>
<td>Statin</td>
<td>74.8% (856/1144)</td>
</tr>
<tr>
<td>Aspirin</td>
<td>85.1% (973/1144)</td>
</tr>
<tr>
<td>Oral anticoagulants</td>
<td>13.0% (149/1144)</td>
</tr>
<tr>
<td>Clopidogrel</td>
<td>12.8% (146/1144)</td>
</tr>
<tr>
<td><strong>Closure</strong></td>
<td></td>
</tr>
<tr>
<td>Venous patch</td>
<td>51.9% (618/1190)</td>
</tr>
<tr>
<td>Dacron patch</td>
<td>34.2% (407/1190)</td>
</tr>
<tr>
<td>Bovine patch</td>
<td>1.5% (18/1190)</td>
</tr>
<tr>
<td>Primary closure</td>
<td>12.4% (147/1190)</td>
</tr>
</tbody>
</table>
with TIA and patients with stroke were 0.56 (0.35 to 0.89) and 0.49 (0.27 to 0.87), respectively, compared with asymptomatic patients (Table 3).

Dacron path closure resulted in an adjusted OR of 2.33 (1.52 to 3.58) for restenosis ≥50% compared with venous patch closure. Primary arterial closure revealed an adjusted OR of 2.32 (1.33 to 4.04).

Patient characteristics, including age, gender, and smoking, did not contribute additionally to the development of restenosis ≥50% in our cohort.

To assess the influence of preoperative timing, subgroup analyses were performed for patients with TIA and patients with stroke. The timing of surgery after TIA did not affect restenosis rates after 1 year. Restenosis after TIA developed in 27 of the 238 patients (11.3%) who underwent CEA within 30 days of TIA and in 57 of the 422 patients (13.5%) operated on after >30 days after TIA (P=0.423; Figure 2B). Perioperative stroke was observed in 5 patients with TIA (2.1%) operated on within 30 days and in 12 patients with TIA (2.8%) operated on after 30 days (P=0.563).

Significantly less restenosis developed in patients who underwent CEA within 30 days after stroke compared with patients who underwent CEA >30 days after stroke. Restenosis was observed in 6 of 91 patients (6.6%) operated on within 30 days versus 30 of 194 patients (15.5%) who underwent surgery more than 30 days after stroke (P=0.043; Figure 2B). After correction for general cardiovascular risk factors, multiple regression analysis revealed that a delay between stroke and CEA exceeding 30 days resulted in an adjusted OR of 2.23 (1.02 to 5.73) for restenosis ≥50%.

Periprocedural stroke was observed in 2 of 91 patients with stroke (2.2%) operated on within 30 days and in 5 of 194 patients with stroke (2.6%) operated on after 30 days (P=0.847). Of all the perioperative strokes in these subgroups, 5 (71.4%) were ipsilateral and 2 (28.6%) were contralateral. The median time between surgery and perioperative stroke for these patients was 1 day (range, 0 to 7 days).

Discussion

The present study shows that asymptomatic patients have an increased risk for restenosis within 1 year after CEA compared with patients with TIA or patients with stroke. Subgroup analysis showed that delayed CEA after stroke is independently associated with an increased risk for restenosis. These clinical characteristics might help to stratify between patients at risk for development of restenosis. To the best of our knowledge, this is the first report considering a large cohort of 1200 patients undergoing CEA that links clinical presentation to restenosis rates. The association between asymptomatic presentation and restenosis is likely to be based on the underlying relatively stable plaque type. It is generally accepted that asymptomatic lesions have a more stable plaque composition characterized by less inflammation and lower lipid content. Stable plaque characteristics have been reported to be associated with increased risk of restenosis. The present study also confirmed the presence of a relatively stable plaque composition in asymptomatic patients and thereby supports previous findings and our hypothesis.

