Surgical treatment of recurrent carotid artery stenosis

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Postendarterectomy recurrent carotid artery stenosis has been increasingly recognized, due in part to longer population survival and follow-up review with noninvasive testing, particularly duplex scanning. Consequently, surgery for recurrent stenosis has also become more frequent. From a technical perspective, this surgery is far more challenging than the initial endarterectomy because of the scarring that may develop both outside and inside the vessel lumen and the friable nature of a recurrent atherosclerotic plaque. In some situations, repeat endarterectomy cannot be performed, and the involved vessel must be excised with placement of an interposition graft.

The problem of recurrent carotid artery stenosis brings to the forefront the controversy regarding primary versus secondary closure of an endarterectomy with a patch graft. One of the compelling arguments favoring a saphenous vein or fabric patch closure of the arteriotomy is that it increases the durability of the endarterectomy and retards recurrent stenosis. There is little doubt that many experienced surgeons obtain excellent results with a primary closure. However, the incidence of postoperative occlusion has been reported as 2% to 6% for patients in whom the arteriotomy was closed primarily compared to 0.4% for those with a vein patch graft. Furthermore, the occurrence of repeat stenosis following a primary closure has been shown to range from 5.9% to 36% (mean 10.7%) over a 2- to 10-year follow-up period. In contrast, in a group of patients treated with a vein patch graft, serial digital subtraction angiograms demonstrated a 1% symptomatic recurrence rate at the 2-year follow-up examination. Hertz and colleagues reported their experience in 896 carotid endarterectomies with 3-year follow-up results. A recurrent stenosis greater than 70% was found in 2.1% of patients in whom a vein patch was used versus 6.9% of patients in whom the arteriotomy was closed primarily.

This report examines the etiology, indications, and techniques for surgical repair of a recurrent carotid artery stenosis. In addition to evaluating different meth-
odds of surgical reconstruction, we analyze the outcome after primary versus patch graft closure during the original endarterectomy.

Clinical Material and Methods

Patient Population

From January, 1972, through December, 1992, 82 patients underwent repeat surgery by surgeons from the Mayo Clinic cerebrovascular neurosurgery services for treatment of recurrent carotid artery stenosis in 92 vessels. During this time, 3111 carotid endarterectomies were performed for primary atherosclerosis. Accordingly, operations for recurrent disease comprised approximately 3% of our operations for occlusive carotid artery disease. For the purposes of this analysis, each operation on a vessel is considered as a separate case. Fifty-seven cases have been discussed in a prior communication and this review constitutes a reanalysis of those as well as a report of 35 additional cases.

In 55 cases the initial surgery was performed at our institution; 37 cases were operated on elsewhere. Forty-five of the cases had a primary arterial closure and 47 had been repaired with a patch graft (44 with saphenous vein grafts and three with Dacron patches). Thirty-five cases of recurrent stenosis occurred in females and 57 in males.

The indications for surgery were as follows: 47 operations were performed for symptoms of transient ischemic attacks (TIA's), many of which were crescendo TIA's; six after a recent cerebral infarction with or without superimposed TIA's; 15 for amaurosis fugax; five for a progressing ischemia; two for acute occlusion following angiography; eight for generalized cerebral ischemia; and two for pseudoaneurysms. Seven asymptomatic patients underwent surgery because of a changing bruit or a progressive stenosis documented by oculoplethysmography or ultrasound study. On angiography, these patients had high-grade complex appearing plaque. Ten patients had occlusion of the contralateral carotid artery.

Operative Technique

All except two patients were monitored by means of intraoperative xenon cerebral blood flow measurements and continuous electroencephalographic (EEG) recording; the two exceptions were emergency cases, which were operated on without monitoring. Significant EEG attenuation associated with severe cerebral blood flow reductions occurred in 28 (30%) of 92 cases and required placement of a shunt. In the rare case in which there were severe EEG changes and an interposition graft was required, placement of a shunt was technically more difficult. In those cases, the patient’s systolic blood pressure was raised to between 160 and 180 mm Hg to increase collateral blood flow and allow completion of the repair without placement of a shunt through the vein graft. No complications were attributable to the use of a shunt in any of the cases.

Sixty-three vessels were reconstructed with a repeat endarterectomy followed by a saphenous vein patch graft in 55, a fabric patch graft in seven, and a primary closure in one. In seven patients with myointimal hyperplasia, the artery lumen was enlarged by use of an onlay patch graft without a direct endarterectomy (vein angioplasty). In 22 patients, it was necessary to resect the diseased artery and perform a reconstruction; of these, 16 underwent an interposition saphenous vein graft, four had an interposition Dacron or bovine graft, one had a combination of saphenous vein and Gore-Tex graft, and one had a direct resection and reanastomosis without an interposition graft.

