Saphenous vein graft bypass of the cavernous internal carotid artery

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Saphenous vein graft reconstruction was performed from the petrous to the supraclinoid internal carotid artery (ICA) to replace the cavernous ICA in six patients during direct intracavernous operations. Four of these patients had intracavernous neoplasms with invasion of the ICA and two had intracavernous ICA aneurysms that could not be clipped or occluded with intraluminal balloons. All but one patient had evidence of poor collateral flow reserve in a balloon occlusion test of the ICA. The superficial temporal artery was not present in four patients, was minuscule in one, and was damaged during the initial dissection in another, making it unsuitable for superficial temporal-to-middle cerebral artery branch anastomosis.

Blood flow within the graft could not be established intraoperatively in one patient (who had excellent collateral circulation) due to the small size of the vein (3 mm). In all others, the grafts were patent on follow-up arteriography and transcranial Doppler studies. Three patients who had severe reduction of cerebral blood flow during test occlusion of the ICA exhibited temporary hemispheric neurological deficits related to the duration of temporary ICA occlusion. All three recovered completely without evidence of infarction on computerized tomography (CT). One patient who clinically could not tolerate the balloon occlusion test of the ICA also had temporary neurological deficits with good recovery but showed evidence of border-zone infarction on CT scans. The present role of saphenous vein graft bypass of the cavernous ICA is discussed.

Key Words: cavernous carotid artery • internal carotid artery • saphenous vein • graft bypass

During direct surgical treatment of neoplastic and vascular lesions involving the cavernous sinus, the surgeon sometimes is faced with the inability to preserve the internal carotid artery (ICA). In such instances, collateral circulation may be adequate to permit occlusion of the ICA without consequence. In some patients, however, some form of revascularization will be necessary, either because of the inadequacy of the collateral circulation or because of the desire to preserve the ipsilateral cerebrovascular flow in a young patient with a long life expectancy. In the past, revascularization has been accomplished by a superficial temporal artery (STA)-to-middle cerebral artery (MCA) branch anastomosis, an external carotid artery-MCA long venous graft, an STA-MCA branch venous graft, or an extracranial ICA-intracranial ICA long venous graft.2,4-6,8-11,18-20 In this article, the use of a short venous graft from the petrous to the supraclinoid ICA, directly bypassing the cavernous ICA, is described as an alternative means of revascularization. The feasibility of such grafting (in cadavers) was first described by Sekhar, et al.14 Since then, the procedure has been used clinically by our group and also by Fukushima (T Fukushima: personal communication, 1988).

Clinical Material and Methods

Patient Population

From 1983 to 1988, the first author has been involved in the direct surgical treatment of the petrous or cavernous ICA in 170 patients with neoplastic or vascular lesions. Vein grafting from the cervical to the petrous ICA or graft reconstruction of the petrous ICA was used in seven of these patients.15 In six patients, vein grafting was performed from the petrous to the supraclinoid ICA, bypassing the cavernous sinus. The latter group is the subject of this report.

