Extracranial-Intracranial Bypass for Cerebral Revascularization

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Introduction

Cerebral revascularization for ischemia remains a viable treatment option in the armamentarium of the neurovascular surgeon. The International Cooperative Study of Extracranial to Intracranial Arterial Anastomoses has helped to redefine the indications for these procedures and has improved our understanding of the pathophysiology of cerebrovascular ischemia. In this monograph we will outline our approach to cerebral revascularization, discuss patient selection criteria, and review our surgical techniques and results.

Theoretical Considerations

Revascularization of the brain and brainstem in the treatment of ischemia has great theoretical merit. A vascular conduit from the extracranial circulation to the intracranial circulation circumventing vessel occlusion or stenosis should be expected to provide a significant additional nutrient blood supply and ameliorate symptoms of ischemia secondary to hypoperfusion. Several individual investigator series have documented improved neurological function following extracranial-intracranial (EC-IC) bypass with long-term resolution of symptoms [2, 3, 7, 9]. Cerebral blood flow studies employing several measurement techniques have demonstrated a marked increase in regional cerebral blood flow in previously ischemic regions following bypass surgery [7].

This rationale and these observations appeared to be invalidated by the findings from the recent International Cooperative Study of EC-IC Arterial Anastomosis [10]. Patients in that study who underwent bypass surgery had a worse outcome and more ischemic symptoms and strokes than did patients randomized to medical treatment. At first glance, it appeared that the EC-IC bypass was an excellent surgical procedure but was without specific indications and of no proven benefit.

Since the initiation of the EC-IC bypass study, much has been learned about the pathophysiology of cerebrovascular ischemia. The results of the Cooperative Study have been analyzed in detail, and the indications for cerebral revascularization have been redefined [1, 10]. Anterior and posterior EC-IC revascularization procedures are now being utilized in a much more rational and judicious manner and, as a result, are performed much less frequently than prior to the announcement of the Cooperative Study results. The EC-IC bypass procedure does have merit; however, patients must be carefully selected. Only those individuals who have recurrent transient ischemia due to hypoperfusion which is refractory to optimal medical management and who are acceptable surgical candidates with respect to anesthetic risk should be considered for EC-IC revascularization.

The most heralded and frequently performed EC-IC anastomosis has been the superficial temporal artery to middle cerebral artery (STA-MCA) bypass for anterior circulation disease. Several variations of this procedure have been performed including STA to middle meningeal artery bypass, a "bonnet" bypass to the contralateral MCA, and the use of various interposition grafts (vein, artery, prosthetic grafts) in attempts to augment cerebral blood flow [2–4, 7]. Several bypass options exist in the treatment of posterior circulation ischemia including STA to posterior cerebral artery (STA-PCA), STA to superior cerebellar artery (STA-SCA), STA to anterior inferior cerebellar artery (STA-AICA), and STA to posterior inferior cerebellar artery (STA-PICA) anastomoses [3, 7]. Frequently the occipital artery, rather than the STA, will be used as the extracranial vascular conduit when attempt-
ing revascularization of the AICA or PICA vascular distributions.

**Patient Selection**

The majority of patients with cerebral ischemia have symptoms due to thromboembolism [1, 7]. Patients with TIAs or stroke from hemodynamic vascular insufficiency nonetheless represent a significant minority. Often, multiple factors are operating simultaneously to produce symptoms in an individual patient. Great care must be taken to correctly diagnose cerebrovascular insufficiency. Vague complaints, such as light-headedness, dizziness, or headache, must be accompanied by more concrete signs and symptoms of hemodynamic compromise and must correlate with demonstrable pathology on the radiological studies. All patients with symptomatic cerebrovascular disease are evaluated with angiography, computerized tomography (CT), stable xenon cerebral blood flow CT, and, recently, magnetic resonance imaging (MRI).

Compulsive four-vessel head and neck angiography (including aortic arch views) is essential to document vascular occlusion or stenosis, the presence or absence of collateral blood supply (or a steal phenomenon), and the location and caliber of extracranial vascular channels. CT studies help identify regions of infarction and provide critical information about ventricular size and the presence of other mass lesions (e.g., cyst, tumor, hematoma, AVM) which might mimic ischemic disease. The stable xenon CT documents regions of relative hypoperfusion, and the MRI studies provide information regarding acute ischemic events and multiple infarctions and give precise views of the brainstem and posterior fossa structures, which are poorly visualized on CT scans.

All patients undergo detailed medical evaluations, including a cardiological work-up for a potential cardiac embolic source. Attendant medical problems are brought under optimal control. If patients remain symptomatic despite trials of aspirin or anticoagulants and they are reasonable candidates for surgery (from an anesthetic risk perspective), then they are considered for a cerebral revascularization procedure. The procedure to be performed is based on individual pathology-anatomy with the bypass directed at the ischemic region of greatest need.

**Technical Considerations**

Several aspects of the general operative anesthetic management of patients treated with cerebral revascularization procedures are the same irrespective of the specific anastomosis to be performed. All operations are performed under general anesthesia with maintenance of normotension, normocapnia, and adequate oxygenation (PO\(_2\) > 100 torr). All patients receive intraoperative monitoring of EEG by compressed spectral analysis and somatosensory and brainstem auditory evoked potentials [3, 6, 7]. Heparin (100 units/kg) is administered intravenously before intraoperative occlusion of the recipient vessel and is not reversed at the conclusion of the procedure. Aspirin (5 grains t.i.d.) is administered preoperatively and continued postoperatively.

Before vascular clamping of the recipient vessel, barbiturates (thiopental, 1–3mg/kg loading dose) are administered to achieve EEG burst suppression. During the period of vessel occlusion, barbiturates are continued at a dose adequate to maintain burst suppression. If hypotension occurs before burst suppression, pressors (usually dopamine) are administered to maintain normotension [3, 6, 7]. Shunts are not used.

The Shaw hemostatic scalpel (Oximetrix Inc., Mountain View, CA) is employed to make the skin incision and to perform the initial dissection. This instrument provides excellent hemostasis and allows a rapid, bloodless approach to both the donor and recipient vessels. A portable Doppler unit is often employed early in the procedure to map the course of the donor vessel when it is otherwise not apparent by inspection. When performing the intracranial anastomosis, a small plastic dam is placed beneath the recipient artery and a Microvac suction (Microvac, PMT Inc., Hopkins, MN) is placed beneath or near the dam to constantly clear cerebrospinal fluid from the operative field [3, 6]. When using a vein interposition graft, great care must be taken to avoid damage to the vessel during harvest. All side branches must be tied securely, and the orientation of the interposition graft once in place must be rechecked to avoid kinking or twisting and compromise of the lumen.

All procedures are performed utilizing the operating microscope with its superb optics, lighting, and magnification. Following surgery, patients are monitored in the intensive care unit for management of postoperative hypo- or hypertension. Patients usually receive follow-up angio-