Reoperation for carotid stenosis is as safe as primary carotid endarterectomy

Bradley B. Hill, MD, Cornelius Olcott IV, MD, Ronald L. Dalman, MD, E. John Harris, Jr, MD, and **Christopher K. Zarins, MD,** *Stanford, Calif*

Purpose: **Patients with recurrent carotid artery stenosis are sometimes referred for carotid angioplasty and stenting because of reports that carotid reoperation has a higher complication rate than primary carotid endarterectomy. The purpose of this study was to determine whether a difference exists between outcomes of primary carotid endarterectomy and reoperative carotid surgery.**

Methods: **Medical records were reviewed for all carotid operations performed from September 1993 through March 1998 by vascular surgery faculty at a single academic center. The results of primary carotid endarterectomy and operation for recurrent carotid stenosis were compared.**

Results: **A total of 390 operations were performed on 352 patients. Indications for primary carotid endarterectomy (n = 350) were asymptomatic high-grade stenosis in 42% of the cases, amaurosis fugax and transient ischemic symptoms in 35%, global symptoms in 14%, and previous stroke in 9%. Indications for reoperative carotid surgery (n = 40) were symptomatic recurrent lesions in 50% of the cases and progressive high-grade asymptomatic stenoses in 50%. The results of primary carotid endarterectomy were no postoperative deaths, an overall stroke rate of 1.1% (three postoperative strokes, one preoperative stroke after angiography), and no permanent cranial nerve deficits. The results of operations for recurrent carotid stenosis were no postoperative deaths, no postoperative strokes, and no permanent cranial nerve deficits. In the primary carotid endarterectomy group, the mean hospital length of stay was 2.6 ± 1.1 days and the mean hospital cost was $9700. In the reoperative group, the mean length of stay was 2.6 ± 1.5 days and the mean cost was $13,700. The higher cost of redo surgery is accounted for by a higher preoperative cerebral angiography rate (90%) in redo cases as compared with primary endarterectomy (40%).**

Conclusion: **In this series of 390 carotid operations, the procedure-related stroke/death rate was 0.8%. There were no differences between the stroke-death rates after primary carotid endarterectomy and operation for recurrent carotid stenosis. Operation for recurrent carotid stenosis is as safe and effective as primary carotid endarterectomy and should continue to be standard treatment. (J Vasc Surg 1999;30:26-35.)**

The emergence of carotid angioplasty and stenting in recent years has called into question the best management of carotid restenosis after carotid endarterectomy.[1] Previous reports have defined the pathophysiology of recurrent stenosis, and it is widely acknowledged that carotid restenosis during the first 2 to 3 years after carotid endarterectomy usually involves the process of myointimal hyperplasia, whereas beyond 3 years, recurrent atherosclerosis is the main contributing factor.[2-4] Common perceptions regarding operations for recurrent carotid stenosis are that the operations are more technically difficult than primary endarterectomy, that they carry a higher risk of nerve injury, and that they are associated with a higher perioperative stroke and mortality rate than primary endarterectomy. These notions have contributed to recent changes in management strategies for carotid restenosis. A number of clinical trials are underway to evaluate the effectiveness and safety of carotid angioplasty and stenting for primary and recurrent carotid artery stenosis.

This report describes the treatment of carotid restenosis in 40 consecutive patients by vascular

From the Division of Vascular Surgery, Stanford University Medical Center.

Presented at the Thirteenth Annual Meeting of the Western Vascular Society, Whistler, British Columbia, Sep 10–13, 1998.

Reprint requests: Christopher K. Zarins, MD, Division of Vascular Surgery, Rm H3642, Stanford University Medical Center, 300 Pasteur Dr, Stanford, CA 94305-5642.

0741-5214/99/$8.00 + 0 **24/6/97878**

Table I. Patient characteristics

	No. of patients (%)
Male	205 (58)
Female	147 (42)
Total	352
Age (years)	72 ± 8 (range, 42 to 93)
Risk factors*	
Hypertension	289 (82)
Significant smoking history	264 (75)
Hyperlipidemia	254 (72)
Coronary artery disease	190 (54)
Diabetes mellitus	109 (31)

*No significant difference between primary and reoperative groups.

Table II. Indications for operations

	No. of patients (%)
Indications for primary carotid endarterectomy:	
Asymptomatic high-grade stenosis	147 (42)
Transient ischemic attacks or amaurosis fugax	122 (35)
Stroke	32 (9)
Global or vertebrobasilar symptoms	49 (14)
Total	350
Operative indications for carotid restenosis:	
Asymptomatic high-grade stenosis	20 (50)
Transient ischemic attacks or amaurosis fugax	15 (38)
Stroke	3 (7)
Global or vertebrobasilar symptoms	2 (5)
Total	40

surgery faculty at a single academic institution. The results are compared with the outcomes of all the patients who underwent primary carotid endarterectomy in the same institution during the same period.

METHODS

The medical records of all patients who underwent carotid operations in a 5-year period by vascular surgery faculty were retrospectively reviewed. Every consecutive carotid operation, as determined by the hospital's quality control oversight committee, was reviewed. No cases were missed or lost. The patient demographic characteristics, risk factors, and details of primary operations were evaluated for all the carotid operations performed.

The assessment of operations for carotid restenosis and outcomes included a review of preoperative duplex scanning and angiographic studies, operative reports, hospital charts, and clinic records. Hospital cost information represented direct and indirect costs of the patient's care, excluding physician fees. Charges billed to patients or third party payers were not included.

