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# Redo Carotid Endarterectomy Versus Primary Carotid Endarterectomy

Ali F. AbuRahma, MD; Tucker G. Jennings, MD; John T. Wulu, PhD; Lisa Tarakji; Patrick A. Robinson, MD

- *Background and Purpose*—Several authorities have recently advocated carotid stenting for recurrent carotid stenosis because of the perception that redo surgery has a higher complication rate than primary carotid endarterectomy (CEA). This study compares the early and late results of reoperations versus primary CEA.
- *Methods*—All reoperations for recurrent carotid stenosis performed during a recent 7-year period by a single vascular surgeon were compared with primary CEA. Because all redo CEAs were done with polytetrafluoroethylene (PTFE) or vein patch closure, we only analyzed those primary CEAs that used the same patch closures. A Kaplan-Meier life-table analysis was used to estimate stroke-free survival rates and freedom from ≥50% recurrent stenosis.
- **Results**—Of 547 primary CEAs, 265 had PTFE or saphenous vein patch closure, and 124 reoperations had PTFE or vein patch closure during the same period. Both groups had similar demographic characteristics. The indications for reoperation and primary CEA were symptomatic stenosis in 78% and 58% of cases and asymptomatic  $\geq$ 80% stenosis in 22% and 42% of cases, respectively (*P*<0.001). The 30-day perioperative stroke and transient ischemic attack rates for reoperation and primary CEA were 4.8% versus 0.8% (*P*=0.015) and 4% versus 1.1%, respectively, with no perioperative deaths in either group. Cranial nerve injury was noted in 17% of reoperation patients versus 5.3% of primary CEA patients; however, most of these injuries were transient (*P*<0.001). Mean hospital stay was 1.8 days for reoperation versus 1.6 days for primary CEA. Cumulative rates of stroke-free survival and freedom from  $\geq$ 50% recurrent stenosis for reoperation and primary CEA at 1, 3, and 5 years were 96%, 91%, and 82% and 98%, 96%, and 95% versus 94%, 92%, and 91% and 98%, 96%, and 96%, respectively (no significant differences).
- *Conclusions*—Reoperation carries higher perioperative stroke and cranial nerve injury rates than primary CEA. However, reoperations are durable and have stroke-free survival rates that are similar to primary CEA. These considerations should be kept in mind when carotid stenting is recommended instead of reoperation. (*Stroke*. 2001;32:2787-2792.)

Key Words: carotid endarterectomy ■ carotid stenosis ■ recurrence ■ stents

Carotid endarterectomy (CEA) has long been one of the most commonly performed vascular procedures in the United States. The North American Symptomatic Carotid Endarterectomy Trial (NASCET)<sup>1</sup> and the Asymptomatic Carotid Atherosclerosis Study (ACAS)<sup>2</sup> both confirmed the benefits that CEA offers to patients with certain degrees of carotid artery stenosis. The emergence of these data has led to an increase in the number of CEAs performed each year. The reported incidence of recurrent carotid stenosis after primary CEA ranges from 10% to 25%.<sup>3-12</sup> Reoperation has been considered necessary in only 1% to 8% of cases.<sup>3-6,12</sup> Given that there has been an overall increase in the number of primary CEAs being performed, it follows that the total number of reoperations will also increase.

It is generally accepted that reoperation for significant recurrent carotid artery stenosis is indicated for patients with symptomatic disease. Several authors also recommend operation for >80% asymptomatic restenosis. The traditional approach for recurrent carotid stenosis involves repeat endarterectomy with patch angioplasty, patch angioplasty alone, or resection of the diseased segment with graft interposition. The advent of carotid balloon angioplasty and stenting has prompted many investigators to advocate this as the procedure of choice for recurrent carotid stenosis,<sup>13–16</sup> because it is perceived that reoperation has a higher complication rate than primary CEA. The present study examines one surgeon's experience with 124 reoperations over a 7-year period and compares early and late results with 265 primary CEAs performed on similar patients.