Direct vein graft bypass of the intracavernous ICA was used in four patients with neoplasms (three meningiomas and one squamous-cell carcinoma) and in two patients with intracavernous aneurysms (one congenital and the other presumably iatrogenic) (Table 1). All patients were evaluated preoperatively by physical and neurological examination, computerized tomog-
TABLE 1
Summary of six patients with graft bypass of the cavernous ICA*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Pathology &amp; Location</th>
<th>Result of BTO</th>
<th>Type of Anastomosis</th>
<th>Patency</th>
<th>Ana- Anastomosis Oclusion Time</th>
<th>ICA New Postoperative Deficits</th>
<th>Follow-Up Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64, F</td>
<td>meningioma: cavernous sinus, clivus, sella</td>
<td>tolerated clinically; bifrontal CBF decrease</td>
<td>end-to-end</td>
<td>end-to-side</td>
<td>angio: 3 mos, TCD 14 mos</td>
<td>1/4 hrs (proximal end redone)</td>
<td>temporary hemiparesis &amp; аулы; worsened III func; delayed VII palsy</td>
</tr>
<tr>
<td>2</td>
<td>48, F</td>
<td>meningioma: cavernous sinus, clivus, sella</td>
<td>tolerated clinically; marked CBF reduction</td>
<td>end-to-end</td>
<td>end-to-side</td>
<td>angio: 3 mos, TCD 3 mos</td>
<td>1 1/2 hrs</td>
<td>temporary hemiparesis; memory problems; VI palsy; delayed VII paresis</td>
</tr>
<tr>
<td>3</td>
<td>44, F</td>
<td>meningioma: cavernous sinus, clivus, sella</td>
<td>not done; good collaterals on angio</td>
<td>end-to-end</td>
<td>end-to-side</td>
<td>occluded at surgery</td>
<td>2 hrs</td>
<td>permanent occlusion</td>
</tr>
<tr>
<td>4</td>
<td>48, M</td>
<td>squamous-cell ca: cavernous sinus, ethmoid, maxilla, orbit</td>
<td>tolerated clinically; CBF reduction</td>
<td>end-to-end</td>
<td>end-to-end</td>
<td>angio: 2 mos, TCD 2 mos</td>
<td>1 1/2 hrs</td>
<td>2 hrs</td>
</tr>
<tr>
<td>5</td>
<td>68, F</td>
<td>intracavernous giant aneurysm</td>
<td>tolerated clinically; marked CBF reduction</td>
<td>end-to-end</td>
<td>end-to-side</td>
<td>angio: 3 days, TCD 2 mos</td>
<td>1 1/2 hrs</td>
<td>3 1/2 hrs</td>
</tr>
<tr>
<td>6</td>
<td>38, F</td>
<td>iatrogenic aneurysm</td>
<td>failed clinically; temporary hemiplegia, aphasia, seizures</td>
<td>end-to-end</td>
<td>end-to-side</td>
<td>angio: 7 mos, TCD 6 mos</td>
<td>2 hrs</td>
<td>2 hrs</td>
</tr>
</tbody>
</table>

* ICA = internal carotid artery; BTO = balloon test occlusion; CBF = cerebral blood flow; TCD = transcranial Doppler ultrasound; CT = computerized tomography; angio = angiogram; ca = carcinoma. Roman numerals denote cranial nerves.
† Autopsy revealed myocardial infarction, a patent vein graft, and no cerebral infarction.

Operative Technique

The cervical ICA was exposed in all patients. A frontotemporal craniotomy was followed by the temporary removal of the superior and lateral rims and walls of the orbit and the zygomatic arch, including the mandibular fossa. Extradural middle fossa dissection was performed to expose and unroof the mandibular nerve, the middle meningeal artery (which was divided), the greater superficial petrosal nerve (which was divided), and the horizontal segment of the petrous ICA. In all patients, it was necessary to remove the bone portion of the eustachian tube and expose the genu of the petrous ICA to facilitate suturing.

Following dural opening and initial dissection, the anterior clinoid process was removed, and the optic nerve was unroofed by bone removal. The distal intracavernous ICA was dissected after the division of the dural rings at its exit from the cavernous sinus. The cavernous sinus was entered by superior and lateral intradural approaches in the patients with benign tumors to determine if the ICA could be dissected free of...
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FIG. 1. Drawings depicting the saphenous vein graft bypass of the cavernous internal carotid artery (ICA) using an end-to-side anastomosis distally (left) or end-to-end anastomosis distally (right). Although the collateral circulation of the ophthalmic artery usually enables its occlusion without loss of vision, occlusion is best avoided when vision is intact preoperatively. Roman numerals denote cranial nerves.

tumor and in the patients with aneurysms to see if the aneurysm could be clipped. However, in the patient with a malignant neoplasm, the contents of the cavernous sinus were excised without entering the sinus.

When direct vein grafting was decided upon, the patient was given 1000 mg of methylprednisolone intravenously, and approximately a 7-cm length of the greater saphenous vein was harvested from the thigh. The distal anastomosis was usually completed first. Three temporary vascular clips were placed on the ICA: one in the neck, one distal to the ophthalmic artery, and one just proximal to the posterior communicating artery. For end (vein)-to-side (ICA) anastomosis, a linear arteriotomy was made on the anterior wall of the ICA (Fig. 1 left). Heparinized saline was used to wash the blood and any clot from the ICA and vein, but systemic heparinization was not employed for fear of causing bleeding from the operative wound. For end-to-end anastomosis, the ICA was divided just superior to the ophthalmic artery and “fish-mouthed” (Fig. 1 right). The end of the vein was trimmed, denuded of adventitia, and fish-mouthed if necessary. Four 7-0 Prolene or 8-0 nylon sutures were placed to attach the vein to the ICA at diametrically opposite points. The rest of the anastomosis was completed with interrupted sutures. To check the anastomosis for leaks, the vein was irrigated with heparinized saline. A continuous suture technique was used in the first patient and subsequently abandoned in favor of an interrupted suturing technique. The latter took more time but provided better approximation without leakage or stenosis at the suture line.

