Durability of Carotid Endarterectomy

Robert D. Ecker, MD; Mark A. Pichelmann, MD; Irene Meissner, MD; Fredric B. Meyer, MD

Background and Purpose—We sought to determine the incidence of recurrent stenosis after carotid endarterectomy.

Methods—One thousand consecutive carotid endarterectomy patients were followed prospectively. The surgery was performed in a standard fashion. Cerebral protection was provided with intraoperative electroencephalographic monitoring and selective shunting. All arteriotomies were repaired with a patch graft. Each patient was seen 3 months after surgery and then yearly, with a duplex ultrasound obtained at each visit. Evidence for new ischemic events or recurrent stenosis of ≥70% was recorded.

Results—The 30-day combined minor and major stroke and death rate was 1.9%. At 7.1-year follow-up, 0.1% of patients had recurrent stenosis ≥70%, the majority of which were asymptomatic.

Conclusions—Carotid endarterectomy is a low-risk procedure for the treatment of carotid occlusive disease, with excellent long-term durability. Although less invasive, carotid angioplasty must demonstrate equal robustness in long-term follow-up before it is considered a routine alternative to surgery. (Stroke. 2003;34:2941-2944.)

Key Words: carotid endarterectomy ■ stenosis ■ stroke

Subjects and Methods

One thousand consecutive carotid endarterectomies performed in 975 patients by a single surgeon (F.B.M.) during 1988–2000 were followed prospectively. Twenty-five patients underwent staged bilateral endarterectomies. All operations were performed on arteries with >70% stenosis. No operations for moderate stenosis were included in this study. When cerebral angiography was available, the degree of stenosis was determined with the use of North American Symptomatic Carotid Endarterectomy Trial (NASCET) methodology. However, carotid ultrasound and MR angiography (MRA) were the primary imaging modalities used in this study. MRA assessment of degree of stenosis has been shown to correlate well with traditional cerebral angiography in determining the presence of a hemodynamically significant lesion.30,31 Baseline and follow-up demographic data were entered into a long-standing departmental database. A Sundt risk classification grade was determined preoperatively for each patient. The Sundt grade determines anatomic, medical, and neurological risk factors and has been documented to be of value in predicting perioperative surgical morbidity and mortality (Table 1).4,32

All patients were given 325 mg of aspirin perioperatively. Before carotid artery clamping, 5000 U of heparin was administered, and the patient’s systolic blood pressure was elevated to approximately 150 to 170 mm Hg. The endarterectomy was performed in a standardized manner with the use of intraoperative electroencephalography.4 In cases in which the intraoperative electroencephalograph demonstrated ischemic changes during clamping of the carotid arteries despite induced hypertension (attenuation of faster frequencies of >4 Hz by >50% along with an increase in the amplitude of delta activity by 50%), a shunt was placed. After removal of the carotid plaque, the arteriotomy was closed with a patch graft. Early in this series the saphenous vein was utilized. However, because of the small risk of vein graft rupture,33 the vast majority of arteriotomies were repaired with a knitted, double-velour collagen impregnated graft (Hemashield; Meadox).34

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Patients were seen in follow-up at 3 months postoperatively and then yearly thereafter. Duplex carotid ultrasound was performed at each visit, and if a 70% stenosis was identified, this was confirmed by either carotid MRA or transfemoral cerebral angiography. Patients with a stenosis of 70% or evidence of new ischemic symptoms were cataloged.

**Results**

The study included 680 men and 320 women aged 69±8 years. The cataloging of patients by Sundt risk grade is listed in Table 1. Of note, 194 patients had concerning anatomic risk factors, including contralateral carotid occlusion, and 496 patients had concurrent significant medical risk factors, primarily coronary artery disease. In 59% of patients, the carotid stenosis was symptomatic.

