Saphenous vein patch grafts in carotid endarterectomy

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The clinical data and findings on the early postoperative intravenous digital subtraction angiograms (IVDSA's) were studied in 61 patients undergoing 70 consecutive conventional carotid endarterectomies and in 46 patients undergoing 50 consecutive carotid endarterectomies with a saphenous vein patch graft (SVPG). The IVDSA's were considered normal in 50 of 70 conventional carotid endarterectomies and in 46 of 50 carotid endarterectomies with SVPG (p = 0.004). The internal carotid artery (ICA) origin was consistently larger and had a more normal configuration after carotid endarterectomy with SVPG. Ballooning at the endarterectomy site was an uncommon finding and occurred with similar frequency in both groups; that is, after three conventional carotid endarterectomies and two carotid endarterectomies with SVPG. In the conventional group, early symptomatic thrombosis occurred in the ICA in one patient and in the common carotid artery (CCA), ICA, and external carotid artery (ECA) in two patients. Silent ICA occlusion was seen in three patients in the conventional group. There were no occlusions in the SVPG group (p = 0.04). Stenosis at the distal end of the ICA arteriotomy was found after nine conventional carotid endarterectomies, and was mild (≤ 33% reduction in the lumen) in seven patients, moderate (34% to 66%) in one, and severe (≥ 67%) in one. Mild distal ICA stenosis was seen in one case after carotid endarterectomy with a SVPG (p = 0.03). Stenosis of 33% or less was found at the proximal end of the CCA arteriotomy after two carotid endarterectomies in the conventional group and one carotid endarterectomy in the SVPG group. Four patients in the conventional group suffered a postoperative cerebral infarct and one patient in the SVPG group suffered a postoperative brain-stem infarct (p = 0.28). The authors' findings have led them to routinely use a SVPG in carotid endarterectomy.

KEY WORDS • carotid endarterectomy • intravenous digital subtraction angiography • cerebral infarction • carotid artery

Clinical Material and Methods

Patient Selection

Criteria for carotid endarterectomy included: 1) symptoms and/or signs of ocular or focal cerebral ischemia with severe ipsilateral stenosis (≥ 67%) of the distal common carotid artery (CCA) or proximal internal carotid artery (ICA) and/or deep ulceration; or 2) no symptoms but with focal stenosis (≥ 80%) of the distal CCA or proximal ICA. The patients were independently evaluated by a staff neurologist before and after surgery. All patients underwent conventional angiographic or IVDSA studies before surgery. These studies included views of the extracranial and intracranial carotid arteries and in most cases the vertebrobasilar arterial system. Patients undergoing carotid endarterectomy before June, 1983, had the conven-
tional procedure and those undergoing carotid endarterectomy since that time have had closure of the arteriotomy with an SVPG.

**Surgical Techniques**

The operations were performed by the same neurosurgeon and were carried out under general anesthesia. The techniques used for conventional carotid endarterectomy were similar to previous descriptions. An SVPG was not used in this group regardless of the size of the ICA. Specific features of the surgical technique included: 1) extension of the arteriotomy approximately 2 to 4 mm proximal and distal to the actual endarterectomy site (that is, into normal-appearing portions of the ICA and CCA); 2) use of great care to remove all atherosclerotic material from the proximal external carotid artery (ECA); 3) closure of the distal arteriotomy with four to eight interrupted 6-0 Prolene sutures, followed by a continuous 5-0 Prolene suture to close the remainder of the arteriotomy; and 4) approximation of the carotid sheath over the previously closed arteriotomy with interrupted 5-0 Prolene sutures.

In cases in which the SVPG was used for closure, the greater saphenous vein was exposed in the distal leg approximately 5 to 10 cm proximal to the medial malleolus. This procedure was carried out by an assistant during the exposure of the cervical carotid arteries. A 5- to 6-cm segment of vein was removed, irrigated with heparinized saline solution, and opened longitudinally. The proximal end of the vein was trimmed to form a gentle taper. A 5-0 Prolene suture was placed through the proximal tip of the vein, passing from the adventitial to the intimal surface. The carotid arteriotomy and endarterectomy were carried out in the same fashion as in the conventional endarterectomy group. The SVPG was anchored at the distal end of the arteriotomy (that is, at the ICA) using the 5-0 Prolene suture previously placed in the SVPG. One side of the SVPG was approximated to one edge of the arteriotomy with the 5-0 Prolene suture using a continuous stitch. This suture was continued to the level of the CCA proximal to the origin of the ECA. The suture was tied and the proximal free edge of the SVPG was tapered. A second 5-0 Prolene suture approximated the SVPG to the distal end of the arteriotomy. This suture was then run the length of the SVPG and extended proximally to close the CCA arteriotomy. As in the conventional group, the carotid sheath was reapproximated with interrupted 5-0 Prolene sutures.