# **Subjects and Methods**

All reoperations for recurrent carotid stenosis performed during a recent 7-year period (October 1991 through October 1998) by a

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From the Department of Surgery (A.F.A., T.G.J.), Charleston Area Medical Center, Robert C. Byrd Health Sciences Center of West Virginia University (L.T.), Charleston, WV; Camcare Health Education and Research Institute (J.T.W.), Charleston, WV; and Boehringer Ingelheim Pharmaceuticals, Inc (P.A.R.), Ridgefield, Conn.

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Correspondence to Ali F. AbuRahma, MD, 3100 MacCorkle Ave SE, Suite 603, Charleston, WV 25304. E-mail Ali.aburahma@camcare.com © 2001 American Heart Association, Inc.

single vascular surgeon (A.F.A.) at the same institution were compared with primary CEA. Because all reoperations were done with polytetrafluoroethylene (PTFE; Goretex, WL Gore, Inc) patching or saphenous vein patching, only primary CEAs that used the same patch closures were analyzed. The pool of primary CEAs performed during this period came from 2 prospective randomized trials done by the main investigator (A.F.A.).<sup>17,18</sup> The reoperation group includes patients who had their primary CEA performed by the author (A.F.A.) and other reoperations for patients who had their primary CEA done by other surgeons, both in and outside of our community.

All patients had carotid color duplex ultrasound/magnetic resonance angiography or arteriography before undergoing a CEA. They also underwent tests for baseline blood cholesterol and triglyceride levels. Preoperative risk factors were determined for each patient, along with the preoperative use of aspirin or antiplatelet therapy. Indications for surgery were categorized into hemispheric transient ischemic attacks (TIAs), amaurosis fugax, hemispheric stroke, nonhemispheric TIAs, and asymptomatic carotid stenoses. All patients were administered aspirin therapy (325 mg daily), if not contraindicated, within 24 hours after the operation. All CEAs were performed under general anesthesia with systemic heparin and routine shunting with a carotid Argyle shunt (CR Bard, Inc).

#### **Surveillance Protocol**

All patients underwent clinical follow-up and immediate postoperative color duplex ultrasound scanning, which was repeated at 30 days, 6 months, 12 months, and every year thereafter with an ATL Ultramark 9 HDI system or HDI 3000 (Advanced Technology Laboratory, Inc). Reportable complications were determined in accordance with the North American Chapter of the International Society of Cardiovascular Surgery/Society for Vascular Surgery Ad Hoc Committee Suggested Standards for Reports Dealing with Cerebrovascular Disease.<sup>19</sup>

Duplex scanning was used to assess the presence of residual or recurrent stenoses. Peak systolic velocities of the internal carotid artery >140 cm/s with spectral broadening throughout systole and an increased diastolic frequency were consistent with hemodynamically significant stenosis (>50% diameter reduction).<sup>20</sup> Peak systolic velocities of >140 cm/s with an end-diastolic velocity >140 cm/s were consistent with hemodynamically significant stenosis was considered to be present only if the abnormality detected by duplex ultrasound was not detected on the first immediately postoperative duplex examination and if it persisted for at least 2 examinations done within 6 months of the original duplex examination. Patients with duplex findings consistent with  $\geq 80\%$  stenosis or occlusion had their diagnosis confirmed by magnetic resonance angiography or conventional arteriography.

#### **Statistical Methods**

The time to the occurrence of events ( $\geq$ 50% recurrent stenosis, stroke, or death) was calculated by the Kaplan-Meier method. Statistical comparisons were made with the Wilcoxon rank sum test. Statistical comparisons of continuous data were examined with the unpaired Student *t* test, and discrete variables were compared with  $\chi^2$  or Fisher exact test.