The combined 30-day death and stroke rate was 1.9%. There were 9 deaths (0.9%) (3 fatal myocardial infarctions, 4 intracerebral hemorrhages, 2 strokes). All deaths occurred in Sundt grade 3 and 4 patients. Any patient in whom there was concern for a possible perioperative ischemic event was examined by a stroke neurologist. There were 10 documented strokes (1.0%). Of these 10 strokes, 1 occurred in a Sundt grade 1 patient, 2 in Sundt grade 2 patients, 4 in Sundt grade 3 patients, and 3 in Sundt grade 4 patients. At 3-month follow-up by the neurologist, 7 of 10 patients were functionally independent as defined by Rankin 2 scores. Other surgical morbidity included 1 infection and 7 cranial nerve palsies, 6 cases of transient vocal cord paresis, 1 permanent spinal accessory nerve injury, and 3 cases of mandibular facial nerve paresis, of

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Author</th>
<th>Study Type</th>
<th>Mean Follow-Up, mo</th>
<th>No. of Operations</th>
<th>Symptomatic, %</th>
<th>Death/Major Stroke (% at 30 days)</th>
<th>Restenosis Criteria</th>
<th>Method of Closure</th>
<th>Restenosis, %</th>
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<tr>
<td>1987</td>
<td>Hertz et al</td>
<td>PS</td>
<td>21</td>
<td>801</td>
<td>49</td>
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<td>1997</td>
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<td>24</td>
<td>500</td>
<td>71</td>
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<td>&gt;80</td>
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<td>1998</td>
<td>Shah et al</td>
<td>RS</td>
<td>18</td>
<td>2723</td>
<td>36</td>
<td>2.3</td>
<td>NR</td>
<td>Patch 3%</td>
<td>Eversion 82%</td>
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<td>PR</td>
<td>33</td>
<td>1353</td>
<td>59</td>
<td>2.6</td>
<td>&gt;50</td>
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<tr>
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<td>Archie</td>
<td>RS</td>
<td>55</td>
<td>1360</td>
<td>62</td>
<td>2.1</td>
<td>&gt;50</td>
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<td>Eversion 0%</td>
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<td>2001</td>
<td>Scavee et al</td>
<td>RS</td>
<td>49</td>
<td>600</td>
<td>46</td>
<td>0.9</td>
<td>&gt;50</td>
<td>Patch 100%</td>
<td>Eversion 0%</td>
<td>5.8</td>
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<tr>
<td>2002</td>
<td>Biasi et al</td>
<td>RS</td>
<td>56</td>
<td>517</td>
<td>58</td>
<td>2.5</td>
<td>&gt;60</td>
<td>Patch 62%</td>
<td>Eversion 0%</td>
<td>1.2</td>
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<td>RS</td>
<td>NR</td>
<td>1648</td>
<td>NR</td>
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<td>&gt;70</td>
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<td>PS</td>
<td>82</td>
<td>1000</td>
<td>59</td>
<td>1.9</td>
<td>&gt;70</td>
<td>Patch 100%</td>
<td>Eversion 0%</td>
<td>5.8</td>
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</tbody>
</table>

PR indicates prospective randomized; PS, prospective series; RS, retrospective series; NR, not reported.
which 2 resolved. There were no permanent significant twelfth nerve palsies.

Ten patients (0.1%) experienced a recurrent stenosis as defined by $\geq 70\%$ stenosis on ultrasound, confirmed by either MRA or cerebral angiography. Of these, 2 were symptomatic. Five of the recurrences went on to reoperation, 3 were treated with carotid angioplasty/stenting, and 2 were left untreated. The time to recurrence was 4.2 years. The follow-up for this study was 7.1 (range, 2.0 to 11) years.

### Discussion

This series of 1000 consecutive endarterectomies describes a combined 30-day minor and major stroke and death rate of 1.9% at a 7-year follow-up. These data are consistent with recent studies of $>500$ carotid endarterectomies that demonstrate 30-day major stroke and death rates ranging from 0.9% to 4% and a restenosis rate of 0.7% to 7.9% over an average of 3.5 years (Table 2).5–12 The present study demonstrating a 0.1% critical restenosis rate provides the longest follow-up data available to date and confirms that carotid endarterectomy is an extremely durable operation.