Carotid duplex scanning studies were performed with an Acuson (Mountain View, Calif) 5.0 MHz multihertz imaging transducer, a 3.5 MHz Doppler scan frequency, and a consistent 60-degree angle of insonation. A *high-grade stenosis* was defined as a ≥80% reduction in internal carotid artery (ICA) diameter. The corresponding blood flow velocities generally included an ICA peak systolic velocity of 3.3 m/s or higher and an ICA end diastolic velocity of 1.3 m/s or higher. An ICA/common carotid artery peak systolic ratio of 3.8 or higher also corresponded to a ≥80% ICA stenosis. These criteria were verified by means of angiography for accreditation by the Intersocietal Commission for the Accreditation of Vascular Laboratories. The angiographic criteria were outlined in the North American Symptomatic Carotid Endarterectomy Trial.[5]

The *persistence or progression* of a high-grade carotid stenosis was defined as a ≥80% stenosis on two or more consecutive duplex scanning studies performed at least 1 month apart. The operations were performed by five vascular surgeons. The patients who underwent operations for asymptomatic recurrent carotid disease all had a high-grade internal carotid stenosis >80% as determined with color-flow duplex scanning, arteriography, or both.

Intraoperative assessment of carotid arteries after primary endarterectomy and reoperative surgery involved assessment with a Doppler scan probe. If flow signals in the common, internal, or external carotid arteries were qualitatively abnormal or if there were other reasons for concern, carotid angiography was performed.

There was no strict postoperative surveillance protocol. However, the patients were typically seen within 2 weeks from the time of surgery. Surveillance carotid duplex scan studies were performed at 1 month, 3 months, and 6 months after surgery. At the discretion of the attending surgeon, some patients underwent repeat duplex scan studies at 3-month intervals for the first 1 to 2 years after surgery, whereas other patients underwent studies at 6-month intervals after the 6th postoperative month. Most patients had yearly studies after 2 years if no recurrent stenosis was detected. When patients were found to have a recurrent stenosis, more frequent studies were sometimes conducted until reoperative surgery was performed, disease progression was stopped, or regression of the stenosis occurred. Carotid angiography was performed in most cases of early recurrence or when duplex scanning failed to show the full extent of recurrent disease.

Table III. Time from primary carotid endarterectomy to reoperation

	No. of patients (%)
Early recurrent stenosis (<24 months)	17 (42)
Late recurrent stenosis (≥24 months)	23 (58)
Mean time from primary endarterectomy to reoperation (months):	72 ± 64 (range, 5 to 252)

Table IV. Operations performed for recurrent carotid stenosis

	No. of patients (%)
Operation performed:	
Endarterectomy with patch	13 (32)
Endarterectomy with primary closure	2 (5)
Patch angioplasty alone	3 (8)
Interposition graft	20 (50)
External carotid to internal carotid transposition	2 (5)
Use of shunt	
Shunt used	33 (82)
No shunt used	7 (18)

RESULTS

The full-time vascular surgical faculty at Stanford University Medical Center performed 350 primary carotid endarterectomies and 40 operations for carotid restenosis between September 1993 and July 1998. These 390 operations were performed on 352 patients (205 men and 147 women). Ages ranged from 42 to 93 years, with a mean age of 72 years. Of the 40 patients who underwent treatment for recurrent disease, 24 had their primary operations performed elsewhere. The most common associated risk factors in the overall group were hypertension (82%), significant smoking history (75%), hyperlipidemia (72%), coronary artery disease (54%), and diabetes mellitus (31%; Table I).

Primary carotid endarterectomy. The indications for primary carotid endarterectomy and operations for carotid restenosis were similar, as outlined in Table II. Primary carotid endarterectomy was performed for asymptomatic high-grade stenosis (42%), amaurosis fugax and transient ischemic symptoms (35%), global symptoms (14%), and previous stroke (9%).

No procedure-related deaths occurred in the primary endarterectomy group during the same 5-year period. The overall stroke rate for primary carotid endarterectomy was 1.1% (three postoperative strokes, one preoperative stroke after angiography). One patient had a postoperative transient ischemic attack. No patients in this group had permanent cranial nerve deficits. Five patients required return trips to the operating room for evacuation of neck hematomas.

The mean length of stay in the primary carotid endarterectomy group was 2.6 ± 1.1 days (range, 1 to 11 days), and the mean hospital cost was $9700. Forty percent of patients underwent cerebral angiography.

Reoperation for recurrent stenosis. Operative indications for recurrent carotid stenosis included asymptomatic high-grade stenosis (50%), transient ischemic attacks (28%), and amaurosis fugax (10%). Three of the 40 patients for redo operation had a high-grade stenosis associated with pulsatile tinnitus, and three had a history of ipsilateral stroke.

The type of closure used at the first carotid operation was primary closure in 72% of the cases and patch closure in 23% of the cases. Carotid reconstruction with an interposition graft was performed in 5% of the redo cases.

Preoperative imaging for patients with recurrent carotid stenosis (n = 40) included only carotid duplex scanning in 12%, both carotid duplex scanning and angiography in 60%, and only angiography in 28%. On the basis of carotid duplex scan imaging alone, of the patients who underwent operations for recurrent stenosis, 21 (72%) had carotid artery diameter stenoses ≥80% and all patients with stenoses <70% had associated ulcers. The mean ipsilateral carotid artery diameter stenosis as determined by means of angiography was 82% ± 15%. Three patients had high-grade stenoses associated with contralateral occlusions.