#### Results

Of 547 primary CEAs, 265 (251 patients) had PTFE or vein patch closures. One hundred twenty-four reoperations (121 patients) with PTFE or vein patch closure were done in the same period. Both groups had similar demographic characteristics. Table 1 summarizes the demographic and clinical data of both groups. Indications for reoperation were symptomatic stenosis in 97 cases (78%) and asymptomatic  $\geq$ 80% stenoses in 27 (22%). Indications for primary CEA were symptomatic stenoses in 154 cases (58%) and asymptomatic  $\geq$ 80% carotid stenosis in 111 (42%, P<0.001). The mean

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	Primary CEA (n=265)	Reoperation (n=124)
Mean age, y (range)	68.6 (38–90)	70.1 (52–81)
Sex, male, n (%)	140 (53)	61 (49)
Smoking, n (%)	155 (58)	71 (57)
Hypertension, n (%)	212 (80)	97 (78)
Diabetes mellitus, n (%)	71 (27)	36 (29)
Mean cholesterol	219	223
Mean triglycerides	232	236
Indications for surgery, n (%)		
Symptomatic (TIA/stroke)	154 (58)	97 (78)*
Asymptomatic >80% stenosis (or nonhemispheric TIA)	111 (42)	27 (22)*

\*P<0.001.

follow-up was 51 months for primary CEA and 49 months for reoperation. All patients who had reoperations had primary closure for their first CEA, except for 4 patients who had carotid patching (1 PTFE patch, 1 vein patch, and 2 collagenimpregnated Dacron patches [Hemashield]). Reoperations were done with PTFE patching in 73 cases (59%) and saphenous vein patching in 51 (41%). The types of reoperations were as follows: 32 (26%) patch angioplasties alone (for intimal hyperplastic lesions) and 92 (74%) redo CEAs with patch closure for atherosclerotic lesions with or without intimal hyperplasia. The time range from primary CEA to reoperation was 7 to 182 months, with a mean of 14 months for intimal hyperplastic lesions versus 73 months for atherosclerotic lesions (P < 0.001).

Table 2 summarizes the perioperative complications and late events. As noted, the 30-day perioperative ipsilateral

TABLE 2. Perioperative Complications and Late Events

	Primary CEA (n=265)	Reoperation (n=124)	Р
30-Day perioperative events			
lpsilateral stroke	2 (0.8)*	6 (4.8)†	0.015
Ipsilateral TIAs	3 (1.1)	5 (4)	NS
Perioperative carotid thrombosis	5 (1.9)	3 (2.4)	NS
Myocardial infarction	1 (0.4)	0	NS
Death	0	0	NS
Bleeding	1 (0.4)	1 (0.8)	NS
Cranial nerve injuries (total)	14 (5.3)	21 (17)	< 0.001
Transient	13 (4.9)	19 (15.3)	0.001
Permanent	1 (0.4)‡	2 (1.6)‡	NS
Late events			
lpsilateral stroke	0	0	NS
Ipsilateral TIA	1 (0.4)	1 (0.8)	NS
Deaths	25 (9.4)	15 (12.1)	NS

\*Both were in symptomatic patients.

+Five were in symptomatic patients and 1 was in an asymptomatic patient.
+All vagal nerve injuries.
All values are n (%).

	Primary CEA	Reoperation	Р	
$\geq$ 50% Stenosis	8 (3)	5 (4)	NS	
$\geq$ 80% Stenosis	3 (1.1)	2 (1.6)	NS	
Values are n (%).				