A meta-analysis of 714 patients in which 44% had both angioplasty and stenting revealed a stroke and death risk of 8%.36 Since the year 2000, 7 studies have been published with larger sample sizes (mean, 222 patients; range, 99 to 528) and 14.9-month follow-up (range, 11.2 to 20 months).36–41 The reported 30-day stroke and death rates range from 1% to 4%, with early restenosis rates of 0.5% to 14% (Table 3).36–41 Therefore, in experienced hands, the 30-day death and stroke rate for carotid angioplasty may be low. However, the available short-term follow-up data suggest that the durability of carotid angioplasty/stenting may be poor.

A review of the carotid endarterectomy literature with respect to restenosis is methodologically challenging because of variations in definitions of restenosis, methods of measuring restenosis, length of follow-up, method of closure at the initial operation, initial lesion pathology, and study design. However, some general considerations regarding method of arteriotomy closure can be drawn from the literature, including those studies listed in Table 2. The preponderance of data indicates that restenosis rates are generally lower with patch closure of the arteriotomy than with primary closure, ranging from 0.1% to 5.8% and 1% to 14%, respectively.5–12

### Conclusions

These data demonstrate that the risk of perioperative complications is low and that the durability of carotid endarterectomy is excellent. Although less invasive, carotid angioplasty/stenting must demonstrate equivalent robustness for this procedure to be considered a viable alternative to surgery. Clinical trials comparing these 2 treatments must incorporate sufficient years of follow-up after treatment to assess restenosis rates and long-term functional outcome.

### References

6. Biai GM, Sternjakob S, Mingazzini PM, Ferrari SA. Nine-year experience of bovine pericardium patch angioplasty during carotid endarterecto-

<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Study Type</th>
<th>Follow-Up, mo</th>
<th>No. of Patients</th>
<th>% Symptomatic</th>
<th>% Stenosis</th>
<th>% Death/Stroke</th>
<th>% Restenosis</th>
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<tr>
<td>2002</td>
<td>Henry et al(^{39})</td>
<td>PST of CAS</td>
<td>17.1</td>
<td>390</td>
<td>42</td>
<td>82.3</td>
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<td>Brooks et al(^{37})</td>
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<td>?</td>
<td>104</td>
<td>100</td>
<td>82–88</td>
<td>0.9 in CEA</td>
<td>?</td>
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<td>Vitek et al(^{41})</td>
<td>PST of CAS</td>
<td>20</td>
<td>99</td>
<td>60</td>
<td>79</td>
<td>4</td>
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<tr>
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<td>CAVATAS(^{36})</td>
<td>PSRT comparing CAS with CA ± stenting</td>
<td>12</td>
<td>251</td>
<td>CA (26% were stented)</td>
<td>97</td>
<td>85–86</td>
<td>10 CEA</td>
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<td>2001</td>
<td>Roubin et al(^{23})</td>
<td>PST of CAS</td>
<td>17</td>
<td>528</td>
<td>52</td>
<td>74</td>
<td>6.3–8.2</td>
<td>3.2</td>
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<tr>
<td>2000</td>
<td>Henry et al(^{35})</td>
<td>PST of CAS</td>
<td>17.1</td>
<td>290</td>
<td>42</td>
<td>82.3</td>
<td>3.2</td>
<td>4.7</td>
</tr>
<tr>
<td>2000</td>
<td>Gupta et al(^{48})</td>
<td>RS of patients &gt;65 deemed inoperable</td>
<td>12.1</td>
<td>100</td>
<td>85</td>
<td>85</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

PST indicates prospective trial; PSRT, prospective randomized trial; RS, retrospective series.
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