The time from primary operation to reoperation for recurrent carotid stenosis ranged from 5 to 252 months, with a mean time interval of 72 months, as indicated in Table III. Late recurrent stenosis (≥2 years) was the most common and occurred in 23 cases (58%), whereas early recurrent stenosis occurred in 17 cases (42%).

The operations performed for carotid restenosis are listed in Table IV. The most common operation was carotid artery reconstruction with an interposition graft in 50% of the patients. A polytetrafluoroethylene (PTFE) graft was used in 12 cases (30%), and a saphenous vein graft was used in eight cases (20%). A saphenous vein, Dacron graft, or PTFE patch was used in combination with carotid endarterectomy in 13 cases (32%). Three patients had patch angioplasty alone. Carotid endarterectomy with primary closure was performed in two

Table V. Location and nature of recurrent stenosis

	No. of patients (%)		
Location of stenosis (n = 40):			
CCA and ICA (± ECA)	18 (45)		
ICA only	16 (40)		
CCA only	5 (12)		
Vein graft stenosis	1 (3)		
Stenosis composition (n = 40):	Myointimal hyperplasia only	Myointimal hyperplasia + athero	Athero only
Restenosis <2 years after CEA (n = 17)	16 (94)	1 (6)	0
Restenosis ≥2 years after CEA (n = 23)	1 (4)	7 (31)	15 (65)

CCA, Common carotid artery; *ICA,* internal carotid artery; *ECA,* external carotid artery; *CEA,* carotid endarterectomy.

instances of late recurrent stenosis. Two patients underwent internal to external carotid artery transposition. Shunts were used in 82% of the cases, according to surgeon preference and the perceived adequacy of cerebral perfusion during clamping.

In the carotid restenosis group at operation, 45% of recurrent disease involved the carotid bifurcation, 40% involved only the ICA, and 12% involved only the common carotid artery. A vein graft stenosis was present in one case (Table V). In the patients who had early recurrent stenosis (<2 years after primary endarterectomy; n = 17), myointimal hyperplasia was found in every case. In one instance of early restenosis, a residual stenosis from the primary endarterectomy and development of myointimal hyperplasia contributed to a 95% ICA restenosis. In the late restenosis group (≥2 years after primary operation; n = 23), 65% of stenoses contained only atheromatous material, 31% contained elements of both atheroma and myointimal hyperplasia, and one consisted only of myointimal hyperplasia.

The operations for recurrent carotid stenosis usually necessitated more operative time to dissect the artery from the surrounding scar tissue while carefully avoiding injury to adjacent structures. Carotid reconstruction with interposition vein grafts necessitated more time than did redo carotid endarterectomy. Overall, the redo operations necessitated less than 1 hour more than the 2 to 3 hours for a typical primary carotid endarterectomy.

Complications that occurred in patients who underwent operations for recurrent carotid stenosis are listed in Table VI. No patient had a stroke or a transient ischemic attack or died. No patient had a permanent cranial nerve deficit. The most common complications were cardiac related. One patient had myocardial infarction associated with tachyarrhythmia and moderate cardiac enzyme elevations but no chest pain, hypotension, or congestive heart failure. Two additional patients had congestive heart failure that prolonged the hospital stay 3 days in one case and 7 days in the other. Transient cranial nerve dysfunction occurred in three cases and included symptoms of hoarseness in two instances, both of which resolved by the 4th postoperative day, and difficulty swallowing in one patient, which resolved by the 2nd postoperative day. One patient had Horner's syndrome, which resolved by the 3rd postoperative month.

Follow-up data were available for 38 of the 40 patients who underwent operations for carotid restenosis. The duration of the follow-up period ranged from 1 to 52 months, with a mean of 14 months. Thirty-four patients (85%) underwent follow-up examination with carotid duplex scanning, four patients (10%) underwent follow-up examination without carotid duplex scanning, and two patients (5%) did not undergo follow-up examination. Of the 34 patients who underwent follow-up duplex scan studies, 82% had widely patent ipsilateral carotid arteries without restenosis. One patient who underwent a redo carotid endarterectomy and Dacron patch angioplasty had an asymptomatic 70% to 79% residual stenosis that was detected on the initial postoperative duplex scan study. Four patients who underwent carotid reconstruction with interposition vein grafts had severe stenoses (90% to 99%) develop between the 1st and 12th postoperative months. These patients all had patent vein grafts without stenosis shown on the first postoperative duplex scan study and stenosis of vein grafts shown on subsequent studies. One preocclusive stenosis was treated with percutaneous transluminal angioplasty without placement of a stent. Initially, the stenosis was reduced to 50% by means of angiographic measurements. Six months later, color-flow duplex scan results revealed recurrence of the stenosis to the 90% to 99% range. Another patient with a severe vein graft restenosis went on have the carotid artery occlude between the 1st and 3rd postopera-

Table VI. Results of primary carotid endarterectomy and reoperative carotid surgery

	Primary carotid endarterectomy (n = 350)	*Reoperative carotid surgery (n = 40)*
Death	0	0
Stroke	4 (1.1%)	0
Transient ischemic attacks	1 (0.3%)	0
Transient cranial nerve dysfunction (<7 days)	—	3 (7.2%)
Myocardial infarction	—	1 (2.5%)
Congestive heart failure	—	2 (5.0%)
Horner's syndrome	—	1 (2.5%)
Reoperation for evacuation of neck hematoma	5 (1.4%)	0
Stroke-death rate	1.1%	0
Permanent cranial nerve deficit	0	0

tive months. The other three severe vein graft stenoses have remained patent at their latest duplex scan evaluations at 12, 19, and 39 months. These patients have undergone treatment with therapeutic warfarin and have not had any strokes or transient ischemic symptoms.