TABLE 3. Late Recurrent Stenosis

stroke rate for primary CEA was 0.8% versus 4.8% for reoperation (P=0.0147). There was no correlation between perioperative strokes and indication for surgery, as noted in Table 2. The 30-day perioperative ipsilateral TIA rate was 1.1% for primary CEA versus 4% for reoperation (P=NS). There were 5 perioperative carotid thromboses in primary CEA patients, 2 associated with ipsilateral stroke and 3 with ipsilateral TIAs, in contrast to 3 perioperative carotid thromboses in reoperations, 2 associated with stroke and 1 associated with ipsilateral TIA. There were no statistically significant differences in the incidence of perioperative myocardial infarction or bleeding. No perioperative deaths were encountered in either group. Cranial nerve injury was noted in 17% of patients who underwent reoperation versus 5.3% of primary CEA cases (P < 0.001); however, most of these injuries were transient. There were a total of 13 transient nerve injuries in the primary CEA group, including 5 involving the vagal nerve or its branches, 4 involving the hypoglossal nerves, and 4 involving the mandibular branches of the facial nerve. In the reoperation group, there were 19 transient nerve injuries, with 8 involving the vagal nerve or its branches, 6 involving the hypoglossal nerves, and 5 involving the mandibular branches of the facial nerve. Permanent cranial nerve injuries were similar in both groups (all vagal nerve injuries). There were no late ipsilateral strokes in either group. Fifteen late deaths (12.1%) were noted in the reoperation group (8 of myocardial infarction, 1 of congestive heart failure, 4 of malignancies, 1 of respiratory failure, and 1 for unknown reasons) in contrast to 25 (9.4%) in the primary CEA group (14 of myocardial infarction, 1 of congestive heart failure, 5 of malignancies, 2 of respiratory failure, 2 of renal failure, and 1 of unknown causes). None of the late deaths were stroke related.

There were no statistically significant differences in the incidence of  $\geq$ 50% or  $\geq$ 80% recurrent stenosis in either group (Table 3). The Kaplan-Meier cumulative stroke-free survival rates at 1, 2, 3, 4, and 5 years were 96%, 95%, 91%, 87%, and 82% for reoperation versus 94%, 92%, 92%, 91%, and 91% for primary CEA, respectively (*P*=NS; Table 4; Figure 1). Kaplan-Meier analysis also showed that freedom from  $\geq$ 50% recurrent stenosis at 1, 2, 3, 4, and 5 years was 98%, 98%, 96%, 96%, and 95% for reoperation versus 98%, 98%, 96%, 96%, and 96% for primary CEA (*P*=NS; Table 5; Figure 2).

Mean hospital stay was 1.8 days for reoperation versus 1.6 days for primary CEA. Mean hospital cost was \$6800 for primary CEA versus \$10 900 for reoperations. The higher cost for reoperation was primarily secondary to the cost of cerebral arteriography.

# Discussion

Most carotid restenoses are asymptomatic and hemodynamically insignificant. However, 1% to 8% of all patients

			Cumulative Stroke-Free	Standard
Interval in Months	No. at Risk at Start	N0. Failed	Survival Rates,	Error,
Drimony CEA		Talleu	70	70
	065	0	100	0
Entry	205	U	100	0
6 months	238	12	95	1.9
12 months	224	4	94	2.2
24 months	186	4	92	2.7
36 months	156	0	92	3.0
48 months	123	2	91	3.6
60 months	84	0	91	4.4
72 months	54	2	88	5.8
Reoperation				
Entry	124	0	100	0
6 months	116	5	96	1.7
12 months	111	0	96	1.7
24 months	93	1	95	1.9
36 months	76	3	91	2.8
48 months	62	3	87	3.5
60 months	50	3	82	4.3
72 months	36	2	79	4.9

undergoing CEA will develop hemodynamically significant recurrent carotid stenoses.<sup>3–6,12</sup> There is a general consensus among vascular surgeons that reoperation for significant symptomatic recurrent carotid stenosis is indicated. Meanwhile, the indication for reoperation for asymptomatic carotid stenosis is controversial. Healy et al<sup>21</sup> reported on their experience with 301 patients who underwent CEAs and follow-up duplex scans, in which only 2 patients had a stroke, and concluded that asymptomatic restenosis does not require reoperation. Others also advocate a nonoperative approach to patients with asymptomatic recurrent carotid stenosis.<sup>22,23</sup> In contrast, O'Donnell et al<sup>24</sup> concluded that there was a higher incidence of unheralded strokes (7.5%) in patients with recurrent stenosis who did not undergo operation, and they believed that a more aggressive approach might be warranted in patients with asymptomatic high-grade stenoses (>75%). O'Donnell et al<sup>24</sup> also indicated that most of the studies that recommended nonoperative therapy for recurrent stenosis



**Figure 1.** Kaplan-Meier life-table analysis comparing time to stroke or death for patients undergoing reoperation with that for patients undergoing primary CEA.