Next, the petrous ICA was divided just proximal to the third division of the trigeminal nerve. There was usually some back bleeding from the intracavernous ICA because of the anastomotic connections of the intracavernous branches. This bleeding was stopped by packing the lumen of the cavernous ICA with Surgicel (oxidized regenerated cellulose). The petrous ICA was then irrigated thoroughly with heparinized saline to clear blood or clot. The vein graft was trimmed to a length of 5 to 6 cm and anastomosed end-to-end with 7-0 Prolene interrupted sutures. Before the last stitch was tied, the graft and the ICA were irrigated again with heparinized saline, and the proximal and distal temporary clips were released long enough to wash out any air bubbles. The intracavernous ICA was ligated permanently just proximal to the ophthalmic artery and divided proximal to the ligature.

During the petrous anastomosis procedure, a temporary clip can be placed on the cavernous ICA proximal to the opthalmic artery and on the vein graft. The two distal temporary clips can be removed to continue collateral flow through the ophthalmic artery (as was done in Case 6, see below).

A regimen of intermittent subcutaneous heparin was used in the early postoperative period, and antiplatelet agents (aspirin or dipyridamole) were administered orally after 10 days to prevent late graft occlusions. If the patient’s eustachian tube was excised, a typanostomy was inserted after 6 weeks.

Summary of Cases

In four patients the STA was absent as a result of prior surgery, in one it was minuscule, and in another it was injured during the operation. The time required to perform anastomosis of the graft ranged from 60 to 90 minutes; however, in Case 1 the ICA was occluded.
for 5 hours because of thrombosis at the proximal anastomotic end of the graft, which was discovered after tumor resection. The anastomosis was reconstructed with a good result. In Case 3 the graft was occluded intraoperatively, probably due to the very small size of the vein (diameter 3 mm). This patient had a good preoperative collateral circulation through the anterior and posterior communicating arteries and did not suffer any hemispheric neurological deficits postoperatively. One patient (Case 4), who had a large squamous-cell carcinoma, recovered well from the operation but died 3 months later of metastatic disease. In Case 5 a giant intracavernous aneurysm could not be clipped upon direct exploration, because it was an eccentric dilatation of the ICA. Graft replacement of the ICA took 2 hours to perform; however, the ICA was temporarily occluded for 3½ hours, because preparations for grafting had not been made. The patient recovered well from the procedure but died suddenly at home 3 months later. Autopsy revealed the cause of death to be myocardial infarction. The graft was patent, and no cerebral infarction was found. Cases 2 and 6 are described below.

Four patients tolerated balloon occlusion test of the ICA without neurological deficit but exhibited significant ipsilateral or bilateral reductions of CBF ranging from 15 to 30 cc/100 gm/min. Three of these patients had temporary hemispheric deficits postoperatively, presumably related to intraoperative ICA occlusion for 2, 3½, and 5 hours. Another patient developed temporary hemiplegia, aphasia, and seizures during test occlusion of the ICA. This patient manifested hemispheric neurological deficits postoperatively, related to temporary intraoperative ICA occlusion. She made a good recovery, but CT revealed evidence of cerebral infarction. Postoperative angiography demonstrated patent saphenous vein grafts in all five of these patients.

Illustrative Case Reports

Case 2

This 48-year-old woman with an extensive basal meningioma had undergone two prior tumor operations. The intracavernous ICA was encased and narrowed by the tumor (Fig. 2 left). The posterior communicating artery was the dominant supplier of the posterior cerebral artery territory and was irregularly narrowed by the tumor. The CBF decreased bilaterally during balloon occlusion test of the ICA, especially at the upper levels. At surgery, the tumor was excised along with the poorly functioning third through sixth cranial nerves. The ICA was replaced with a vein graft. Postoperatively, the patient had a mild hemiparesis for 2 days. Follow-up arteriography revealed a patent vein graft (Fig. 2 right). Seven months after the operation, the patient had a Karnofsky score of 80. A small tumor remnant in the clival area was treated with gamma knife radiotherapy.

