Extracranial–intracranial bypass for symptomatic occlusive cerebrovascular disease not amenable to carotid endarterectomy

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Object. The role of cerebral revascularization remains unclear in symptomatic occlusive cerebrovascular disease refractory to medical therapy. Despite the disappointing findings of the Cooperative Study on Extracranial–Intracranial Bypass, a subpopulation of patients with ischemic cerebrovascular disease and poor hemodynamic reserve may benefit from extracranial–intracranial (EC–IC) bypass. The authors reviewed the records of 65 patients who underwent 71 EC–IC bypass procedures at their institution over the past 6 years.

Methods. All patients except one presented with repeated transient ischemic attacks (TIAs) that were referable to the involved vascular region. Eight patients underwent EC–IC bypass urgently for "crescendo" TIAs refractory to antiplatelet and anticoagulation therapy. Indications for surgery included cervical internal carotid artery (ICA) occlusion in 28, supraclinoid ICA stenosis in two, middle cerebral artery stenosis or occlusion in 14, moyamoya disease in 18, and ICA dissection in three. Cerebral angiography demonstrated poor collateral flow to the involved region in each case.

There were no postoperative strokes or deaths in this series. Following EC–IC bypass, the vast majority (95.4%) of patients experienced cessation of their ischemic events and stabilization of preexisting neurological dysfunction. Of the eight patients who underwent EC–IC bypass urgently for crescendo TIAs, two awoke with increased neurological deficits that improved rapidly within 24 hours of surgery.

Conclusions. Although the Cooperative Study failed to show benefit from this treatment modality, the authors have continued to perform EC–IC bypass in certain cases. Carefully selected individuals with occlusive cerebrovascular disease and persistent ischemic symptoms refractory to maximal medical therapy appear to benefit from cerebral revascularization.

KEY WORDS • extracranial–intracranial bypass • cerebrovascular disease • revascularization

Following introduction of EC–IC bypass, the procedure was accepted rapidly as a way to increase cerebral perfusion in patients with ischemic cerebrovascular disease. The disappointing results of the Cooperative Study on Extracranial–Intracranial Bypass in 1985, however, led to the virtual abandonment of this procedure for the treatment of occlusive cerebrovascular disease.[5] Since then, bypass has been reserved largely for the treatment of complex intracranial aneurysms and skull base lesions. Nonetheless, many experienced neurovascular surgeons believe that there are selected patients with ischemic cerebrovascular disease that may benefit from EC–IC bypass.[1,2,4,9,11] This procedure would seem to be an intuitively appropriate treatment for symptomatic patients with compromised hemodynamic reserve in whom maximal medical therapy fails to resolve symptoms. In an attempt to define the role of cerebral revascularization in the treatment of this population of patients, we reviewed the records of all patients who underwent EC–IC bypass procedures for occlusive cerebrovascular disease at our institution over the past 6 years.

CLINICAL MATERIAL AND METHODS

Patient Population

A retrospective review identified 65 patients who underwent 71 EC–IC bypass procedures for occlusive cerebrovascular disease between January 1996 and October 2002. The follow-up duration ranged from 2 months to 6 years (mean 1.3 years). The hospital records, neuroimaging studies, operative reports, and clinic notes obtained in all patients were reviewed. No patient was lost to follow up. Patients who underwent bypass during the same time period for complex intracranial aneurysms or skull base tumors were excluded from this review. Patients who underwent posterior circulation bypass procedures were also excluded.