TABLE 5. Life-Table Analysis of Time to ≥50% Stenosis

Interval in Months	No. at Risk at Start	≥50% Stenosis	Cumulative Recurrent Stenosis–Free Rates, %	Standard Error, %
Primary CEA				
Entry	265	0	100	0
6 months	214	6	98	1.4
12 months	199	0	98	1.5
24 months	163	0	98	1.7
36 months	132	2	96	2.3
48 months	103	0	96	2.6
60 months	65	0	96	3.3
72 months	40	0	96	4.3
Reoperation				
Entry	124	0	100	0
6 months	118	3	98	1.4
12 months	112	0	98	1.4
24 months	94	0	98	1.4
36 months	75	1	96	1.8
48 months	63	0	96	1.8
60 months	50	1	95	2.5
72 months	37	2	90	3.9

failed to discriminate between high-grade (>80%) and moderate (50% to 80%) recurrent carotid stenoses. Their data suggested that a significant difference existed in the incidence of neurological events between these 2 stenotic groups. Only 1 TIA developed in 21 arteries in the 50% to <75% stenosis group in their series, whereas 1 TIA and 2 strokes developed in the 9 arteries with 75% to 99% stenosis.

Surgical treatment for recurrent carotid stenosis is more technically challenging than primary procedures; however, recent studies document that reoperation can be performed with stroke rates generally considered similar to that of primary surgery.<sup>9–12</sup> The present study shows a higher incidence of perioperative stroke rates in redo patients than in

patients with primary endarterectomies (4.8% and 0.8% respectively, statistically significant). The American Heart Association Stroke Council consensus statement of 1989 set the upper limit of acceptable stroke-death rates for operative treatment of recurrent carotid stenosis at 10%.<sup>25</sup> Our results fall well within this range.

Bernstein et al<sup>26</sup> reported on the results of 6 surgical series involving 284 patients operated on for recurrent stenoses and noted that the operative mortality rate varied from 0% to 3.1% (an average of 1.4%), with a perioperative stroke rate of 0% to 10.4% (an average of 3.9%). O'Donnell et al<sup>24</sup> also reported on the results from a meta-analysis of 6 series that showed a 4.2% stroke rate and a 1% mortality rate, for a combined stroke and death rate of 5.2%. O'Donnell et al<sup>24</sup> also indicated that cardiovascular morbidity after reoperation for recurrent stenosis was comparable to that encountered with primary CEA and that the incidence of cranial nerve injuries in patients with redo surgery averaged 8.5% in these series versus 16% in their series.

Recently, Hill et al,<sup>27</sup> in a study of 390 carotid operations (350 primary CEAs and 40 redo operations), concluded that there was no difference between the stroke/death rates after primary CEA and operations for recurrent carotid stenosis. We attempted to create as much uniformity as possible in our 2 study groups to draw more accurate comparisons. Both groups had similar demographics, and only 1 surgeon's experience was analyzed. Because all reoperations were performed with only PTFE or vein patch closure, these were compared only with primary endarterectomies that used the same patch closure. Kaplan-Meier and life-table analyses were used to determine the significance of our data. Although our data showed a difference in early stroke rates, we found no statistically significant difference in late neurological events. There was no significant difference in early and late deaths between the 2 groups. As illustrated in Figures 1 and 2, the cumulative stroke-free survival rates for reoperation and primary CEA at 1, 3, and 5 years were 96%, 91%, and 82% versus 94%, 92%, and 91%, respectively. The rates of freedom from >50% recurrent stenosis for reoperations and primary CEA were 98%, 96%, and 95% versus 98%, 96%,



Figure 2. Kaplan-Meier life-table analysis comparing time to ≥50% stenosis for patients undergoing reoperation with that for patients undergoing primary CEA.