Case 6

This 38-year-old woman presented with several severe episodes of epistaxis. She had an aneurysm arising...
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from the intracavernous ICA and projecting medially into the sphenoid sinus (Fig. 3 left). This was presumed to have resulted from two prior transsphenoidal operations and one transthyroidal pituitary procedure for Cushing's disease. Arteriography showed the STA to be absent, but cross flow through the anterior communicating artery was present after ipsilateral common carotid artery compression. Permanent balloon occlusion of the ICA was planned. However, the patient developed hemiplegia, aphasia, and seizures after test occlusion of the ICA and recovered slowly. An urgent operation was performed with electroencephalographic (EEG) monitoring. The intracavernous aneurysm was explored directly but not clipped because the cavernous sinus was found to be filled with granulation tissue. It was elected to perform vein graft bypass of the cavernous ICA. During the 2-hour temporary ICA occlusion for vein grafting, the blood pressure was elevated 40 torr, and no EEG changes were observed. However, postoperatively the patient suffered hemiplegia (which resolved in 5 days), dysphasia (which resolved in 14 days), and memory problems (which resolved slowly). Angiography revealed a patent graft (Fig. 3 right). Results of a CBF study on the 1st postoperative day were normal, but another study 1 week later revealed hyperemic areas in the border zone between the anterior, middle, and posterior cerebral arteries. These regions evolved into CT-defined infarcts. Seven months later, the patient had made a nearly complete recovery of her neurological deficits and had a Karnofsky score of 80.

Discussion

Technical Factors

The advantages and disadvantages of using vein grafts as arterial conduits, important technical points regarding graft harvesting and anastomosis, and postoperative management were reviewed extensively by Sundt and Sundt. When vein grafting is used to reconstruct the ICA, the shortest possible length of the graft and end-to-end anastomosis at both ends of the graft are preferable to reduce turbulent flow. However, because of the position of the ophthalmic artery, an end-to-side anastomosis is technically easier to carry out at the distal end. An end-to-end distal anastomosis can be performed if the ophthalmic artery is sacrificed (because of orbital exenteration) or if there is an adequate length of healthy intracavernous ICA proximal to the ophthalmic artery.

It proved easier to perform the distal anastomosis first. When the proximal anastomosis was undertaken first, blood ran down from the skull-base area along the graft and made the distal anastomosis more difficult. In Case 3 the proximal anastomosis was achieved first and the temporary clip was opened to check graft flow, because the vein was small. This resulted in clotting of the graft, because systemic heparinization was not used and the volume of flow was small.

In this series, intraluminal shunts were not utilized because of technical difficulties and for fear of embolic complications.

Postoperative Neurological Deficits

In three of the four patients who had a reduced CBF (but no neurological deficits) after balloon occlusion test of the ICA, temporary neurological deficits were observed postoperatively, corresponding to the areas of CBF reduction. In the patient with the poorest preoperative collateral circulation, hyperemia and subsequent infarction were demonstrated in the border-zone areas between vascular territories. No embolic occlusions of distal vessels were seen on postoperative arteriography.
These facts reinforce the belief that the temporal neurological deficits were caused by intraoperative flow reduction due to ICA occlusion and not by emboli from the anastomotic site.

In this group of patients, hypertension was induced during temporary ICA occlusion, but drugs to protect the brain against ischemia, such as high-dose barbiturates, etomidate, or the “Sendai cocktail,” were not used.1,17,22 Subsequently treated patients who have undergone prolonged temporary ICA occlusion have been given intraoperative thiopental sodium intravenously to achieve burst suppression on EEG recordings, with better results.

**Direct Vein Graft Reconstruction of Cavernous ICA**

When the intracavernous ICA must be excised in a patient who has a long life expectancy, it is preferable to revascularize the brain, even when the preoperative collateral circulation is adequate. The reasons for this are the following: 1) the ipsilateral cerebrovascular reserve is preserved by revascularization; 2) many intracavernous lesions, especially meningiomas and aneurysms, tend to involve both sides; and 3) there appears to be an increased risk of aneurysm formation after unilateral ICA occlusion.7

Many methods of cerebral revascularization are available to the surgeon. Direct venous reconstruction of the cavernous ICA has the advantage of providing a high-flow conduit immediately with the shortest possible length of vein, leading from a large artery to another large artery. The disadvantages are a 90- to 120-minute period of temporary ICA occlusion and the potential for graft occlusion. The long-term status of these grafts in terms of patency and other pathological changes such as aneurysm formation at branch sites is unknown at present.

Revascularization techniques using the STA still carry the lowest risk to the patient and must be used whenever possible.4,6,8 However, the STA-MCA bypass alone may be inadequate to prevent a stroke after acute ICA occlusion in patients with a very poor preoperative collateral circulation.13 Possible alternatives for revascularization, depending on the status of the preoperative collateral circulation, are outlined in Table 2.

**References**


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