All patients presented with repeated TIAs that were

Abbreviations used in this paper: CA = carotid artery; CE = carotid endarterectomy; CT = computerized tomography; EC–IC = extracranial–intracranial; ICA = internal carotid artery; MCA = middle cerebral artery; MR = magnetic resonance; STA = superficial temporal artery; TIA = transient ischemic attack.

referable to the involved vascular territory, except one patient who underwent bypass for acute M_1 occlusion. Eight patients underwent EC–IC bypass urgently for "crescendo" TIAs refractory to combination antiplatelet/anticoagulation therapy. All patients underwent four-vessel cerebral angiography, which revealed cervical ICA occlusion in 28, supraclinoid ICA stenosis in two, MCA stenosis or occlusion in 14, moyamoya disease in 18, and ICA dissection in three. Of the 14 patients with MCA stenosis, M_1 stenosis or occlusion was demonstrated in 13 and M_2 stenosis was present in one. Angiography demonstrated poor collateral flow to the involved region in each case. Early in the series, Xe-enhanced CT scanning with and without acetazolamide challenge was conducted to assess cerebrovascular reserve. In recent cases, we have also used perfusion-weighted CT scanning and MR imaging.

Surgical Technique

All patients underwent STA–MCA anastomosis. The surgical technique has been described elsewhere in detail.[6] Briefly, a linear incision is made over the proximal STA anterior to the tragus, and the STA is then dissected for approximately 7 cm. If the anterior branch is chosen for anastomosis, the incision is curved forward to provide increased exposure. After the temporalis fascia and muscle are divided, a 2.5-cm craniectomy is performed at the level of the squamosal suture. The craniectomy can be expanded toward the angular gyrus as needed until a suitable recipient cortical MCA branch is identified for anastomosis. The recipient vessel is cleared of arachnoid for 1 cm and dilated locally by using a cotton ball saturated with papaverine. The STA is then cut obliquely to produce a beveled end. An elliptical incision is made in the recipient vessel. Under temporary vessel occlusion, a direct end-to-side anastomosis is created using running and interrupted No. 10-0 sutures. Intraoperative Doppler ultrasonography is performed to verify the patency of the bypass. For closure, we perform a cranioplasty in which titanium mesh is used, taking care not to injure the bypass. The temporalis fascia is then reapproximated loosely. Finally, the scalp is closed in two layers, and a nonconstricting dressing is applied.

RESULTS

Following EC–IC bypass, the vast majority (95.4%) of patients experienced cessation of their ischemic events or stabilization of preexisting neurological dysfunction. All patients continued to undergo antiplatelet therapy (325 mg of aspirin daily) after surgery. In each case, CT angiography or conventional cerebral angiography (Fig. 1) demonstrated bypass patency.

There were no postoperative strokes or deaths. One patient experienced a TIA in the immediate postoperative period during an episode of hypotension (systolic blood pressure $<$ 90 mm Hg). The patient was kept flat for 24 hours, and antihypertensive agents were withheld. A postoperative angiogram confirmed the patency of the bypass. The patient was mobilized gradually without further incidents.

Of the eight patients who underwent EC–IC bypass urgently for crescendo TIAs, two awoke with increased neurological dysfunction that improved rapidly within 24 hours of surgery. All eight patients underwent anticoagulation therapy in which intravenous heparin was administered, and the heparin was stopped at the conclusion of the bypass procedure. Intraoperative and early postoperative hypotension was avoided.

The majority of the remaining complications were related to wound healing. One patient developed a superficial wound dehiscence and infection requiring only antibiotic therapy. Two patients with infections required antibiotic agents and wound revision, one of which involved a rotational scalp flap to facilitate healing. Another patient developed a persistent pseudomeningocele that resolved with wound revision. Miscellaneous complications in the early postoperative period included seizures treated successfully with antiepileptic medications in one patient and acalculous cholecystitis requiring laparoscopic cholecystectomy in another patient.

