

## TREATMENT OF GIANT INTRACRANIAL ANEURYSMS WITH SAPHENOUS VEIN EXTRACRANIAL-TO-INTRACRANIAL BYPASS GRAFTING: INDICATIONS, OPERATIVE TECHNIQUE, AND RESULTS IN 29 PATIENTS

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**OBJECTIVE:** The treatment of giant intracranial aneurysms is a challenge because of the limitations and difficulty of direct surgical clipping and endovascular coiling. We describe the indications, surgical technique, and complications of saphenous vein extracranial-to-intracranial bypass grafting followed by acute parent vessel occlusion in the management of these difficult lesions.

**METHODS:** Between January 1990 and December 1999, 29 patients with giant intracranial aneurysms underwent 30 saphenous vein bypass grafts followed by immediate parent vessel occlusion. There were 11 men and 18 women with a mean follow-up period of 62 months. Twenty-five patients harbored aneurysms involving the internal carotid artery, 2 had middle cerebral artery aneurysms, and 2 had aneurysms in the basilar artery. Serial cerebral or magnetic resonance angiograms were obtained to assess graft patency and aneurysm obliteration.

**RESULTS:** All 30 aneurysms were excluded from the cerebral circulation, with 28 vein grafts remaining patent. Two patients had graft occlusions: one because of poor runoff and the other because of misplacement of a cranial pin during a bypass procedure on the contralateral side. Other surgical complications included one death from a large cerebral infarction, homonymous hemianopsia from thrombosis of an anterior chorioidal artery after internal carotid artery occlusion, and temporary hemiparesis from a presumed perforator thrombosis adjacent to a basilar aneurysm.

**CONCLUSION:** With appropriate attention to surgical technique, a saphenous vein extracranial-to-intracranial bypass followed by acute parent vessel occlusion is a safe and effective method of treating giant intracranial aneurysms. A high rate of graft patency and adequate cerebral blood flow can be achieved. Thrombosis of perforating arteries caused by altered blood flow hemodynamics after parent vessel occlusion may be a continuing source of complications.

**KEY WORDS:** Brain aneurysm, Extracranial-intracranial bypass, Giant intracranial aneurysm, Saphenous vein

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Intracranial aneurysms are most commonly treated by the placement of a clip across the neck while blood flow in the parent vessel is preserved. In the case of giant intracranial aneurysms (>2.5 cm), however, the presence of a wide neck, atheroma, or calcification at the base may preclude safe surgical clipping (7). The use of Guglielmi detachable coils is useful for the endovascular occlusion of aneurysms (4, 11). Unfortunately, for giant aneurysms, the presence of a large neck frequently prevents adequate coil density at the

aneurysm-parent vessel interface, leading to coil compaction and recanalization (13). In 1969, Yaşargil performed the first extracranial-to-intracranial (EC-IC) bypass with ligation of the middle cerebral artery (MCA) in the successful treatment of a complex cerebral aneurysm (23). Since then, a number of authors have reported using EC-IC bypass surgical techniques with parent vessel occlusion for the treatment of patients with giant intracranial aneurysms (1, 3, 6, 8, 9, 12, 14-16, 18-21). Perioperative ischemia and graft occlusion are frequent and

distressing complications, however, and the optimal method for bypass is not clear. To minimize these difficulties, we used a nonreversed, preauricular tunneled saphenous vein bypass graft followed by acute parent vessel occlusion in 29 patients with giant intracranial aneurysms. In this article, we report indications, imaging evaluations, operative techniques, and outcomes in patients who underwent this procedure.

**PATIENTS AND METHODS**

**Patient Series**

Between January 1990 and December 1999, 29 patients with giant intracranial aneurysms underwent 30 saphenous vein bypass grafts (1 patient had bilateral cavernous aneurysms) followed by immediate parent vessel occlusion. The characteristics of the patient series are summarized in *Table 1*.

**Imaging Evaluation and Indications for Bypass**

All patients underwent magnetic resonance imaging (MRI) and/or computed tomographic (CT) scanning of the brain and cerebral angiography in conjunction with balloon test occlusion (BTO) when appropriate. The aneurysms in this study were considered to be surgically unclippable on the basis of MRI, CT scanning, and cerebral angiography. The indication for an EC-IC bypass in 27 of 29 patients (27 aneurysms) was a failed BTO, which was defined as the development of a neurological deficit during the 20-minute parent vessel occlusion

and/or inadequate cerebral blood flow (CBF) (<30 ml/100 g/min) on test occlusion xenon blood flow tomography (10). Patients who did not demonstrate clinical ischemia during BTO and had adequate CBF (>30 ml/100 g/min) did not undergo cerebral revascularization and were excluded from this study. In the remaining two patients (three aneurysms), the indications for cerebral revascularization included a giant aneurysm of the contralateral cavernous carotid artery eroding into the sphenoid sinus and progressive hemiparesis that was most likely related to hemodynamic insufficiency caused by a previously sacrificed ipsilateral common carotid artery (CCA). Our algorithm for the treatment of giant cerebral aneurysms is shown in *Figure 1*.