The mean length of stay in the redo group was 2.6 ± 1.5 days (range, 1 to 7 days). The mean hospital cost was $13,700. The higher hospital costs in the redo group were accounted for by the cerebral angiography that was performed in 90% of the redo cases as compared with 40% of the primary endarterectomy cases. The mean hospital cost for cerebral angiography was $3500.

DISCUSSION

The procedure-related stroke-death rate after reoperation for carotid restenosis in this series was 0%. There were no increases in complications, lengths of stay, or surgery-related costs. These results compare favorably with the results of primary carotid endarterectomy, which has been established with prospective randomized trials as the standard of care for patients with severe symptomatic and asymptomatic carotid stenosis.[6]

Previous reports have addressed the pathophysiology and natural history of carotid restenosis.[2-4] Mackey[7] studied the natural history of recurrent carotid stenosis in 688 patients. Five percent of the patients had strokes more than 30 days after carotid endarterectomy. The patients who had strokes within 36 months after primary carotid endarterectomy were less likely to have restenosis than were the patients who had strokes more than 36 months after endarterectomy (51% vs 31%). This finding suggested that early restenosis was associated with a lower risk of stroke than was late restenosis.

A significant finding of the Aymptomatic Carotid Atherosclerosis Study (ACAS) was the incidence of carotid restenosis after carotid endarterectomy for asymptomatic disease.[8] Patients who underwent carotid endarterectomy for a primary carotid stenosis >60% had a 14% cumulative incidence of residual and recurrent stenosis (residual stenosis, 4%; recurrent stenosis, 10%).[9] Strandness[10] found regression of lesions in some patients but a persistent carotid restenosis rate of 21%.

Operative techniques and risk factors that may decrease the likelihood of carotid restensosis have been identified. In the ACAS, patch angioplasty closure and placement of distal tacking sutures were each associated with a decrease in carotid restenosis.[9] Intraoperative duplex scanning may reduce the incidence of residual carotid stenosis but not the incidence of recurrent stenosis.[11] Patient risk factors that may increase the likelihood of carotid restenosis include age of more than 65 years and cigarette smoking.[12]

Consistent with previous reports, 95% of patients in this series who had recurrent stenosis develop within 2 years had lesions that consisted entirely of myointimal hyperplasia.[4] At reoperation, these lesions appeared smooth and pearly white. Either patch angioploasty or carotid reconstruction with an interposition graft is usually appropriate in such cases. Carotid restenosis that arises after 4 years is more likely the result of recurrent atherosclerosis. Patients with these lesions tend to have a higher incidence of embolization related complications—transient ischemic attacks, amaurosis fugax, and stroke. In these cases, redo carotid endarterectomy in conjunction with patch angioplasty is often the procedure of choice. Fig 1 shows a magnetic resonance angiogram of a focal high-grade stenosis at the carotid bifurcation. Recurrent atherosclerosis, frequently seen in late restenosis, may have an ulcerative, irregular pattern (Fig 2).

In 1976, Stoney and String[13] reported that 1.6%

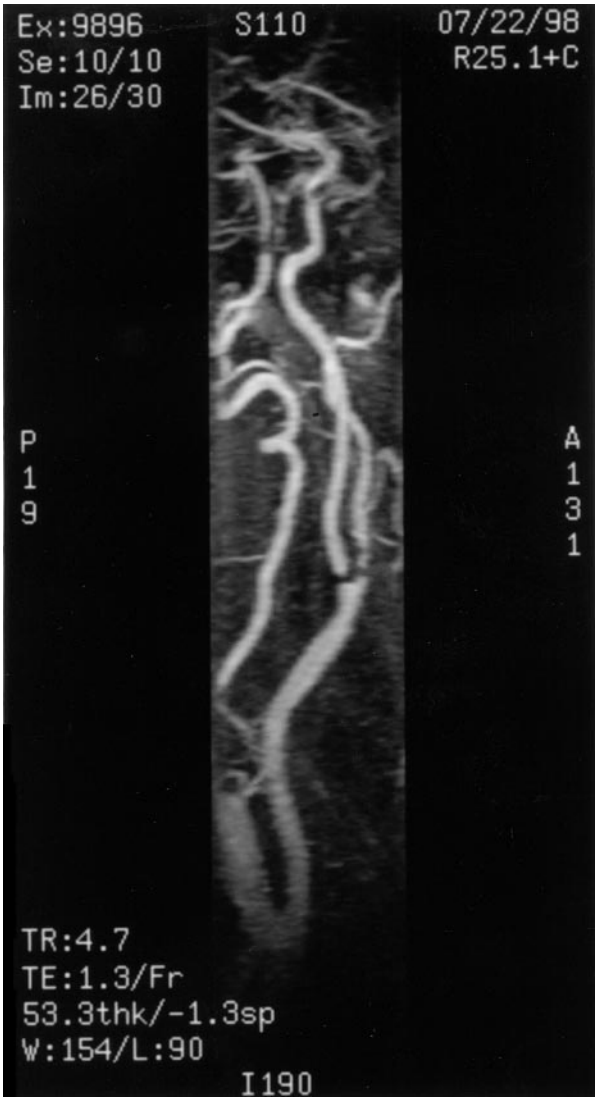

Fig 1. Magnetic resonance angiogram shows focal high-grade stenosis at carotid bifurcation in patient who was asymtomatic 2 years after ipsilateral carotid endarterectomy. Carotid duplex ultrasound scan results revealed frequency criteria consistent with 90% to 99% stenosis of proximal internal carotid artery.