The initial approach for these operations was via exposure of the carotid artery and its branches typical of a standard carotid endarterectomy. At the beginning of the exposure, it is best to identify the common carotid artery (CCA) proximal to the previous dissection at which the omohyoid and sternocleidomastoid muscles form a V. Typically, there is less scarring underneath the omohyoid muscle, which allows easier identification and control of the CCA with a vascular loop. In this way, if there is premature entry into the carotid artery, hemostasis can be achieved quickly by temporarily occluding the CCA. Because of the dense scar tissue that may be present around the carotid bifurcation and its branches, planes of dissection are often difficult to delineate from the surrounding tissue. Therefore, it is usually advisable to identify the distal internal and external carotid artery after isolating the CCA before attacking the region of the carotid bifurcation and previous endarterectomy. Once distal and proximal vessel control has been achieved, the carotid bifurcation is dissected along its lateral aspect just medial to the internal jugular vein. The surgeon must be wary of the hypoglossal nerve, which is often adherent to the distal carotid bifurcation, and must also avoid dissecting under the carotid bifurcation so as not to injure the trunk and branches of the vagus nerve, particularly the superior laryngeal nerve.

After completion of the dissection, 5000 U of heparin is administered and the CCA is occluded with a soft-shoed Fogarty clamp, followed by occlusion of the external and internal carotid arteries with vascular loops or temporary vascular clips. In most situations, the site of the prior arteriotomy suture can be identified, and the incision is made into the CCA along this line and extended distally with Pott's scissors above the point of the previous closure. The surgeon is then able to inspect the interior of the CCA, the bifurcation, and the internal carotid artery (ICA) to determine whether a standard endarterectomy can be achieved.

If there is simple recurrent atherosclerosis, a clean repeat endarterectomy can often be performed. However, sometimes this recurrent atherosclerosis is associated with dense scarring, making a standard endarterectomy impossible because of the lack of a cleavage plane. In cases of myointimal hyperplasia, there is diffuse thickening of the intima and media without recurrent atherosclerosis, and a good cleavage plane is usually impossible to achieve. In this circumstance, enlargement of the artery lumen is achieved by perform-
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When a long arteriotomy and repair with an onlay patch graft.

Rarely in primary surgery or reoperation for carotid occlusive disease is elongation of the ICA sufficient that it can be mobilized to facilitate a direct excision and primary anastomosis of the ICA to the CCA. In this direct anastomosis, the back walls of the ICA and CCA are anastomosed with interrupted 6–0 Prolene sutures. The anterior side of the arteriotomy is then repaired with a saphenous vein patch graft. In this direct reconstruction, the external carotid artery is doubly ligated, and the anastomosis between the ICA and CCA is performed just below the level of the bifurcation where normal arterial wall is present.

When an interposition graft must be performed, a saphenous vein can often be harvested from the leg and dilated to a sufficient size to serve as an interposition graft (Fig. 1 upper). Alternatively, a fabric graft can be used if no vein is available. The graft is anastomosed end to end from the CCA to the ICA excluding the external carotid and superior thyroid arteries (Fig. 1 lower), usually suturing the distal anastomosis first. There are three general types of anastomoses, as illustrated in Fig. 2, which can be used for both the proximal and distal anastomoses. The primary determinant of the type of anastomosis is the relative diameters of vessels. For example, when there is a significant difference between diameters, anastomosis of the back wall followed by a roof patch graft can achieve a smoother taper between a large CCA and a small ICA.

Pathological Examination

There were five general causes for recurrent carotid artery stenosis. The most frequent was recurrent atherosclerosis, which occurred in 43 cases. In the majority of these patients, the lumen of the ICA at the bifurcation was filled with a soft substance consisting of caseous material from the plaque itself and often associated with thrombus. In general, the recurrent atherosclerosis was similar in appearance to a primary stenosis, although it was frequently more friable. In most cases with recurrent atherosclerosis, the recurrent plaque was in the bed of the previous endarterectomy site.

The second most frequent cause of recurrent carotid artery stenosis was myointimal hyperplasia, occurring in 20 cases. This is an incompletely understood phe-
Complications of carotid endarterectomy for recurrent carotid artery stenosis in 92 procedures

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nomenon, but appears to result in a fibrous hypertrophic "scar" throughout the endarterectomy site. Due to this thickening, a definitive plane of cleavage between the myointimal hyperplasia and underlying vessel wall is not present.

Organized thrombus without a significant underlying component of atherosclerosis was found in 20 cases. In two of these, the thrombus appeared to have originated from an aneurysmal outpouching in the posterior wall of the vessel and in another two from an aneurysmal dilatation at the distal end of the previous saphenous vein patch graft. A small amount of myointimal hyperplasia was associated in two cases. In three vessels, the underlying intima appeared to be relatively normal, and there was no obvious cause for the intraluminal thrombus. In one of these patients, a clotting disorder was identified.