**Surgical Technique**

The surgical technique used for the saphenous vein EC-IC bypass is illustrated in *Figure 2*. A long segment of saphenous vein is harvested between the ankle and the knee. The vein is not reversed and is marked before harvesting to prevent twisting during the tunneling from the cervical incision to the cranial incision. Next, the CCA, the internal carotid artery (ICA), and the external carotid artery (ECA) are exposed by

**TABLE 1. Patient demographics and clinical findings**

	No. (%)
<b>Vital statistics</b>	
No. of patients	29
Female	18
Male	11
No. of aneurysms	30
Average age (yr)	57
<b>Aneurysm location</b>	
Internal carotid artery	26 (87%)
Paraclinoid	12
Cavernous sinus	8
Posterior communicating artery	6
Middle cerebral artery	2 (6.5%)
Basilar artery	2 (6.5%)
<b>Clinical presentation</b>	
Mass effect	15 (52%)
With cranial neuropathy	12
With hemiparesis	3
Headache	7 (24%)
Subarachnoid hemorrhage	4 (14%)
Transient ischemic attack	2 (7%)
Seizure disorder	1 (3%)

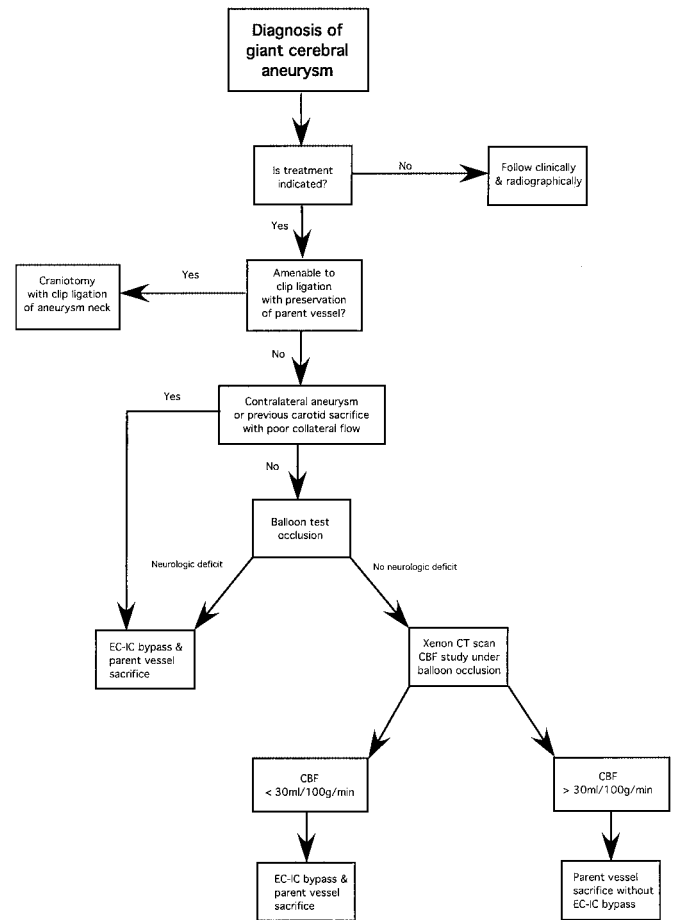
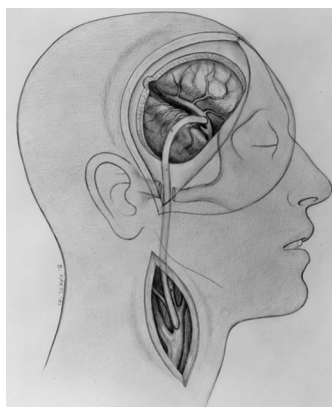


FIGURE 1. Treatment algorithm for giant cerebral aneurysms.

making a cervical incision along the anterior aspect of the sternocleidomastoid muscle. A pterional craniotomy is performed with wide dissection of the sylvian fissure. The base of the zygoma is drilled to fashion a conduit for the graft when it is placed in the preauricular position. A large vascular trocar is used to tunnel the graft from the cervical to the cranial incision to minimize compression of the graft by soft tissue.



**FIGURE 2.** Illustration depicting the preauricular ECA (end-to-side) to M2 segment MCA (end-to-side) nonreversed saphenous vein bypass technique used for the treatment of giant cerebral aneurysms.