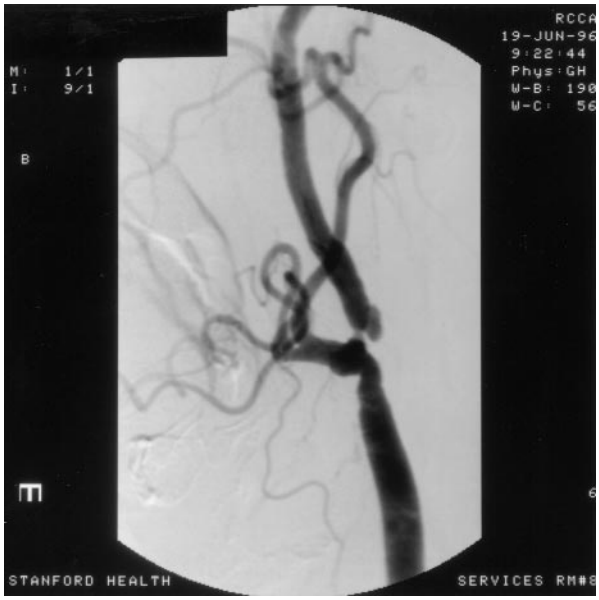

Fig 2. Carotid angiogram reveals ulcerated stenosis involving proximal internal carotid artery in patient with transient ischemic symptoms referable to ipsilateral cerebral hemisphere.

of patients who underwent primary carotid endarterectomy later required reoperation on the same artery. Little controversy exists regarding reoperation for symptomatic carotid restenosis. However, selection criteria have not been firmly established for reoperative carotid surgery in patients who are asymptomatic. Bernstein et al[14] reported the results of 566 consecutive carotid endarterectomies. Follow-up duplex scan examination revealed a >50% restenosis in 10.1% of arteries, including eight carotid occlusions. Interestingly, their results suggested that patients with recurrent carotid stenosis had a better life expectancy and a higher likelihood of remaining stroke free than did those patients who did not have recurrent stenosis after carotid endarterectomy.

An asymptomatic recurrent carotid stenosis >80% presents a management dilemma. Healy et al[15] showed that a stenosis >80% may progress to occlusion of the carotid artery, an event that carries a 25% chance of completed stroke. The present series shows that the risk of reoperative carotid surgery is no higher than the risk of primary carotid endarterectomy. Therefore, reoperative surgery should be considered for the patient who is asymptomatic and who has a high-grade carotid stenosis that is believed to be at risk for occlusion.

The overall stroke rates in this series for primary carotid endarterectomy (1.1%) and recurrent stenosis (0%) were low, and no deaths occurred in either group. The low stroke rates may be related to careful operative technique to avoid embolization and attention to ensure adequate cerebral perfusion. Intraluminal shunts were used in more than 80% of the operations in both groups. Guidelines that define acceptable stroke-death rates for carotid surgery have been suggested. A 1995 American Heart Association consenses statement defined acceptable stroke-death rates for carotid endarterec-

tomy as less than 6% for patients who are symptomatic with stenoses >70% and as less than 3% for patients who are asymptomatic with stenoses >60%. The formation of these standards for primary endarterectomy was made mainly on the basis of results from the North American Symptomatic Carotid Endarterectomy Trial and the ACAS.[5-7] The American Heart Association Stroke Council consensus statement of 1989 set the upper limit of acceptable stroke-death rate for operative treatment of recurrent carotid stenosis at 10%.[16] Little and Meyer[17] reported a stroke-death rate of 8.5% for 113 cases of recurrent carotid stenosis treated surgically at the Mayo Clinic, whereas Mansour et al[18] reported a lower stroke-death rate of 4.8%. Similar to the results in this series, Ballinger et al[19] reported the outcomes of 67 patients who underwent surgical treatment for recurrent carotid stenosis in an 11-year period. The 30-day overall stroke-death rate was 2.8%, which is well within acceptable limits for primary carotid endarterectomy. A metanalysis of all series reporting reoperative carotid surgery is of limited value because study parameters, such as technical aspects of surgery and surgeon experience, cannot be standardized.

The incidence of transient cranial nerve dysfunction lasting less than 1 week was 8% in this series. There were no permanent cranial nerve deficits. Similarly, Mansour et al[18] reported an overall transient or permanent cranial nerve dysfunction of 7%. The incidence of cranial nerve palsies has been reported as high as 20%; however, most have been transient.[6] To minimize the risk of stroke and cranial nerve injury, most authorities emphasize that reoperative carotid surgery should only be performed by surgeons with extensive experience in dealing with carotid restenosis. Careful patient selection and risk assessment are also critical.[6,9,20]

Four of the eight saphenous vein interposition grafts in this series developed severe stenoses between the 1st and 12th postoperative months, and one of these occluded before the 3rd postoperative month. Therefore, the late failure rate for saphenous vein grafts in this series was 50%. Likewise, Rockman et al[21] recently reported the results of 82 carotid reoperations in 74 patients. Three patients had strokes, and carotid arteries reconstructed with interposition vein grafts had a significantly higher rate of late failure (stroke, restenosis, or occlusion) than those that used prosthetic material (20.0% vs 2.3%; $P = .002$). Because the number of vein graft reconstructions in this series was small, we cannot draw firm conclusions regarding the appropriateness of vein grafts for carotid reconstruction. However, we do conclude that carotid reconstructions with PTFE interposition grafts have a favorable outcome in our experience.