All patients received aspirin (5 gr/day, orally) before and after surgery. Continuous electroencephalographic (EEG) monitoring was performed during surgery. A temporary internal shunt was used in patients who showed EEG changes considered to represent ischemia. The patients were completely heparinized prior to clamping of the carotid arteries, each received 1000 IU/10 kg of body weight. Upon reopening the carotid arteries, approximately one-half of the heparin dose was reversed with protamine sulfate (5 mg/1000 IU of heparin).

**Postoperative IVDSA**

Intravenous digital subtraction angiography of the extracranial carotid arteries has been routinely performed during the early postoperative period in our unit since February, 1981. In the present study, all patients underwent IVDSA of the extracranial carotid arteries within 1 week of surgery. The technique of IVDSA has been described in detail previously. The contrast medium was injected through a 20-cm No. 16 angiocatheter inserted into a peripheral arm vein. Renografin-76 (40 cc) followed by a 5% dextrose solution (20 cc) was administered at a rate of 12 to 20 cc/sec, depending on the size of the arm vein. The carotid bifurcations were studied using 70° right and left posterior oblique projections. Additional views were obtained with lesser or greater degrees of obliquity if the arteries were not adequately visualized on the initial views.

**Results**

The 61 patients undergoing 70 conventional carotid endarterectomies included 40 males and 21 females (mean age 66 years). Nine of the 61 patients had bilateral carotid endarterectomies. Fifty-six patients in this group presented with symptoms and signs of transient cerebral ischemia, transient ocular ischemia, or minor stroke. Five patients in this group underwent surgery for an asymptomatic carotid artery stenosis (≥ 80% reduction in the ICA lumen). Preoperative angiographic findings included severe carotid artery stenosis (≥ 67%) in 53 of 70 patients and moderate carotid artery stenosis (34% to 66%) with deep ulceration in 17. In the symptomatic patients, the carotid artery lesion was ipsilateral to the side of the preoperative symptoms.

The 46 patients undergoing 50 carotid endarterectomies with an SVPG included 27 males and 19 females (mean age 64 years). Four of the 46 patients had bilateral carotid endarterectomies. Thirty-eight patients in this group presented with symptoms and signs of transient cerebral ischemia, transient ocular ischemia, or minor stroke. Eight patients in this group underwent surgery for an asymptomatic carotid artery stenosis (≥ 80% reduction in the ICA lumen). Preoperative angiographic findings included severe carotid artery stenosis in 40 of 50 patients and moderate carotid artery stenosis with deep ulceration in 10 of 50 patients. In the symptomatic patients, the carotid artery lesion was also ipsilateral to the side of the preoperative symptoms.

**Operative Findings**

The severity of the carotid artery stenosis and ulceration corresponded closely to the preoperative angiographic findings. The period of carotid artery clamping
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time was approximately 15 minutes longer in the SVPG group than in the conventional group.
Intraoperative EEG changes compatible with cerebral ischemia were seen after carotid artery clamping in six patients in the conventional group and in six patients in the SVPG group. Temporary shunts were used in these patients.

Postoperative IVDSA Findings

The IVDSA studies in all patients were of satisfactory quality for interpretation. There were no adverse reactions or complications related to these studies. One patient in the SVPG group required femoral vein catheterization because of inadequate arm veins. Eight IVDSA studies, including six in the conventional group and two in the SVG group, were performed in the early postoperative period because of a change in neurological findings. The remaining studies were performed 5 to 7 days after surgery.

The findings of the postoperative IVDSA studies are listed in Table 1. Figure 1 shows the typical angiographic appearance with each type of procedure. Three of six patients with early postoperative neurological deficit in the conventional group underwent emergency IVDSA studies, which showed CCA, ICA, and ECA occlusion in two, and ICA occlusion only in one. Three other patients in the conventional group were found to have ICA occlusion 1 week after surgery, but they had no symptoms of ipsilateral cerebral or ocular ischemia (Fig. 2 left). Only one of the six patients in the conventional group with postoperative carotid artery occlusion had been found at the time of surgery to have a small ICA. Occlusion of the CCA and/or ICA was not found in the SVPG group (Fisher’s one-tailed exact test: p = 0.04). Solitary ECA occlusion was not seen in either group.