Once the proximal and distal sites are prepared for the anastomoses, 3000 U heparin and 10 mg dexamethasone are administered intravenously, and barbiturates are administered until burst suppression is obtained by performing electroencephalography. The distal anastomosis is performed first in an end-to-side fashion with 8-0 or 9-0 monofilament nylon sutures. Twenty-one grafts were connected to the M2 segment, three were connected to the M1 segment, and one was connected to the M3 segment of the MCA; three were connected to the supraclinoid ICA; one was connected to the posterior cerebral artery; and one was connected to the superior cerebellar artery (Table 2). When feasible, to preserve distal collaterals, the proximal anastomosis is placed in an end-to-side

manner to the ECA using 7-0 monofilament nylon sutures. This was not possible in three patients because of early ECA branching or improper graft angulation. In these cases, the proximal graft was anastomosed end-to-side to the CCA.

In the last 5 years of the study, intraoperative angiography was performed to evaluate graft patency and the adequacy of the anastomoses. A 20-gauge angiocatheter was used to directly puncture the exposed CCA, obviating the need for a groin sheath and catheterization of the great vessels in the aorta. Blood flow measurements through the graft were also performed with intraoperative Doppler ultrasonography.

Once the adequacy of flow through the graft was ascertained, the parent vessel of the aneurysm was proximally occluded. For aneurysms originating from the cavernous, paraclinoid, and communicating segments of the carotid artery, the ICA was suture ligated in the neck (26 cases). The M1 segment was clip ligated just proximal to the aneurysm for MCA bifurcation aneurysms (two cases). For posterior circulation aneurysms, the vertebral arteries were occluded above the posterior inferior cerebellar arteries with a detachable balloon or coils in the interventional angiography suite within 24 hours of surgery (two cases). At the end of the procedure and before closure, anticoagulation was reversed with protamine. All patients began receiving aspirin (325 mg/d) immediately after the operation.

## RESULTS

### Graft Patency

Twenty-eight of the 30 saphenous vein grafts remained patent during a mean radiographic follow-up period of 62 months (range, 6–120 mo), as confirmed by serial cerebral or magnetic resonance angiography (Table 2). No patients experienced subarachnoid hemorrhage or aneurysm recanalization during the follow-up period. One graft occlusion occurred in a patient who underwent bilateral EC-IC bypasses for bilateral giant cavernous aneurysms, both of which had eroded into the sphenoid sinus. This patient had good collateral blood flow, and the revascularization was performed solely to prevent the possibility of rupture of the contralateral aneurysm until it was definitively treated. During the second bypass procedure, a cranial pin was placed in close proximity to the graft, stretching the skin and compressing the bypass, causing the graft to occlude. Fortunately, collateral flow through the posterior communicating artery enabled the patient to remain asymptomatic.

The other graft occlusion occurred in a patient with a 9-cm calcified and mostly thrombosed left MCA aneurysm. He had undergone ligation of the left CCA at another institution 10 years earlier and now presented with stepwise, progressive hemiparesis. The cause of his hemiparesis was unclear, but it was presumed to be either thromboembolism related to his giant aneurysm or hemodynamic insufficiency secondary to the previous CCA occlusion. Preoperative xenon blood flow tomography of the symptomatic hemisphere revealed poor CBF (<30 ml/100 g/min). Because of the size of the aneurysm,

**TABLE 2. Surgical outcomes and complications**

	No. (%)
Location of distal anastomosis	
Middle cerebral artery	25 (84%)
M1 segment	3
M2 segment	21
M3 segment	1
Internal carotid artery	3 (10%)
Posterior cerebral artery	1 (3%)
Superior cerebral artery	1 (3%)
Patency of bypass grafts	
Patent	28 (93%)
Occluded	2 (7%)
Poor distal runoff	1
Headholder pin placement	1
Complications	
Transient hemiparesis	1 (3%)
Hemianopsia	1 (3%)
Death	1 (3%)

exposure of the proximal intracranial vessels was not possible, and the distal anastomosis had to be placed on the M3 branch of the MCA. The previous CCA ligation precluded the placement of a superficial temporal artery-MCA bypass, and a long saphenous vein CCA-MCA bypass was performed. Adequate runoff was lacking because of the size discrepancy between the donor and recipient vessels. The graft occluded after surgery, but the patient remained neurologically stable.

### Complications

There were three complications in our series, including one death, at a mean clinical follow-up of 62 months (range, 6–120 mo) (Table 2). The first complication was in a patient with a giant posterior communicating artery segment aneurysm who underwent a saphenous vein bypass graft with ICA occlusion. She awoke with hemiplegia and homonymous hemianopsia immediately after surgery. A postoperative angiogram revealed a patent bypass, an obliterated aneurysm, and thrombosis of the anterior choroidal artery. The hemiplegia resolved completely within 24 hours, but the hemianopsia persisted. A postoperative MRI scan of the brain revealed an ipsilateral pulvinar infarction.