The safety and benefit of new catheter-based therapies for treatment of carotid stenosis should be evaluated and judged against standard reoperative therapy. CREST, the Carotid Revascularization: Endarterectomy versus Stent Trial, is a prospective multi-center clinical study currently underway to compare the results of operative and endovascular management of carotid stenosis.[22,23] During the period from 1989 through 1997, recurrent carotid stenosis was managed with reoperation in 16 cases and with carotid angioplasty and stenting in 15 cases. Patients who had recurrent stenosis within 18 months after primary carotid endarterectomy were identified for carotid angioplasty and stenting. In both the reoperative and angioplasty-stent groups, no strokes or postprocedure deaths occurred. The reoperative group had no reported complications. Duplex ultrasound scan results in the angioplasty-stent group revealed no restenosis or stent occlusions with a mean follow-up period of 7 months.[24]

A larger series reported by Robbin et al[25] involved duplex ultrasound scan studies on 87 carotid arteries immediately after carotid angioplasty and stenting and on 83 carotid arteries at various time intervals, with a mean interval of 7 months postprocedure. One stent occlusion and one stent collapse were detected, and a 63% recurrent stenosis was detected in one patient. Despite good short-term success, the authors were unable to present convincing long-term data that proved efficacy and safety compared with operative management.

Serious complications that have resulted from carotid angioplasty and stenting for primary carotid artery stenosis and restensosis include carotid dissection and acute occlusion,[26] stent deformation,[27] stroke caused by air embolism,[28] transient ischemic attack,[29] and progressive stenosis that necessitated operation.[30,31] Bergeron et al[26] reported a 33% neurologic complication rate in 17 patients who underwent carotid angioplasty without stent placement for treatment of carotid restenosis. A 21% neurologic complication rate was reported by Vozzi et al,[32] who described 24 carotid angioplasty and stenting procedures in 22 patients, 12 of whom were asymptomatic. Three patients had seizures during the procedure, and two patients had strokes, one of whom died as a result. The durability of carotid angioplasty and stenting in cases of "technical success" is also questionable. Mathur et al[28] reported a 16% inci-

dence of Palmaz stent collapse in cervical carotid arteries by 6 months postprocedure.

Early carotid restenosis is associated with myointimal hyperplasia at the endarterectomy site, and late recurrent stenosis is related more to the development or progression of new atheromatous plaque. We agree with previous authors who have recommended observation of asymptomatic recurrent carotid stenoses that are not high grade (<80% artery diameter reduction) and reoperation for symptomatic or high-grade lesions that are believed to be at risk for carotid occlusion. Surgical management of recurrent carotid stenosis can be as safe as primary carotid endarterectomy with sound clinical decision making, strategic preoperative planning, and careful operative technique. Vein interposition grafts may be prone to a higher rate of failure than PTFE grafts when used for carotid reconstruction.

The standard of care for the patient with recurrent cartotid stenosis, who is deemed at risk for stroke, should be evaluation and treatment by a vascular surgeon experienced in all aspects of carotid surgery. Carotid angioplasty and stenting should be reserved for patients enrolled in controlled clinical trials to minimize patient risk and to help define its role in treating carotid restenosis. Operation for recurrent carotid stenosis should serve as the standard of treatment. Angioplasty and stenting for recurrent carotid stenosis should be compared with this standard.