Mild stenosis (≤ 33%) at the distal end of the ICA arteriotomy was found in seven cases after conventional carotid endarterectomy (Fig. 2 center left) and in one case after carotid endarterectomy with SVPG. In these cases, the narrowing was thought to be the result of either an intimal flap, a small thrombus, or suturing. The stenosis in these cases was not considered severe enough to warrant reexploration. Moderate stenosis of the distal ICA was found in one case and severe stenosis of the distal ICA was found in another case after conventional endarterectomy. The patient with severe stenosis underwent reexploration and was found to have narrowing as the result of poor suture technique. Overall, ICA stenosis occurred significantly more frequently in the conventional group (Fisher’s one-tailed exact test: p = 0.03). Mild stenosis (≤ 33%) at the proximal end of the CCA arteriotomy was found in two cases in the conventional group and in one case in the SVPG group (Fig. 2 center right).

Studies of the SVPG group consistently showed a wider CCA and ICA lumen than in the conventional group. However, an excessively enlarged or “ballooned” ICA (that is, more than three times the diameter of the distal ICA lumen) was seen in three studies in the conventional group and in two studies in the SVPG group (Fig. 2 right). Slight irregularity at the endarterectomy site or the presence of an intimal ledge at the proximal end of the CCA endarterectomy were not considered to be abnormal findings. Overall, no abnormalities were found in 50 of the 70 studies in the conventional group or in 46 of the 50 studies in the SVPG group (Fisher’s one-tailed exact test: p = 0.004).

As noted above, three patients in the conventional group were shown on emergency postoperative IVDSA

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Postoperative IVDSA findings*</th>
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<tbody>
<tr>
<td>IVDSA Abnormalities</td>
<td>Conventional Group</td>
</tr>
<tr>
<td>ICA occlusion</td>
<td>4</td>
</tr>
<tr>
<td>ICA stenosis ≤ 33%</td>
<td>7</td>
</tr>
<tr>
<td>34%-66%</td>
<td>1</td>
</tr>
<tr>
<td>≥ 67%</td>
<td>1</td>
</tr>
<tr>
<td>CCA stenosis ≤ 33%</td>
<td>2</td>
</tr>
<tr>
<td>ECA occlusion</td>
<td>0</td>
</tr>
<tr>
<td>ICA, ECA, and CCA occlusion</td>
<td>2</td>
</tr>
<tr>
<td>ICA “ballooned”†</td>
<td>3</td>
</tr>
<tr>
<td>no abnormalities</td>
<td>50</td>
</tr>
<tr>
<td>total cases</td>
<td>70</td>
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</tbody>
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* IVDSA = intravenous digital subtraction angiography; SVPG = saphenous vein patch graft; ICA = internal carotid artery; CCA = common carotid artery; ECA = external carotid artery. See text for statistical analysis.
† Enlarged more than three times the diameter of the distal ICA lumen.

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to have occluded carotid arteries. Three other patients in the conventional group undergoing emergency IVDSA were found to have no abnormalities. The two patients in the SVPG group undergoing emergency postoperative IVDSA were also found to have no abnormalities at the operative site.

Postoperative Course

Six patients in the conventional group developed symptoms and signs of ipsilateral cerebral ischemia within 8 hours of surgery. The neurological deficit did not resolve in four cases and was transient in two. Emergency IVDSA was performed in these six patients. In two of them the ipsilateral CCA, ICA, and ECA were not visualized, and in another patient the ipsilateral ICA was not seen. Subsequent exploration revealed thrombosis of the nonvisualized carotid arteries, but there were no obvious causes for this complication. The neurological deficit persisted in these three patients despite reestablishment of carotid artery patency. One patient with postoperative neurological deficit had a normal IVDSA but the neurological deficit persisted. The two patients with transient cerebral ischemia also had normal IVDSA's. The remaining 55 patients in the conventional group recovered without complication.