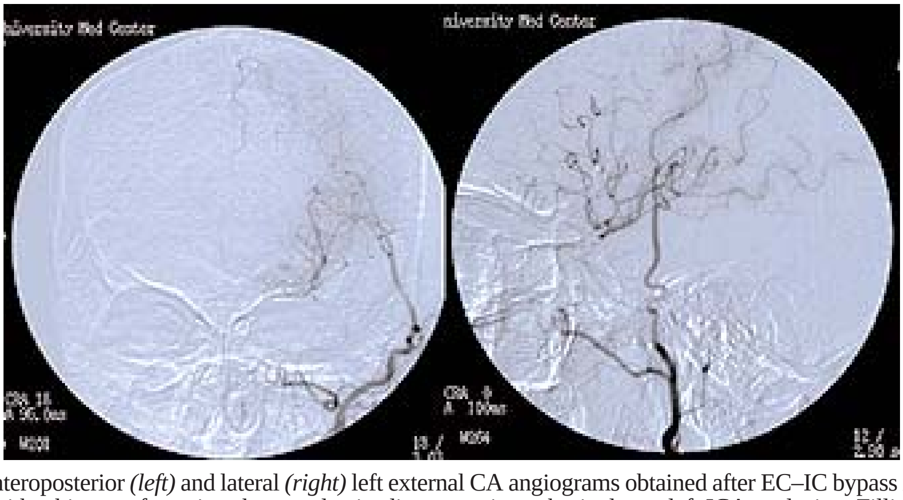

Fig. 1. Anteroposterior *(left)* and lateral *(right)* left external CA angiograms obtained after EC–IC bypass in a 40-year-old woman with a history of cocaine abuse and episodic expressive aphasia due to left ICA occlusion. Filling of the distal MCA branches is seen through the patent bypass.

ILLUSTRATIVE CASE

This 33-year-old right-handed woman with Down syndrome presented with a history of episodic dizziness. On MR imaging we observed bilateral signal changes in the deep white matter (Fig. 2). Magnetic resonance imaging angiography revealed bilateral CA occlusive disease in which attempted collateral formation was apparent, consistent with moyamoya disease–related changes. These findings were confirmed by cerebral angiography (Fig. 3). The patient underwent a left-sided STA–MCA bypass (Fig. 4), and she was discharged from the hospital 3 days later. Postoperatively, her symptoms resolved completely.

DISCUSSION

In general, cerebral ischemia may result from distal arterial embolic occlusion or reduced regional cerebral perfusion secondary to proximal arterial occlusion or stenosis. Investigators in the various CE trials have validated the surgical prevention of stroke in patients with hemodynamically significant stenosis of the cervical CA.[7,8] The benefit of CE may be derived from removal of an embolic source, assumed to be the major cause of stroke in the setting of atherosclerotic disease, or endarterectomy may increase cerebral perfusion by eliminating critical arterial stenosis.

In the setting of symptomatic, occlusive CA disease not amenable to CE, current available medical treatment includes antiplatelet therapy, anticoagulation, and/or the cessation of antihypertensive agents. Surgical therapy consists of cerebral revascularization in the form of EC–IC bypass. The surgical augmentation of regional cerebral perfusion is a theoretically sound concept.[10] The Cooperative Study on Extracranial–Intracranial Bypass, however, failed to demonstrate a clinical benefit from revascularization in this group of patients.[5]

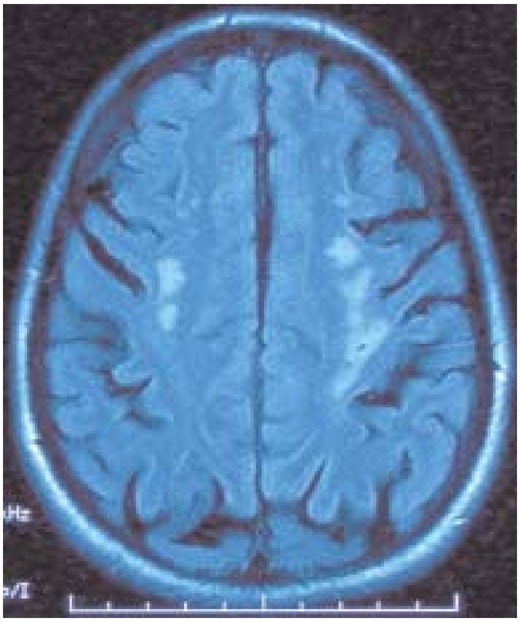

Fig. 2. Axial fluid attenuation inversion recovery sequence of an MR image revealing hyperintensities bilaterally in the centrum semiovale. These signal changes suggest cerebrovascular ischemic disease.