REFERENCES

1. Beebe HG, Kritpracha B. Carotid stenting versus carotid endarterectomy: update on the controversy. Semin Vasc Surg 1998;11:46-51.
2. Toursarkissian B, Rubin BG, Sicard GA. Recurrent carotid artery stenosis. J Am Coll Surg 1997;184:93-8.
3. Mansour MA. Recurrent carotid stenosis: prevention, surveillance, and management. Semin Vasc Surg 1998;11:30-5.
4. Hunter GC. Edgar J. Poth Memorial/W.L. Gore and Associates, Inc. Lectureship. The clinical and pathological spectrum of recurrent carotid stenosis. Am J Surg 1997;174: 583-8.
5. North American Symptomatic Carotid Endarterectomy Trial Collaborators. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. N Engl J Med 1991;325:445-53.
6. Zarins CK. Carotid endarterectomy: the gold standard. J Endovasc Surg 1996;3:10-5.
7. Mackey WC. Surgical management of recurrent carotid artery stenosis. In: Ernst C, Stanley JC, editors. Current therapy in vascular surgery, 3rd ed. St Louis: Mosby; 1995. p. 78-80.
8. Asymptomatic Carotid Atherosclerosis Study. Clinical advisory: carotid endarterectomy for patients with asymptomatic internal carotid artery stenosis. Stroke 1994;25:2523-4.
9. Moore WS, Kempczinski RF, Nelson JJ, Toole JF. Recurrent carotid stenosis: results of the asymptomatic carotid atherosclerosis study. Stroke 1998;29:2018-25.
10. Strandness E. Recurrent carotid artery stenosis following endarterectomy. In: Ernst C, Stanley JC, editors. Current therapy in vascular surgery, 3rd ed. St Louis: Mosby; 1995.
11. Lipski DA, Bergamini TM, Garrison RN, Fulton RL. Intraoperative duplex scanning reduces the incidence of residual stenosis after carotid endarterectomy. J Surg Res 1996;60:317-20.
12. Ladowski JS, Shinabery LM, Peterson D, Peterson AC, Deschner WP. Factors contributing to recurrent carotid disease following carotid endarterectomy. Am J Surg 1997;174:l18-20.
13. Stoney RJ, String ST. Recurrent carotid stenosis. Surgery 1977;8:597-605.
14. Bernstein EF, Torem S, Dilley RB. Does carotid restenosis predict an increased risk of late symptoms, stroke or death? Ann Surg 1990;212:629-36.
15. Healy DA, Zierler RE, Nicholls SC, Clowes AW, Primozich JF, Bergelin RO, et al. Long-term follow-up and clinical outcome of carotid restenosis. J Vasc Surg 1989;10:662-9.
16. Beebe HG, Clagett GP, DeWeese JA, et al. Assessing risk associated with carotid endarterectomy: a statement for health professionals by an Ad Hoc Committee on Carotid Surgery Standards of the Stroke Council, American Heart Association. Circulation 1989;79:472-3.
17. Little NS, Meyer FB. Carotid endarterectomy—indications, techniques, and Mayo Clinic experience. Neurol Med Chir (Tokyo) 1997;37:277-35.
18. Mansour MA, Kang SS, Baker WH, Watson WC, Littooy FN, Labropoulos N, Greisler HP. Carotid endarterectomy for recurrent stenosis. J Vasc Surg 1997;25:877-83.
19. Ballinger BA, Money SR, Chatman DM, Bowen JC, Ochsner JL. Sites of recurrence and long-term results of redo surgery. Ann Surg 1997;225:512-7.
20. Ricotta JJ, O'Brien-Irr MS. Conservative management of residual and recurrent lesions after carotid endarterectomy: long-term results. J Vasc Surg 1997;26:963-72.
21. Rockman CB, Riles TS, Lamparello PJ, Giangola G, Adelman MA, Jacobowitz GR, Landis R, Imparato AM. Anesthetic methods in reoperative carotid surgery. Ann Vasc Surg 1998;12:163-7.
22. Hobson RW, Brott T, Ferguson R, et al. CREST: carotid revascularization endarterectomy versus stent trial [editorial]. Cardiovasc Surg 1997;5:457-8.
23. Baker W. CREST: a moral and ethical conundrum [editorial]. Cardiovasc Surg 1997;5:461-2.
24. Hobson RW II, Goldstein JE, Jamil Z, Lee BC, Padberg FT Jr, Hanna AK, et al. Carotid restenosis: operative and endovascular management. J Vasc Surg 1999;29:228-35.
25. Robbin ML, Lockhart ME, Weber TM, Vitek JJ, Smith JK, Yadav J, et al. Carotid artery stents: early and intermediate follow-up with Doppler US. Radiology 1997;205:649-50.
26. Bergeron P, Chambran P, Benichou H, Alessandri C. Recurrent carotid disease: will stents be an alternative to surgery? J Endovasc Surg 1996;3:76-9.
27. Calvey TAJ, Gough MJ. A late complication of internal carotid artery stenting. J Vasc Surg 1998;27:753-5.
28. Mathur A, Roubin GS, Gomez CR, Iyer SS, Wong PM, Piamsomboon C, et al. Elective carotid artery stenting in the presence of contralateral occlusion. Am J Cardiol 1998;81: 1315-7.
29. Atar E, Garnick A, Rabi I, Morag B, Rubinstein Z. Angioplasty and stenting of the carotid artery [Hebrew]. Harefuah 1997;132:388-91.
30. Vale FL, Fisher WS III, Jordan WD Jr, Palmer CA, Vitek J. Carotid endarterectomy performed after progressive carotid

stenosis following angioplasty and stent placement [case report]. J Neurosurg 1997;87:940-3.
31. Johnson SP, Fujitani RM, Leyendecker JR, Joseph FB. Stent deformation and intimal hyperplasia complicating treatment of a post-carotid endarterectomy intimal flap with a Palmaz stent. J Vasc Surg 1997;25:764-8.
32. Vozzi CR, Rodriguez AO, Paolantonio D, Smith JA, Wholey MH. Extracranial carotid angioplasty and stenting. Initial results and short-term follow-up. Tex Heart Inst J 1997;24:167-72.
33. Estes JM, Donaldson MC, Whittemore AD. Stenting for carotid stenosis? N Engl J Med 1997;337:427-8.

Submitted Sep 15, 1998; accepted Jan 19, 1999.

DISCUSSION

Dr Ralph B. Dilley. This was an excellent presentation by Dr Hill and his colleagues and supports the work of others in showing that reoperation for recurrent carotid stenosis is safe and durable. In 40 patients undergoing reoperation for recurrent stenosis, there were no deaths, strokes, transient neurologic events, or permanent cranial nerve deficits. Three patients had mild cranial nerve dysfunction, and one patient had a postoperative Horner's syndrome. These results are exemplary and mirror the equally good results achieved in a group of patients undergoing primary carotid endarterectomy.