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and 96%. There was no statistically significant difference between the 2 groups with respect to either stroke-free survival or freedom from recurrence. These results suggest that reoperations provide durable protection from late stroke and recurrent stenosis.

As expected, we found an increase in the number of transient cranial nerve injuries in the reoperation group compared with the primary CEA group (15.3% versus 4.9%). However, there was no statistically significant difference between the 2 groups with respect to permanent cranial nerve injuries. Only 1.6% of reoperation patients in the present series had permanent cranial nerve deficits. This number compares favorably with other similar studies. Mansour et al<sup>10</sup> reported transient or permanent cranial nerve deficits in 7.3% of redo CEAs, whereas Zarins<sup>28</sup> reported the incidence of cranial nerve palsies to be as high as 20%.

The type of operative technique for reoperations depends on the cause of the recurrent carotid artery disease. Myointimal hyperplasia, which is responsible for recurrent stenosis that occurs early in the postoperative period, has a smooth luminal surface and appears to be associated with a low potential for embolization. Therefore, in patients with intimal hyperplasia, simple patching may be all that is necessary. By contrast, the soft nature of the plaque in recurrent atherosclerosis, which appears later, theoretically has a greater potential for embolization. Therefore, in patients with atherosclerosis, repeat CEA with carotid patch angioplasty is preferable. We have shown in a previous study that in primary CEAs, primary closure had a higher incidence of postoperative stroke and recurrent stenosis than did patching.17 We therefore believe that primary closure has no role in reoperations. Other types of techniques have been used for reoperations, such as saphenous vein interposition grafts. However, Hill et al<sup>27</sup> reported that vein interposition might be prone to a higher rate of failure than PTFE grafts that were used for carotid reconstruction.

Transcatheter intervention is increasing in popularity and has been advocated by some investigators as an alternative to surgery when dealing with carotid restenosis. The safety and efficacy of this approach is currently being investigated. The Carotid Revascularization: Endarterectomy versus Stenting Trial (CREST),<sup>29,30</sup> which is currently under way, is comparing the results of operative and endovascular treatment of carotid stenosis.

Hobson et al<sup>31</sup> reported comparable early results for reoperation and endovascular therapy for patients with carotid restenosis. During the period from 1989 through 1997, restenosis was managed with reoperation in 16 cases and with carotid angioplasty/stenting in 15. Patients who had early recurrent stenosis (within 18 months after primary endarterectomy) were identified for carotid angioplasty and stenting. There were no perioperative strokes or deaths in either group. Duplex ultrasound scan results in the PTA/stenting group revealed no restenosis or stent occlusion with a mean follow-up of 7 months.

Yadav et al<sup>13</sup> reported their experience with angioplasty/ stenting for carotid restenosis and found a 4% perioperative stroke rate and no secondary restenoses at 6-month follow-up. Although these studies have shown good short-term success, long-term follow-up data are still lacking. Furthermore, other studies have not shown such favorable results. Vozzi et al<sup>14</sup> reported a 21% neurological complication rate in 22 patients who underwent carotid angioplasty and stenting, whereas Diethrich et al<sup>15</sup> showed a 10.9% stroke rate in their experience with 110 patients undergoing carotid stenting. Mathur et al<sup>32</sup> also reported a 16% incidence of Palmaz stent collapse by 6 months after surgery. At this stage, the exact role of transcatheter intervention in the management of carotid artery disease remains to be seen.

# Conclusion

Reoperation has higher perioperative stroke and cranial nerve injury rates than primary CEA. However, redo operations are durable and have stroke-free survival rates that are similar to primary CEA. These considerations should be kept in mind when carotid stenting is recommended versus reoperation. We believe that reoperation is still the standard of care for recurrent carotid artery stenosis in most good-risk patients.

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