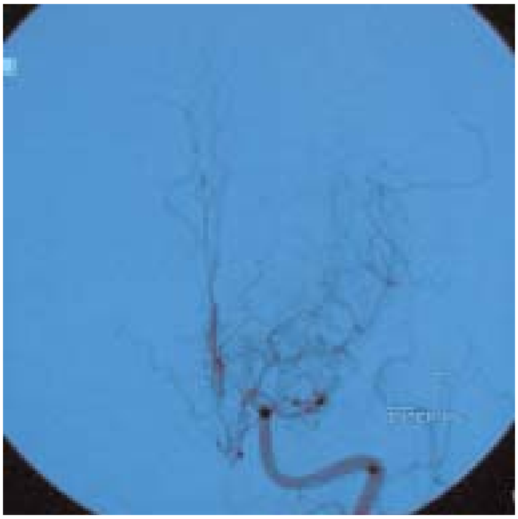

Fig. 3. Left ICA angiogram demonstrating distal occlusion with attempted collateral formation consistent with moyamoya disease–related changes.

As a result of the conclusions reported in the Cooperative Study, EC–IC bypass has been labeled a "wonderful procedure looking for an indication."[3] The methodology and results of the study have been discussed extensively, and its major flaw lies in the process of patient selection. Because a large number of patients were asymptomatic, the study population was composed of many individuals not likely to benefit from bypass.[1–3] The subgroups likely to benefit from EC–IC bypass, those with poor cerebrovascular reserve and those in whom maximal medical therapy failed, were not studied specifically. The potential benefit of bypass in stroke prevention in these subgroups may have been statistically insignificant because of the

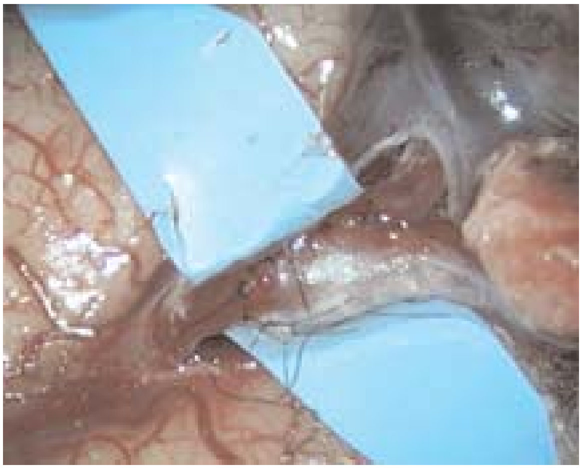

Fig. 4. Intraoperative photograph of completed left-sided end-to-side STA–MCA bypass. Intraoperative Doppler ultrasonography confirmed the patency of the bypass.

large number of low-risk patients enrolled in the trial. Furthermore, many eligible patients at the study centers underwent surgical treatment without randomization to the trial.[11] As a result, extrapolation of the study's conclusions to the entire stroke population and especially these high-risk subgroups has been criticized and considered inappropriate. Additional criticism was directed at the fact that investigators provided no assessment of cerebrovascular reserve or collateral circulation in the studied population.[1–3] Many of the imaging modalities available today such as CT or MR imaging perfusion-weighted studies, MR spectroscopy, positron emission tomography, and single-photon emission CT were not available widely during the study period between 1977 and 1982.

Armed with a refined capacity to study cerebrovascular reserve, there has been a revival of the EC–IC bypass in recent years.[4,9] In the present series, we examined patients in whom cerebrovascular compromise was documented and maximal medical therapy failed. Most of the recent literature on EC–IC bypass has been retrospective and anecdotal. Our series and the recent experiences of others, however, provide impetus for a new EC–IC bypass trial in which long-believed but as yet unproven value of this procedure for cerebral ischemic disease can be appropriately evaluated.

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