Recurrent stenosis from scarring along the proximal end of the original arteriotomy site occurred in seven cases. This scarring is distinct from myointimal hyperplasia and usually occurs in the CCA at the proximal end of the prior arteriopathy at the transition point between the endarterectomized segment and the thickened proximal atherosclerosis. This repeat stenosis was associated with a dense cicatrix in all cases. Finally, two patients in this series underwent surgery for a pseudoaneurysm, one from a saphenous vein patch graft and one from a Dacron patch graft.

Results

Neurological Complications

As listed in Table 1, there were five cases of major neurological complications in the perioperative period, all of which occurred in patients who were symptomatic preoperatively; three of these were intraoperative embolizations and one was a postoperative thromboembolic event. There was also one ischemic stroke complicating a vein patch rupture following endarterectomy and vein patch repair for recurrent symptomatic atherosclerosis. In the three cases of intraoperative embolization, the event occurred during the initial exposure of the carotid artery, as evidenced by changes in the intraoperative EEG recording during the exposure and prior to the temporary carotid artery clamping. The primary underlying pathology in these three cases was recurrent atherosclerosis of a caseous nature associated with intraluminal soft thrombus. In two cases (opposite sides in the same patient), intracranial embolization occurred immediately following the endarterectomy. In both vessels, the underlying pathology was primarily soft thrombus in the lumen of the vessel without recurrent atherosclerosis. The indications for surgery on each occasion in this patient were continued TIA's while the patient was receiving anticoagulation medication. The deficits largely cleared after the first operation but remained severe after the second. Angiograms performed immediately after each event confirmed intraluminal thrombus in both cases, which subsequently resolved on follow-up angiograms. It is suspected that this patient had an altered coagulation state, perhaps a heparin-induced coagulopathy, which accounted for thromboembolic events after each surgery.

There were four perioperative deaths, due to cerebral hemorrhage in two patients and myocardial infarction in two. Therefore, the combined rates of major morbidity and mortality were 10.8%. Three other patients had transient perioperative neurological complications that resolved prior to discharge from the hospital. There was no association between occurrence of complications and type of surgical procedure (Figs. 3 and 4). All but one of the major neurological complications occurred in preoperatively symptomatic patients who had intraluminal thrombus confirmed at surgery. There were no complications in the patients with myointimal hyperplasia.

Incidence of Recurrent Stenosis

Of the 55 cases with initial surgery at our institution, 13 underwent a primary arterial closure and 42 a repair with a patch graft. During the time of the study, 426 carotid endarterectomies were performed using a primary closure and 2685 using a patch graft closure. Accordingly, the incidence of recurrent carotid stenosis was 3.1% in those patients who had a primary closure and 1.6% in those in whom a patch graft was used. The denominator of primary versus secondary closures is unknown in those patients who had their initial surgery elsewhere. Of the 45 primary closure cases, 40% suffered repeat stenosis within 2 years compared to 17% in the 47 cases with a patch graft.

Discussion

Operative Complications

One of the most impressive statistics in this study is the major complication rate of approximately 10%. Compared to our overall experience with patients undergoing primary carotid endarterectomy for atherosclerotic stenosis, this is a five- to sixfold increase in overall risk. There are several possible explanations for this observation. First, the dense scar tissue surrounding the artery makes the initial dissection more difficult. In patients with recurrent atherosclerosis, the lesion is caseous, associated with intraluminal thrombus, and more friable than the typical primary atherosclerotic plaque. Therefore, the risk of embolization

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Fig. 3. Upper Left: Angiogram in a patient who presented with a left hemispheric transient ischemic attack due to a recurrent carotid artery stenosis. The initial surgery had been performed 10 years earlier with a saphenous vein patch graft closure. Upper Right: Angiogram demonstrating recurrent atherosclerosis, which was densely adherent to the intima. A repeat endarterectomy could not be achieved; accordingly, an interposition saphenous vein jump graft was performed. Lower: Intraoperative photograph showing the interposition saphenous vein graft. The saphenous vein-common carotid artery anastomosis used is illustrated in Fig. 2C.

prior to the endarterectomy is higher in this situation. It is difficult to dissect the artery without excessive manipulation of the vasculature, which predisposes to dislodging intraluminal thrombus. Second, it is our impression that soft thrombus within the lumen of the vessel associated with the recurrent stenosis was far more common than that observed in patients with a primary stenosis. Third, it is probable that in some patients, the recurrent stenosis was associated with increased thrombogenicity in the segment of the vessel involved with the recurrence or with a systemic hypercoagulable state. This is supported by the observation that postoperative thromboembolic complications or occlusions were higher in this group of patients with recurrent stenosis than in those with primary atherosclerosis. It is noteworthy that no patient with myointimal hyperplasia had thromboembolic complications.