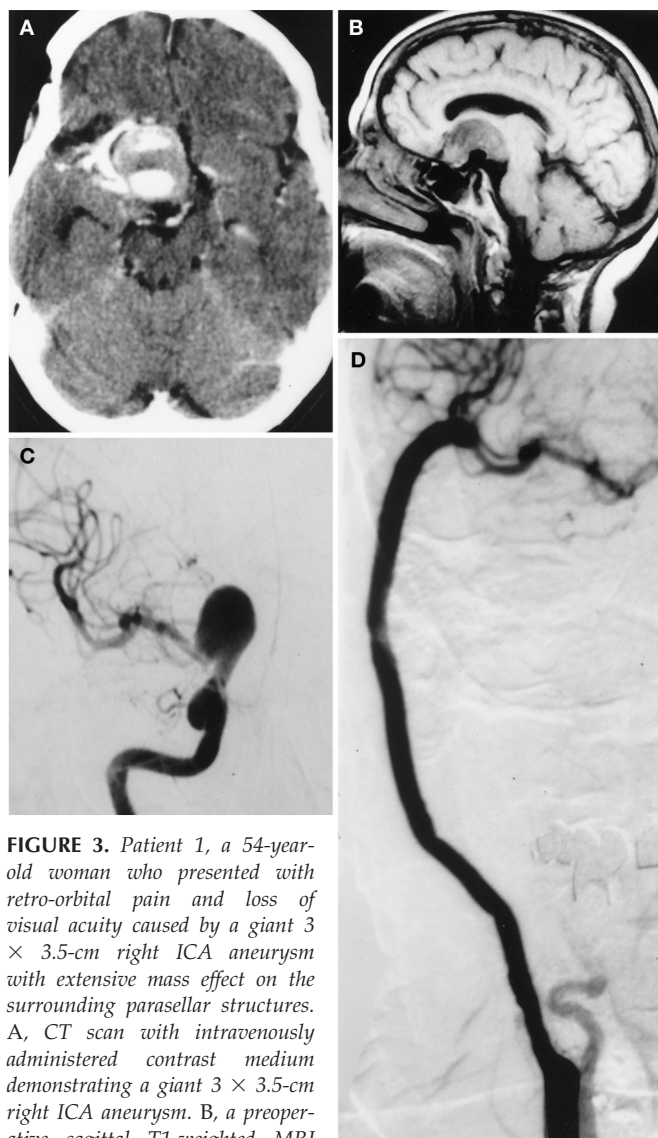
The second complication occurred in a patient with a giant midbasilar aneurysm who presented with severe left trigeminal neuralgia and progressive right-sided hemiparesis from mass effect. After surgery, he awoke with worsening of his hemiparesis. However, his facial pain had resolved. Angiography revealed a patent bypass and no evidence of large-vessel occlusion. At the 6-month follow-up examination, he had improved relative to his preoperative state. We presume that his temporary worsening was caused by a perforator occlusion adjacent to the trapped aneurysm (see description of Patient 2 below).

One death occurred early in our experience in a patient with a giant left cavernous segment aneurysm who presented with progressive ophthalmoplegia. The distal end of the graft was anastomosed to the M1 segment. Temporary occlusion time was approximately 1 hour. Despite intraoperative administration of barbiturates to produce electroencephalographic burst suppression and the use of intravenous corticosteroids, the patient sustained a massive left hemispheric cerebral infarction and died. An immediate postoperative angiogram demonstrated a widely patent bypass. In all other patients, temporary occlusion time during the performance of the distal anastomosis was 20 minutes or less.

### Illustrative Case

#### Patient 1

A 54-year-old woman presented with a 4-month history of progressive loss of visual acuity in her right eye and retro-orbital headaches. A CT scan with intravenously administered contrast medium demonstrated a giant 3 × 3.5-cm right ICA aneurysm with extensive mass effect on the surrounding parasellar structures, as well as a large intraluminal thrombus (Fig. 3A). A sagittal T1-weighted MRI scan showed that the giant aneurysm had caused extensive compression of



**FIGURE 3.** Patient 1, a 54-year-old woman who presented with retro-orbital pain and loss of visual acuity caused by a giant 3 × 3.5-cm right ICA aneurysm with extensive mass effect on the surrounding parasellar structures. A, CT scan with intravenously administered contrast medium demonstrating a giant 3 × 3.5-cm right ICA aneurysm. B, a preoperative sagittal T1-weighted MRI study demonstrating the giant aneurysm with extensive compression of the brainstem and hypothalamus. The majority of the aneurysm was thrombosed. C, an AP right ICA angiogram revealing an ICA aneurysm with an isolated circulation. D, a postoperative AP CCA angiogram showing patency of the bypass graft with brisk filling of the MCA circulation, including retrograde filling of the lateral lenticulostriate perforators.