One patient in the SVPG group had a single ipsilateral cerebral transient ischemic attack shortly after surgery. Emergency postoperative IVDSA revealed normal vessels, and the neurological symptoms and signs did not recur. Another patient developed signs of pontomedullary ischemia 30 minutes following surgery. These findings developed during a 15-minute period of severe systemic hypotension (systolic blood pressure \( \leq 70 \text{ mm Hg} \)). Before surgery, this patient was found to have bilateral vertebral artery occlusion, ipsilateral severe proximal ICA stenosis, and contralateral severe stenosis of the ICA siphon. A temporary shunt was used in this patient during carotid clamping. This patient had a normal EEG upon completion of the operative procedure. He underwent an emergency postoperative IVDSA, which showed a widely patent carotid artery on the operated side. Despite improvement, a neurological deficit was present at the time of discharge. The remaining 44 patients in the SVPG group recovered without neurological complications. Overall, the incidence of postoperative stroke was not significantly different between the two groups (Fisher's one-tailed exact test: \( p = 0.28 \)). Two patients in the SVPG group had delayed healing of the leg wound, which prolonged the hospital stay by 7 days in each case.

Discussion

Prior to the advent of IVDSA, limited information was available regarding the early angiographic findings following carotid endarterectomy. In most previous reports dealing with this subject, the number of patients studied was small and the patients were not consecutive. Consequently, important questions regarding the incidence of postoperative carotid artery patency and other abnormalities, as well as their relationship to the clinical course, remained unanswered.

Information about the angiographic appearance of operated carotid arteries has been derived from intraoperative studies. Blaisdell, et al., reported the findings of intraoperative angiography in 100 consecutive procedures. In their series, 5% of the ICA's were found to...
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be occluded and 21% were stenotic (≥ 30% luminal narrowing). These angiographic defects were satisfactorily corrected in 25 of 26 cases. In another report, Rosental, et al., demonstrated ICA occlusion in 1% of 260 carotid endarterectomies. Other abnormalities included ECA occlusion or stenosis in 4% of the cases, ICA stenosis and/or thrombosis in 2%, and CCA stenosis and/or thrombosis in 1%. Similar intraoperative findings to those of Rosental, et al., were subsequently reported by Andersen, et al.1

Hertzer, et al., have reported IVDSA findings after 262 carotid endarterectomies. Their studies were performed during the same hospital admission. Occlusion of the ICA was found in 2% of cases. Moderate stenosis (≥ 30%, according to their criteria) of the distal ICA was present in 1% of cases, and mild stenosis (≤ 20%) of the distal ICA was present in 4% of cases. Occlusion of the ECA was identified in 5%. Similar findings have been reported by Little, et al.6,7

In the present study, postoperative occlusion of the operated carotid arteries was not seen in the SVPG group, whereas it occurred in six patients undergoing conventional carotid endarterectomy. It resulted in three of four cerebral infarcts seen in the series and was the leading cause of postoperative neurological morbidity. The patency rates in the two groups were significantly different (p = 0.04), being better in the SVPG group.

Carotid artery occlusion in patients undergoing conventional carotid endarterectomy did not appear to be related to a small ICA, as only one of the ICA's was found to have a small lumen at the time of initial surgery. Moreover, reexploration in three patients failed to reveal any technical cause for thrombosis, including an intimal flap, inadequate removal of atherosclerotic plaque, and/or reduction of ICA luminal dimensions from suturing. The absence of postoperative carotid artery occlusion in the SVPG group might be partly the result of a larger ICA lumen and/or the presence of viable endothelium on the inner surface of the SVPG.

Overall, the luminal dimensions of the ICA after surgery were consistently larger and had a more normal configuration in the SVPG group. Excessive luminal dimensions, or "ballooning," was uncommon in both groups. Distal ICA stenosis occurred significantly more frequently in the conventional group (p = 0.03), but in most cases the narrowing was mild. In previous studies, similar mild stenosis was usually seen to resolve over time.6,7

The risk of postoperative hemorrhage in cases in which a SVPG is used is potentially greater because of the longer suture line. In the present series, no patient in either group suffered this potentially dangerous complication. It is our feeling that reapproximation of the carotid sheath over the length of the arteriotomy closure reinforces the suture line and reduces the possibility of postoperative hemorrhage. In addition, the routine use of the antiplatelet agent, aspirin, did not appear to increase the incidence of troublesome bleeding during surgery or the development of postoperative wound hematoma.

In conclusion, the postoperative IVDSA findings in this series of cases were significantly better in the SVPG group (p = 0.004) than in patients with conventional carotid endarterectomy only. On the basis of the IVDSA results, as well as the apparent reduction of postoperative neurological findings, we now routinely use an SVPG in carotid endarterectomy.5,10

References

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