The underlying mechanism to explain the association between plaque phenotype and restenosis is believed to be lipid- and inflammation-driven and therefore has dual components. First, endarterectomy of lipid-rich plaques is be-

### Table 2. Histological Plaque Characteristics for Different Groups of Clinical Presentation

<table>
<thead>
<tr>
<th>Histological Parameters</th>
<th>Asymptomatic (n=177)</th>
<th>TIA (n=712)</th>
<th>Stroke (n=295)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macrophages, median (range)</td>
<td>0.50 (0–6.88)</td>
<td>0.59 (0–15.10)</td>
<td>0.55 (0–8.12)</td>
<td>0.322</td>
</tr>
<tr>
<td>Smooth muscle cells, median (range)</td>
<td>2.13 (0–18.68)</td>
<td>1.58 (0–17.60)</td>
<td>1.46 (0–20.85)</td>
<td>0.014*</td>
</tr>
<tr>
<td>Moderate/heavy calcifications</td>
<td>67.2% (199/177)</td>
<td>56.5% (402/712)</td>
<td>55.6% (164/295)</td>
<td>0.023*</td>
</tr>
<tr>
<td>Moderate/heavy collagen</td>
<td>84.2% (149/177)</td>
<td>80.0% (569/711)</td>
<td>80.7% (238/295)</td>
<td>0.454</td>
</tr>
<tr>
<td>Lipid core ≥40%</td>
<td>23.6% (42/178)</td>
<td>30.5% (217/712)</td>
<td>35.9% (106/295)</td>
<td>0.018*</td>
</tr>
<tr>
<td>Vessels per hotspot, median (range)</td>
<td>7.8 (0–27.3)</td>
<td>7.7 (0–35.7)</td>
<td>8.0 (0–47.0)</td>
<td>0.872</td>
</tr>
</tbody>
</table>

*P<0.05.

Figure 2. A, Restenosis ≥50% 1 year after CEA in relation to clinical presentation before carotid endarterectomy. B, Restenosis ≥50% 1 year after CEA and the time between last event and carotid endarterectomy.
The process of plaque repair in symptomatic lesions starts after plaque rupture, which contributes to stabilization over time and results in a less inflammatory atherosclerotic carotid lesion. Therefore, we hypothesized that the timing of carotid surgery after the initial event would affect the rate of restenosis. For patients with stroke, carotid surgery within 30 days significantly decreased the rate of restenosis. These observations might be explained by plaque stabilization over time after the initial event and thereby support the concept from previously published work. These findings suggest that the longer the delay from stroke until revascularization, the more the lesion stabilizes and the higher the risk for restenosis. The timing of surgical revascularization was not associated with the incidence of restenosis in patients with TIA compared with patients with stroke. Early CEA for symptomatic lesions to prevent recurrent ischemic events is a current subject of discussion. Delay in surgery has been reported to be associated with an increased incidence of recurrent adverse cerebrovascular ischemic events. On the other hand, a relationship was shown with early surgery and increased procedurally related complications, including stroke and death. Nevertheless, other studies showed that early carotid interventions after TIA or stroke significantly decreased the risk for recurrent clinical events without an increased periprocedural risk of stroke and death. We did not observe increased risks for

### Table 3. Effect of Clinical Parameters on Restenosis ≥50%, Expressed in ORs With 95% CI, Calculated With Binary Logistic Regression