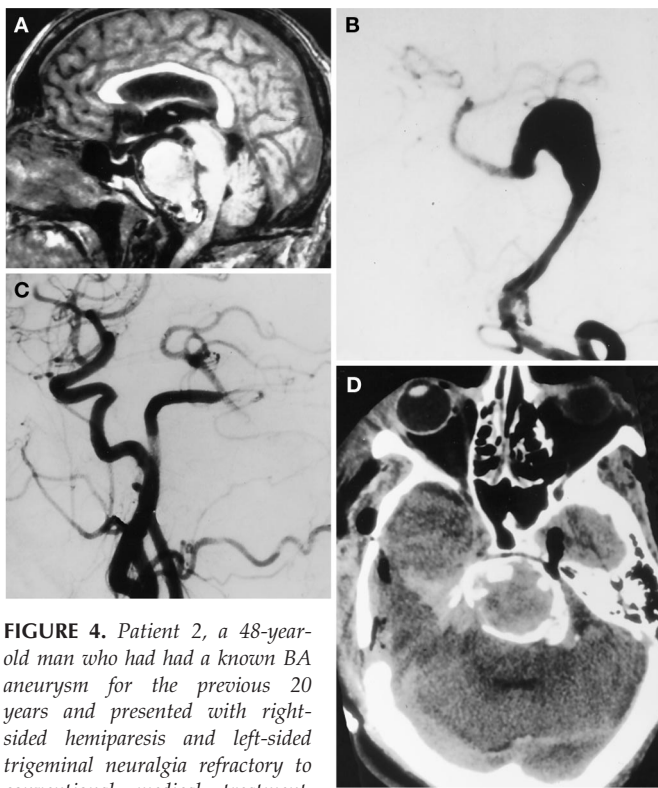
the brainstem and hypothalamus. The majority of the aneurysm was thrombosed (Fig. 3B). An anteroposterior (AP) right ICA angiogram revealed the takeoff of the aneurysm to be proximal to an isolated ipsilateral cerebral circulation (Fig. 3C).

After the criteria for bypass had been satisfied, a right CCA-to-MCA saphenous vein bypass graft was performed, followed by immediate proximal ligation of the parent artery. A postoperative AP CCA angiogram showed the patency of the bypass graft with brisk filling of the MCA circulation, including retrograde filling of the lateral lenticulostriate perforators and no filling of the aneurysm (Fig. 3D). The patient had resolution of her retro-orbital pain and improvement of her visual acuity after surgery.

### Patient 2

A 48-year-old man who had had a known basilar artery (BA) aneurysm for the previous 20 years presented with an 18-month history of progressive right-sided hemiparesis and a 12-month history of intolerable left-sided trigeminal neuralgia refractory to conventional medical treatment and radiofrequency lesioning. A preoperative sagittal T1-weighted MRI study revealed a giant  $3 \times 5$ -cm BA aneurysm with significant intraluminal thrombus and calcification (Fig. 4A). The brainstem was markedly compressed and displaced posteriorly. An AP vertebral artery angiogram revealed a giant fusiform BA aneurysm with partial intraluminal filling (Fig. 4B). The contralateral vertebral artery ended in the posterior inferior cerebellar artery. Posterior communicating arteries could not be visualized by performing angiography.

The patient underwent a right-sided ECA-to-superior cerebellar artery saphenous vein bypass graft, followed by endovascular occlusion of the parent vertebral artery. A postoperative lateral right CCA angiogram confirmed the exclusion of the aneurysm from the vertebrobasilar system and a patent saphenous vein bypass graft supplying the basilar and posterior cerebral arteries (Fig. 4C). A postoperative non-contrast CT scan revealed the extent of aneurysm wall calcification (Fig. 4D). The patient's hemiparesis was worse after surgery but improved with rehabilitation.



**FIGURE 4.** Patient 2, a 48-year-old man who had had a known BA aneurysm for the previous 20 years and presented with right-sided hemiparesis and left-sided trigeminal neuralgia refractory to conventional medical treatment. A, a preoperative sagittal T1-weighted MRI revealed a giant  $3 \times 5$ -cm BA aneurysm with significant intraluminal thrombus and calcification. B, an AP vertebral artery angiogram revealed a giant fusiform BA aneurysm with partial intraluminal filling. C, a postoperative lateral right CCA angiogram confirmed exclusion of the aneurysm from the vertebrobasilar system and a patent saphenous vein bypass graft. D, non-contrast CT scan (obtained after surgery) reveals the extent of aneurysm wall calcification.

## DISCUSSION

The complication and graft patency rates in our study compare favorably with those described in previous clinical reports in which supplemental revascularization was used for the treatment of patients with giant or complex cerebral aneurysms (14, 16, 18, 19) (Table 3).