Fig. 4. Left: Angiogram in a patient who presented with right hemispheric transient ischemic attacks due to a recurrent carotid stenosis. Nine months earlier, she had undergone a carotid endarterectomy with a primary closure. Right: Angiogram in the same patient after anastomosis. It was not technically feasible to remove the recurrent atherosclerosis. The recurrent stenosis was fibrotic and densely adherent to the intima, so an interposition graft was used. Because this patient had previously undergone cardiac surgery with harvesting of the saphenous veins, it was necessary to use an interposition fabric graft.

Surgery for recurrent symptomatic atherosclerotic disease should be considered and performed with caution. During the exposure, the surgeon must avoid excessive manipulation because the risk of dislodging intraluminal thrombus or friable recurrent atherosclerosis is greater than for primary carotid disease. Accordingly, we would advocate surgery only in those patients in whom the recurrent stenosis is symptomatic or in highly selected patients with advanced, progressive stenosis who had been symptomatic prior to the original carotid endarterectomy. In the latter situation, it would be reasonable to postulate that the risk of future cerebral ischemic events would be high as the recurrent stenosis progressed.

Stenosis and Method of Closure

Although many surgeons use primary closure for carotid arteriotomy, we prefer to use a saphenous or fabric patch graft in the majority of closures, reserving primary closure for those patients with a short plaque and a large ICA. In our accumulated cases, the incidence of recurrent symptomatic carotid artery stenosis is 3.1% in those patients who have had a primary closure versus 1.6% in those in whom a patch graft was used. This would suggest that the risk of a recurrent carotid stenosis with a primary closure is twice that for a patch graft repair. Upon reviewing the published surgical series, the incidence of recurrent symptomatic carotid artery stenosis ranges from 5.9% to 36% (mean 10.7%) for patients in whom a primary closure has been performed.5,8,14,16,20,22,26,29,40 Alternatively, we have observed
that the risk of a symptomatic recurrent stenosis, as identified by clinical criteria and digital subtraction angiography, is approximately 1% in the first 2 years following closure with a saphenous vein patch graft.36,38 Although our data indicate that recurrent stenosis increases to 1.6% over a longer follow-up period, this is significantly less than that reported for primary closure.36,38,39,40 Furthermore, the risk of postoperative occlusion with a primary closure has been reported to be 2% to 6%,36,37,38,39,40 whereas it is 0.4% in patients with a saphenous vein patch graft. Therefore, it is our opinion that the immediate and long-term results of carotid endarterectomy with patch grafting are superior to those with primary closure. However, we are in the minority and only a few centers prefer this method of closure.36,37,38,39,40 Excellent results with primary closure are reported by many experienced surgeons, and nationwide this is probably the more common type of repair.22,32,33,34,35 The advocacy of a saphenous vein patch graft must be tempered with the fact that there is occasionally failure of the patch graft causing rupture and devastating hemorrhage.36,37,38,39,40 We have found that reinforcing the saphenous vein patch graft with a Teflon wrap and utilizing only a “stout” vein segment have largely eliminated this complication. In addition, we now frequently close the arteriotomy with a fabric patch graft to avoid any risk of saphenous vein patch graft rupture.

Causes for Repeat Stenosis

The causes for recurrent atherosclerosis and myointimal hyperplasia have not yet been clearly identified.41,42,43 It is our impression that repeat atherosclerosis occurs more often in patients who continue to use tobacco after the initial carotid endarterectomy. We now routinely place patients on antiplatelet therapy following the carotid endarterectomy with the goal of preventing a recurrent atherosclerotic plaque. It has been suggested that myointimal hyperplasia may be related to technical aspects of the first surgical repair.41,42,43 The presence of a soft thrombus superimposed on relatively normal-appearing underlying endothelium occurred in 20 patients, suggesting that a hypercoagulability state may have been a predisposing factor in some of our cases.

Conclusions

Surgery for recurrent carotid artery stenosis is a significantly more difficult procedure and is associated with a significantly higher risk than surgery for primary atherosclerosis. This high risk is multifactorial and includes the nature of the recurrent plaque, which is friable and associated with intraluminal thrombus, increasing the risk of embolization during the initial carotid exposure. In this series, the incidence of recurrent stenosis was 3.1% in patients who had a primary closure compared to 1.6% in those with a patch graft repair at the initial surgery. In patients with recurrent atherosclerosis, there is often a plane of cleavage and a repeat endarterectomy can be achieved; however, in patients with intraluminal scarring or in those without a defined plane of cleavage between the recurrent stenosis and underlying media, an interposition graft may be the best method of repair.

Acknowledgment

The authors are indebted to Ms. Mary Soper for preparation of this manuscript.

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Manuscript received June 29, 1993. Accepted in final form September 14, 1993.

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