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>No Restenosis</th>
<th>Restenosis ≥50%</th>
<th>Univariate OR (95% CI)</th>
<th>P</th>
<th>Multivariate OR (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>1025</td>
<td>178</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, mean ± SD, years</td>
<td>67.9 ± 9.2</td>
<td>66.8 ± 8.2</td>
<td>0.99 (0.97–1.01)</td>
<td>0.166</td>
<td>1.00 (0.98–1.02)</td>
<td>0.769</td>
</tr>
<tr>
<td>Male gender</td>
<td>69.6% (713/1025)</td>
<td>61.2% (109/178)</td>
<td>0.69 (0.49–0.96)</td>
<td>0.028*</td>
<td>0.70 (0.46–1.06)</td>
<td>0.092</td>
</tr>
<tr>
<td>Current smoker</td>
<td>35.6% (337/946)</td>
<td>34.6% (56/162)</td>
<td>0.96 (0.67–1.36)</td>
<td>0.795</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>20.5% (187/914)</td>
<td>20.8% (32/154)</td>
<td>1.02 (0.67–1.55)</td>
<td>0.928</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>85.9% (804/936)</td>
<td>87.7% (137/156)</td>
<td>1.18 (0.71–1.98)</td>
<td>0.520</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index, mean ± SD, kg/m²</td>
<td>26.3 ± 3.7</td>
<td>26.8 ± 3.9</td>
<td>1.04 (0.99–1.09)</td>
<td>0.099</td>
<td>1.02 (0.97–1.07)</td>
<td>0.526</td>
</tr>
<tr>
<td>History of coronary intervention</td>
<td>20.4% (209/1025)</td>
<td>22.5% (40/178)</td>
<td>1.13 (0.77–1.66)</td>
<td>0.527</td>
<td></td>
<td></td>
</tr>
<tr>
<td>History of peripheral intervention</td>
<td>17.1% (167/979)</td>
<td>18.1% (31/171)</td>
<td>1.07 (0.71–1.64)</td>
<td>0.732</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Symptoms

- **Asymptomatic**: 13.5% (138/1025) 23.6% (42/178)
  - Univariate OR (95% CI): 0.90 (0.55–1.47) 0.028
  - Multivariate OR (95% CI): 1.00 (0.58–1.71) 0.99

- **TIA**: 60.7% (622/1025) 55.6% (99/178)
  - Univariate OR (95% CI): 0.53 (0.35–0.80) 0.002
  - Multivariate OR (95% CI): 0.56 (0.35–0.89) 0.017

- **Stroke**: 25.9% (265/1025) 20.8% (37/178)
  - Univariate OR (95% CI): 0.46 (0.28–0.75) 0.002
  - Multivariate OR (95% CI): 0.49 (0.27–0.87) 0.014

### Contralateral stenosis

- **No**: 59.3% (549/926) 40.4% (65/161)
  - Univariate OR (95% CI): 2.11 (1.45–3.08) 0.001
  - Multivariate OR (95% CI): 1.80 (1.17–2.79) 0.008

- **Stenosis 50%–99%**: 26.8% (248/926) 38.5% (62/161)
  - Univariate OR (95% CI): 2.23 (1.41–3.52) 0.001
  - Multivariate OR (95% CI): 2.38 (1.41–4.03) 0.001

- **Occlusion**: 13.9% (129/926) 21.1% (34/161)
  - Univariate OR (95% CI): 0.56 (0.32–1.00) 0.050
  - Multivariate OR (95% CI): 0.54 (0.27–1.09) 0.086

### Lesion

- **De novo stenosis**: 96.3% (964/1001) 94.8% (165/174)
  - Univariate OR (95% CI): 0.72 (0.47–1.12) 0.14
  - Multivariate OR (95% CI): 0.71 (0.46–1.11) 0.12

- **Restenosis after CEA**: 3.7% (37/1001) 5.2% (9/174)
  - Univariate OR (95% CI): 1.42 (0.67–2.99) 0.356
  - Multivariate OR (95% CI): 1.42 (0.67–2.99) 0.356

### Medication use

- **Statin**: 73.5% (717/975) 82.2% (99/178)
  - Univariate OR (95% CI): 1.67 (1.10–2.54) 0.017
  - Multivariate OR (95% CI): 1.73 (1.04–2.87) 0.034

- **Aspirin**: 84.2% (821/975) 89.9% (152/169)
  - Univariate OR (95% CI): 1.67 (0.99–2.85) 0.056
  - Multivariate OR (95% CI): 1.54 (1.04–2.30) 0.033

- **Oral anticoagulants**: 13.8% (135/975) 8.3% (14/169)
  - Univariate OR (95% CI): 0.56 (0.32–1.00) 0.050
  - Multivariate OR (95% CI): 0.54 (0.27–1.09) 0.086