### Surgical Technique: Maximizing Graft Patency

In the treatment of giant aneurysms, when acute occlusion of a major intracranial vessel is contemplated, a saphenous vein bypass graft provides higher flow and better approximates normal physiological conditions than a superficial temporal artery bypass does (18). Intraoperative blood flow measurements of saphenous vein bypass grafts have been noted to exceed 250 ml/min, as compared with 90 ml/min in the best superficial temporal artery bypasses.

When possible, we prefer to anastomose the proximal bypass graft end-to-side to the ECA, because this type of anastomosis will maintain normal ECA blood flow, thus preserving intracranial collaterals. End-to-side ECA anastomosis was not possible in three patients, however, because of either very early branching of the ECA or improper graft angulation. In these three patients, the proximal anastomosis was placed end-to-side on the CCA.

To minimize soft tissue compression, the bypass grafts were tunneled with a large vascular trocar through a predrilled conduit in the zygomatic arch. Although some advocate reversing saphenous vein bypass grafts before the anastomosis (5), we did not do so. A reversed saphenous vein necessitates the use of a valvulotome to the graft, which may cause endothelial damage and predispose the patient to the development of bypass thrombosis.

Intraoperative angiography allowed immediate verification of graft patency, identification of bypass graft compression or kinking, and evaluation of the anastomoses. In agreement with Barrow et al. (2), we have found that intraoperative angiography documenting graft function is a good predictor of long-term graft patency.

The high flow provided by a saphenous vein graft requires the recipient intracranial vessel to have significant hemodynamic demand. Without this demand, the graft may be predisposed to occlusion, as occurred in one patient in our series in whom the graft was connected to a small M3 segment. We therefore prefer to use an M2 branch as the recipient vessel of choice if the MCA is the site of the distal anastomosis. After ICA occlusion, the recruitment of blood flow by this caliber of vessel seems to be ideal for a saphenous vein bypass.

Acute occlusion of the proximal parent vessel also increases hemodynamic demand on the bypass graft, which further promotes graft patency. Therefore, we do not recommend delayed parent vessel occlusion, as practiced by Hachein-Bey et al. (14). Despite postocclusion heparinization, isovolemic hemodilution, and low-dose warfarin for several weeks after discharge in this series, one patient had graft occlusion 10 days after surgery. The authors presumed that because the ante-

TABLE 3. Results of surgery in patients with giant or complex aneurysms treated with revascularization<sup>a</sup>

Series (ref. no.)	No. of patients	Bypass type	Early graft occlusion	Late graft occlusion	Neurological morbidity	Mortality rate
Lawton et al., 1996 (16)	61	STA/SVG	5%	0%	16%	2%
Hacein-Bey et al., 1997 (14)	9	STA/SVG	11%	0%	11%	0%
Sekhar et al., 1999 (18)	23	SVG/RAG	29%	4%	13%	4%
Sekhar et al., 2001 (19)	17	RAG	6%	0%	12%	12%
Present series (2002)	29	SVG	7%	0%	6%	3%

<sup>a</sup> STA, superficial temporal artery; SVG, saphenous vein graft; RAG, radial artery graft.

grade MCA flow was left intact, a lack of hemodynamic demand caused graft occlusion.

### Thromboembolic and Ischemic Complications

Thromboembolism after parent vessel occlusion remains the most important complication of this procedure. Two of three complications in our series were thrombotic in nature and were probably caused by altered blood flow dynamics in the intracranial circulation after the saphenous vein bypass had been placed and the parent vessel had been occluded. The exact cause of this complication is not known. Perioperative anticoagulation and/or antiplatelet therapy may reduce thromboembolism, but the risk of intracranial hemorrhage has tempered its use. In the study by Hacein-Bey et al. (14), anticoagulation with intravenous heparin was continued for 48 hours after endovascular occlusion of the parent artery. Although none of the nine patients in their series developed thromboembolic complications after carotid occlusion, three patients (33%) had other complications that were probably related to anticoagulation, including one subdural hematoma and two femoral pseudoaneurysms.

Our third complication was a massive hemispheric infarction and death. This complication occurred early in our series and was caused by prolonged temporary occlusion time in the M1 segment of the MCA artery (60 min) as a result of technical difficulties in a patient who did not have adequate collateral reserve. Since that incident, in addition to using shorter temporary occlusion times (mean, 20 min), we have favored constructing the distal bypass on an M2 segment of the MCA, thus interrupting CBF during temporary occlusion to a vessel supplying a smaller volume of brain parenchyma.

### Indications for Bypass

Lawton et al. (16) advocated revascularization in every patient with a complex aneurysm treated with parent vessel occlusion. This recommendation was supported by a delayed stroke risk of 0–1.9%/yr in patients with major intracranial vessel occlusion without universal bypass. The primary morbidity from occluding intracranial vessels for the treatment of giant aneurysms seems to be thromboembolism near the site

of vessel occlusion, and whether universal bypass reduces this complication by altering local hemodynamics is unclear. We have had success using a more selective approach based on BTO and xenon blood flow tomography (Fig. 1) (10).