I have three questions for the authors:

First, several studies suggest that patients with early recurrence (that is, those with myointimal hyperplasia) are less prone to develop symptoms than are those with late recurrence, where the pathology is generally caused by recurrent atherosclerosis. In addition, other studies have demonstrated occasional regression of these early lesions. Therefore, in the 17 patients submitted for operation because of an early recurrence, how many were symptomatic? What was the average time in this group from primary carotid endarterectomy to reoperation? What is your overall incidence of significant early recurrent stenosis (that is >50%), and have you documented any regression of these lesions?

Second, when do you perform the first postoperative duplex scan evaluation? Is it possible that some of the early recurrences, in fact, could be residual disease? Do you use intraoperative assessment to ensure a perfect result? Although many surgeons do not do intraoperative assessment, we continue to believe it is necessary and continue to use intraoperative angiography because in our hands this is the study that can be done most quickly.

Third, how do you decide whether to replace the artery with a vein or prosthetic graft as opposed to performing repeat endarterectomy with patch or patch angioplasty alone? In our more recent experience, we have tended to replace the segment with recurrent disease with a vein interposition graft. We generally use a thigh saphenous vein, which closely matches the size of the proximal and distal carotid artery, and have not been impressed with recurrent stenosis in this group. I was somewhat surprised that four of your vein interposition grafts have shown recurrent disease. Where are the recurrences, at the anastomosis or in the body of the graft? And are you able to characterize the nature of the obstruction?

Finally, a word about carotid stenting. We would certainly agree that there is a major effort by cardiologists to recommend stents for carotid obstructive disease, particularly recurrent carotid artery stenosis. I may be naive, but it seems to me that if a patient develops recurrent carotid stenosis in response to an operative procedure and his vessels are prone to this response, they would equally respond with further obstruction after placement of a stent, unless a patch or interposition graft is placed. Secondly, although it is difficult to be certain of the exact number of neurologic complications associated with stent placement at the carotid bifurcation, my best guess is that they occur at a rate of 7% to 8%, and this is based on reviewing a number of papers where stents have been placed. Now, not all of these neurologic complications are serious, but in my view a small stroke or a transient stroke is a significant event, and I certainly would not want one myself. Although several large scale studies that propose to compare stents with carotid endarterectomy are under consideration, none yet have been funded, and I believe there are many ethical considerations to consider before wholeheartedly supporting such studies. It is important that we as surgeons continually track our own results and publish the excellent results of reoperative carotid surgery, such as we have heard today.

Thank you for allowing me to discuss this paper.

Dr Bradley B. Hill. Dr Dilley, thank you for raising these important questions. Of the 17 patients who had early recurrent stenosis, only three patients (18%) were symptomatic. The remaining 14 patients (82%) had >80% stenoses, most of which were progressive or high grade, and there were concerns that these arteries might have gone on to occlude without surgery. As you mentioned, a significant percentage of early recurrent stenoses, perhaps up to 30%, will undergo some degree of regression. Consistent with this, we have documented regression of early recurrent lesions in some instances. In general, we recommend serial duplex scanning studies for recurrent stenoses that are not high grade (<80%).

In this series, the mean time from primary carotid

endarterectomy to reoperation in patients with early recurrent stenosis was 12 months (range, 5 to 21 months). Of the 390 carotid operations performed, 40 (10%) were redo procedures, and 22 of these patients had their primary endarterectomies at another facility. Overall, only a fraction (<5%) of redo operations were performed in patients whose primary carotid endarterectomies were included in the 350 primary operations in the series. In my estimation, the incidence of early recurrent stenosis after primary endarterectomy was consistent with previously published reports, approximately 20% or so, and most of these restenoses were asymptomatic, not high grade, and did not necessitate reoperation.

In answer to your second question about postoperative duplex scan evaluation, we routinely perform the initial postoperative study within 4 to 6 weeks from the time of surgery. Only one patient for redo surgery had a residual stenosis detected at the initial postoperative duplex scan study, and this was a 60% asymptomatic stenosis in the distal internal carotid artery. We routinely use a handheld pencil Doppler scan intraoperatively to assure patency of the artery, and we believe that this is adequate unless we hear abnormal flow signals or have other reasons to suspect a problem. We have occasionally used duplex ultrasound scanning to evaluate the artery through the open incision, and we have also performed carotid arteriography on rare occasions.

Our decision to replace a diseased carotid artery with an interposition graft as opposed to performing a redo carotid endarterectomy or patch angioplasty alone is made on the basis of a number of considerations. If the artery is diffusely thickened without an endarterectomy plane or if significant periarterial scar tissue is present, replacement with an interposition graft may be easier and may lessen the chances of cranial nerve injury. If the recurrent stenosis is late, the best option may be redo endarterectomy and patch angioplasty. Intraoperative decision making is important in these cases, and the best option may depend on what is found at the time of surgery.

Of the 40 redo operations performed in this series, eight involved carotid reconstructions with interposition vein grafts. Four of the vein grafts developed recurrent stenoses >90%, all of which were near or at the distal anastamosis. One of these four late failures went on to occlude without an associated stroke or other neurologic event. Because the number of vein interposition grafts in this series was small, we cannot make any definitive comments regarding their use for carotid reconstruction other than to say that our results with them have not been good. Interestingly, 12 patients in this series underwent carotid reconstruction with interposition PTFE grafts, and none of these reconstructions occluded or developed a recurrent stenosis. Therefore, in our experience, PTFE has been a good interposition graft for carotid reconstruction and we usually prefer it over saphenous vein in these cases.