### Closure

- **Venous patch**: 55.1% (559/1015) 33.7% (59/175)
  - Univariate OR (95% CI): 1.16 (0.90–1.50) 0.26
  - Multivariate OR (95% CI): 1.16 (0.90–1.50) 0.26

- **Dacron patch**: 31.9% (324/1015) 47.4% (83/175)
  - Univariate OR (95% CI): 2.43 (1.69–3.84) <0.001
  - Multivariate OR (95% CI): 2.33 (1.52–3.58) <0.001

- **Bovine patch**: 1.3% (13/1015) 2.9% (5/175)
  - Univariate OR (95% CI): 3.64 (1.26–10.58) 0.017
  - Multivariate OR (95% CI): 1.14 (0.13–9.92) 0.904

- **Primary closure**: 11.7% (119/1015) 16.0% (20/125)
  - Univariate OR (95% CI): 2.23 (1.36–3.64) 0.001
  - Multivariate OR (95% CI): 2.32 (1.33–4.04) 0.003

*P<0.05.
periprocedural stroke for patients who underwent early revascularization, and the 2.1% to 2.8% incidence of adverse events in our cohort is lower than the 4.6% to 5.6% risk for stroke and death after CEA that a large pooled data analysis reported.16 The outcomes of the present study therefore support and strengthen the principle of early carotid surgery after stroke.

The importance of patch angioplasty after CEA has been widely accepted, and venous patch closure is still considered to be the gold standard.29,30 We observed an increased risk for restenosis after Dacron patch and primary closure compared with the reference group with venous patch closure with adjusted ORs of 2.33 (1.52 to 3.58) and 2.32 (1.33 to 4.04), respectively. Naylor et al observed that the freedom from restenosis during a 3-year follow-up period was significantly lower in the venous-patched group compared with the Dacron-patched group,31 which is in line with our data.

Limitations
The current study has some limitations. The analysis of subgroups of patients with TIA and patients with stroke resulted in a slightly significant beneficial effect of early revascularization in patients with stroke. We therefore stress that it is a subgroup analysis and naturally hypothesis-generating. Our findings will have to be confirmed by data from large trials with randomization between early and delayed surgery.

The group of patients with stroke operated on within 30 days is relatively small. This is probably due to the growing amount of evidence in favor of early surgery over time. Patients operated on early were included more recently, whereas delayed surgery was more common in the early years of this study. Nevertheless, we believe that this study has enough power for statistical analyses, resulting in reliable observations.

The estimated time between stroke and surgery is generally well defined due to hospitalization, neurological examination, and diagnostic imaging. The estimated time between TIA and CEA is mainly dependent on patient anamnesis and might therefore be less accurate.

Patients with clinically symptomatic significant carotid stenosis without signs of fresh ischemia on imaging and symptoms <24 hours were classified as TIA. Repetition of imaging at a later stage was left to the decision of the neurologist in charge. Patients who were classified as TIA could have developed ischemia that was not detected on the initial scan. This might have caused some overlap between the TIA and stroke groups. Nevertheless, independent from the diagnosis of TIA or minor stroke, symptomatic patients with a significant carotid stenosis have an indication for revascularization. It is therefore unethical to wait for the results of repeated imaging, also due to the high risk of a secondary cerebrovascular event. This overlap is therefore an inevitable limitation, but we feel that the number of patients in the 3 groups provides sufficient power to minimize possible confounding.

A small part of the patients that had 1-year restenosis ≥50% also showed residual stenosis at 3 months. There were no differences in clinical presentation between patients with and without residual stenosis. We therefore expect that it will not be a confounding factor for the research question of the current study.