Two patients in our series had postoperative graft occlusion without clinical ramifications. As mentioned above, one patient received a bypass to prevent rupture of a contralateral cavernous carotid aneurysm protruding into the sphenoid sinus, and the other had a previous CCA ligation with poor CBF distally. After graft occlusion in the second patient, the CBF continued to be low but unchanged. Because his preoperative neurological decline stabilized after surgery despite bypass occlusion, the preoperative deficit was presumed to be from thromboembolism, not hemodynamic insufficiency.

Being an invasive test, BTO is associated with a procedural risk of 0 to 7%, with neurological deficits being secondary to a thromboembolic phenomenon and/or vessel dissection (10, 17, 22). One large series of 300 patients undergoing BTO evaluation had a neurological morbidity rate of 1.7%, with permanent deficits occurring in 0.7% of patients (22). Although BTO with clinical assessment only can be associated with a significant false-negative rate, when supplemented with CBF analysis, the false-negative rate may be minimized (10, 14). Patients with giant aneurysms treated with proximal vessel occlusion without supplemental bypass were excluded from our study; therefore, the false-negative rate for our selective approach to revascularization cannot be determined from the data presented.

## CONCLUSIONS

In properly selected patients and with meticulous attention to surgical technique, saphenous vein EC-IC bypass grafting followed by acute parent vessel occlusion is a safe and effective treatment for patients with giant intracranial aneurysms. A high rate of graft patency and CBF can be achieved. Thrombosis of perforating arteries caused by altered blood flow hemodynamics may be a continued source of complications.

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## COMMENTS

Jafar et al. review 30 saphenous vein extracranial-to-intracranial (EC-IC) bypasses performed to treat giant aneurysms in 29 patients during a 9-year period. They used trial balloon test occlusion (BTO) to select patients for EC-IC bypass in addition to parent vessel occlusion. They report acute patency rates of 93% and a combined morbidity and mortality rate of 9%. No patients experienced subarachnoid hemorrhage or aneurysm recanalization during a mean follow-up period of 62 months. These results are consistent with those in other series that have used saphenous vein bypasses to treat aneurysms.

However, the use of BTO to select patients for bypass has weaknesses. First, BTO testing is associated with a 2 to 22% (1, 3, 4) false-negative rate. Origitano et al. (3) reported ischemic complications in 22% of their patients who passed the BTO, and their mortality rate was 5.5%. Second, the test itself is associated with a 1.7 to 7% morbidity rate (3, 5). Tarr et al. (5) reported 300 patients who underwent BTO, and a 3.7% complication rate was associated with the test. Also, internal carotid artery (ICA) occlusion is associated with a risk of delayed stroke. Oldershaw and Voris (2) reported a 10% incidence of stroke after ICA occlusion during a mean follow-up period of 5.2 years (stroke risk, 1.9%/yr). Finally, de novo aneurysm formation has been reported in as many as 10% of patients after ICA occlusion.

These potential problems must be considered in the treatment of patients with complex cerebrovascular pathology. We use the BTO test to help determine the need for EC-IC bypass in patients with unclippable aneurysms, but we also consider other factors, such as the patient's age and specific findings. For example, we tend to be more aggressive with revascularization in younger patients than in the elderly because of the possibility of de novo aneurysm formation after ICA occlusion. We use low-flow superficial temporal artery-to-middle cerebral artery (STA-to-MCA) bypasses for patients who do not need a high-flow bypass. This alternative is attractive because the patency rates associated with STA-to-MCA bypasses are high; also, compared with saphenous vein bypasses, STA-to-MCA bypasses are associated with significantly lower morbidity rates.

The results of this study by Jafar et al. and their detailed description of the indications and techniques used for this

challenging patient population with giant aneurysms are noteworthy. EC-IC bypass remains a critical part of the cerebrovascular surgeon's armamentarium in the treatment of patients with lesions that are not amenable to clipping or endovascular techniques.