Overestimation of the degree of restenosis can be caused by several factors. First, primary closure has been reported to cause increased peak systolic velocity compared with patch closure.82 This might have resulted in an overestimation of the risk of restenosis in patients who underwent primary closure after CEA. On the other hand, primary closure has been reported as a common risk factor for restenosis compared with patch angioplasty, which shows our data are in line with the currently available literature.79 Second, contralateral stenosis or occlusion can result in overestimation of the degree of stenosis. Hence, we also corrected for the presence of contralateral stenosis or occlusion in multiple regression models. Finally, a certain amount of overestimation is present in our series due to the use of European Carotid Surgery Trial (ECST) criteria. It is commonly accepted that ECST criteria result in a relatively high degree of stenosis in comparison with North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria.33 Nevertheless, the goal of the current study was to describe the occurrence of restenosis in relation to patient characteristics and timing of CEA rather than in relation to the degree of stenosis.

Conclusions
The main finding of the current study is that asymptomatic patients have an increased risk for restenosis ≥50% compared with patients with TIA and patients with stroke. Furthermore, we show that early surgical revascularization resulted in a decreased risk for restenosis ≥50% for patients with stroke without a significantly increased perioperative risk. These observations can be explained by the underlying stable plaque phenotype in asymptomatic patients and plaque stabilization over time after stroke. These findings might help to identify patients who are at risk for restenosis and additionally indicate that early CEA is favorable after stroke. We therefore emphasize the importance of early referral of patients with stroke for carotid surgery.

Disclosures
The following authors are consultants for Cavadis, a start-up company for diagnostic plaque biomarker kits: D.P.V.d.K., F.L.M., and G.P. However, the content of this article is not related with the activities of the company.

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경동맥 수술 후 재협착
임상 발현 양상과 수술 시기의 중요성

**Restenosis After Carotid Surgery**
The Importance of Clinical Presentation and Preoperative Timing

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*(Stroke. 2011;42:965-971.)*

**Key Words:** asymptomatic carotid stenosis ■ carotid endarterectomy ■ restenosis ■ stroke risk factors ■ timing of surgery ■ transient ischemic attack

배경과 목적
경동맥의 안정된 축적형판(atherosclerotic plaque)의 절개
습은 재협착(restenosis)의 위험 증가와 연관이 있다. 일차
성협착방식(transient ischemic attack) 또는 뇌졸중을 가진
환자들은 대체적으로 불안정한 축적형판을 가진다. 불안정한
경동맥 수술은 재협착의 위험 요소로 간주된다. 재협착이
발생하는 경우의 관리와 예방을 위한 연구가 필요하다.

방법
본 연구는 2002년부터 2009년까지 CEA를 받은 환자 1,203
명을 대상으로 진행되었다. 임상 발현 양상이 CEA 1년 후 재
협착의 발생에 미치는 영향을 분석하였고, 분석은 심혈관 위
험인자, 약물 복용, 성별, 과거 병력, 혈관 수술 등을

초음과 영상을 통하여 평가하였다. 재협착은 내막절제술 부위
에서 50% 이상의 혈착이 재발한 경우로 정의하였다.

결과
주적 시간 1년 후 재협착은 일차성협착방식 또는 뇌졸중을 가
진 환자에서보다 무증상의 환자에서 더 빈번하게 관찰되었다. 재
협착에 대한 보정 교차비는 무증상 환자와 비교할 때 일차성협
착관 환자에서 0.56 (95% 신뢰구간[CI]: 0.35~0.89), 뇌졸
중 환자에서 0.49 (95% CI: 0.27~0.87)였다. 하위 그룹 분석
에서 CEA가 뇌졸중 발생 30일 이후에 시행되었을 때 재협착
률이 증가하는 것으로 관찰되었다(보정 교차비, 2.23; 95%
CI: 1.02~5.73).

결론
무증상 환자들은 일차성협착방식 또는 뇌졸중을 가진 환자들에
비하여 CEA 이후 1년에 관찰하였을 때 높은 재협착율을 가진다.
뇌졸중 이후 30일 이내에 CEA를 시행한 경우 재협착률이 감소
한다는 결과는 뇌졸중 후 조기 수술적 치료 제안을 지지한다.