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**C**ertainly, this article is interesting with respect to the number of patients involved in the study. Other studies with a larger number of patients have been conducted as well. Recently, radial artery bypass grafts have been preferred to saphenous vein bypass grafts, for many reasons. In our recently published article (1), we indicated the pros and cons of different kinds of bypasses:

1. Saphenous vein graft bypasses are very tricky to perform and involve many technical details. The flow rate is high (70-140 ml/min), and the flow is turbulent secondary to flow mismatch between the graft and the parent vessels, which may be the pathophysiological explanation for the thromboembolic complications in two of the patients reported.
2. With the radial artery graft bypass, the flow is moderate (70 ml/min), with a better size match to IC vessels. Another advantage of the radial artery graft is the ability to implant it into vessels as small as 1.5 mm. In the series described in this article, for example, the occlusion of the graft in the patient in whom the saphenous vein was anastomosed to the M3 segment could have been avoided. The alterations in the cerebral blood flow hemodynamics after a saphenous vein graft may be reduced by the use of a radial artery graft. This may reduce postoperative thromboembolic events. Possible spasm in the radial artery graft may be prevented by hydrostatic angioplasty (i.e., pressure distension) (1).
3. For the surgical technique used for the saphenous vein graft bypass, in cases in which ECA cannot be used for the proximal anastomosis, we prefer the use of the ICA rather than the common carotid artery. This technique preserves the flow in the ECA and its important anastomotic branches.

In addition, the M1 segment of the MCA should not be used, as demonstrated by Sundt. In this segment, perforators do not tolerate temporary occlusion. We prefer distal anastomosis in the M2 bifurcation when possible. The M3 segment is too small for saphenous vein graft anastomosis. It is not clear whether placing the angiography needle directly into the common carotid artery has any advantages over its placement in the groin. Also, if surgery is planned after preoperative angiography, the sheath can be left in place and be used for intraoperative angiography, thus avoiding additional puncture.

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1. Sekhar LN, Duff JM, Kalavakonda C, Olding M: Cerebral revascularization using radial artery grafts for the treatment of complex intracranial aneurysms: Techniques and outcomes for 17 patients. *Neurosurgery* 49:646-659, 2001.

**T**he authors present their experience in managing 30 unclipable giant ICAs by saphenous vein EC-IC bypass grafting followed by parent vessel occlusion. The series included 30 saphenous vein grafts in 29 patients harboring 30 giant IC aneurysms. Treated lesions were assessed by serial cerebral or magnetic resonance angiography. They comprised 25 ICAs, 2 MCAs, and 2 basilar artery aneurysms. Patient selection for bypass was conducted on the basis of response to BTO and quantitative xenon blood flow tomographic testing. Overall, 28 (93%) of 30 long-term grafts were patent, and all treated aneurysms were excluded from the circulation. Three complications included one transient hemiparesis, one permanent homonymous hemianopsia, and one death thought to be directly attributable to prolonged temporary occlusion time. The authors present their treatment algorithm for giant cerebral aneurysms and conclude that despite technically excellent anastomoses, thrombosis of perforators secondary to altered hemodynamics is a significant potential source of complications.

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**T**he authors describe their surgical management of 30 giant aneurysms that clearly fall into the complex category. Each patient was managed with a combination of acute Hunterian ligation after saphenous vein interposition grafting. The authors' treatment algorithm is quite rational and reserves bypass grafting for those patients who clearly have hemodynamic compromise or overt ischemia during BTO. It is important to look at each case presentation in its own right, because there are substantial differences between the use of this strategy for the carotid circulation and the vertebral basilar circulation. The carotid tree lends itself much better to ICA sacrifice with saphenous interposition grafting to either the supraclinoid carotid artery or the MCA, because there are no



significant branches between the cervical ICA origin and the ophthalmic artery. Typically, the ophthalmic artery restores orthograde flow of the supraclinoid segment, maintaining the anterior choroidal artery circulation if the MCA is chosen as the recipient site. Such is not the case in the posterior circulation, in which the basilar trunk is laced with numerous critical perforating branches. Although thrombosis of the ICA segment is a desired consequence of this strategy in patients with cavernous lesions, such thrombosis is disastrous in patients with complex basilar artery disease. The technique described certainly makes good sense, and I plan to follow their lead in resecting part of the zygoma to expand the soft tissue bed in which the graft will ultimately lie. The authors describe complications relating to prolonged temporary arterial occlusion, trapped perforating vessels in the posterior circulation, and graft occlusion. Their incidence of graft occlusion in the use of saphenous vein material was very low. I totally agree with their recommendation to use the external carotid artery whenever possible, because in carotid sacrifice, using the petrous

carotid or cervical ICA requires ischemia time for two anastomoses rather than one.

I could add to the complications described by the authors one type of complication that our patients experienced recently. We were treating a progressive traumatic supraclinoid carotid aneurysm in a young athlete who also had an isolated MCA circulation. We elected to use an end-to-end saphenous graft into the M1 trunk. The patient awakened beautifully from the procedure but 8 hours later sustained a major ICA hemorrhage, which was followed by a second hemorrhage after evacuation. Each of these bleeds was noted on expiration to have massive flow through the lenticulostrates, leading me to believe that we simply had provided too much flow into the MCA because of the size mismatch in that particular case. In such circulations, perhaps a radial artery or even a large superficial temporal artery would be a more appropriate conduit.

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