Extracranial-Intracranial Vascular Shunt Procedures

ROMAS SAKALAS, M.D.

Assistant Professor, Division of Neurological Surgery, Medical College of Virginia, Health Sciences Division of Virginia Commonwealth University, Richmond, Virginia

Cerebrovascular occlusive disease has been and continues to be a leading cause of death and disability throughout the world. In the United States there are about 400,000 new strokes each year.[1] Some 90% of strokes are a result of vascular occlusion of the extracranial circulation.[2] Surgical treatment of occlusive vascular diseases, principally carotid endarterectomy, has become an accepted method of treatment of a large number of patients. However, only about 70% of patients with cerebrovascular disease have surgically accessible lesions in the extracranial circulation. The remaining 30% are a result of intracranial occlusive disease which cannot at present be treated by carotid endarterectomy.

Endarterectomies or embolectomies or both have been attempted intracranially but have carried high morbidity and mortality rates. Middle cerebral artery embolectomy, for example, has been successfully performed technically, but the results have been poor. Presently, bypass procedures seem to carry a smaller mortality and morbidity rate and a better clinical result. Austin has estimated that there are about 12,000 patients with inoperable lesions by conventional vascular techniques who might be candidates for a bypass procedure of an obstructed or stenosed intracranial vessel.[3]

The first intracerebral bypass procedure was performed in 1944 by Henschen.[4] He transplanted a pedicle of temporalis muscle over the surface of the brain. The patient apparently improved, but this bypass procedure did not become popular. In 1967, following the development of the operating microscope and the reduction in size of suture material, a new microvascular bypass procedure was developed by Donaghy and Yasargil.[5,6] Blood was diverted from a scalp vessel, the superficial temporal artery, to a small middle cerebral artery branch on the surface of the brain to provide a blood supply distal to the site of the occluding lesion. This approach offered the possibility of surgical treatment for previously inoperable lesions in order to prevent, delay, or lessen the possibility of infarction.

The extracranial-intracranial anastomosis as described by Donaghy and Yasargil[5,7,8] is performed with minor modifications (Figure). A frontal temporal incision is made to include both branches of the superficial temporal artery. The branches of the artery are meticulously dissected, using the operating microscope. This is often the longest part of the procedure. The brain is exposed over the sylvian fissure through a craniectomy of about 3 to 4 cm in diameter. A cortical artery is selected on the basis of size, absence of penetrating branches, and location. The most commonly used branches have been the opercular, the angular, and the temporal. If the situation suggests that a particular area is at risk, and if a suitable cortical vessel can be identified as serving the area, this vessel is selected. Temporary clips are placed across the selected artery, an elliptical incision is made, and an internal silicone rubber stent is inserted to keep the edges apart. The superficial temporal artery is brought into the field and an end-to-side anastomosis is performed using a 10-0 suture. The stent and temporary clips are removed. Patency

Correspondence and reprint requests to Dr. Romas Sakalas, Department of Neurological Surgery, Box 758, Medical College of Virginia, Richmond, Virginia 23298.

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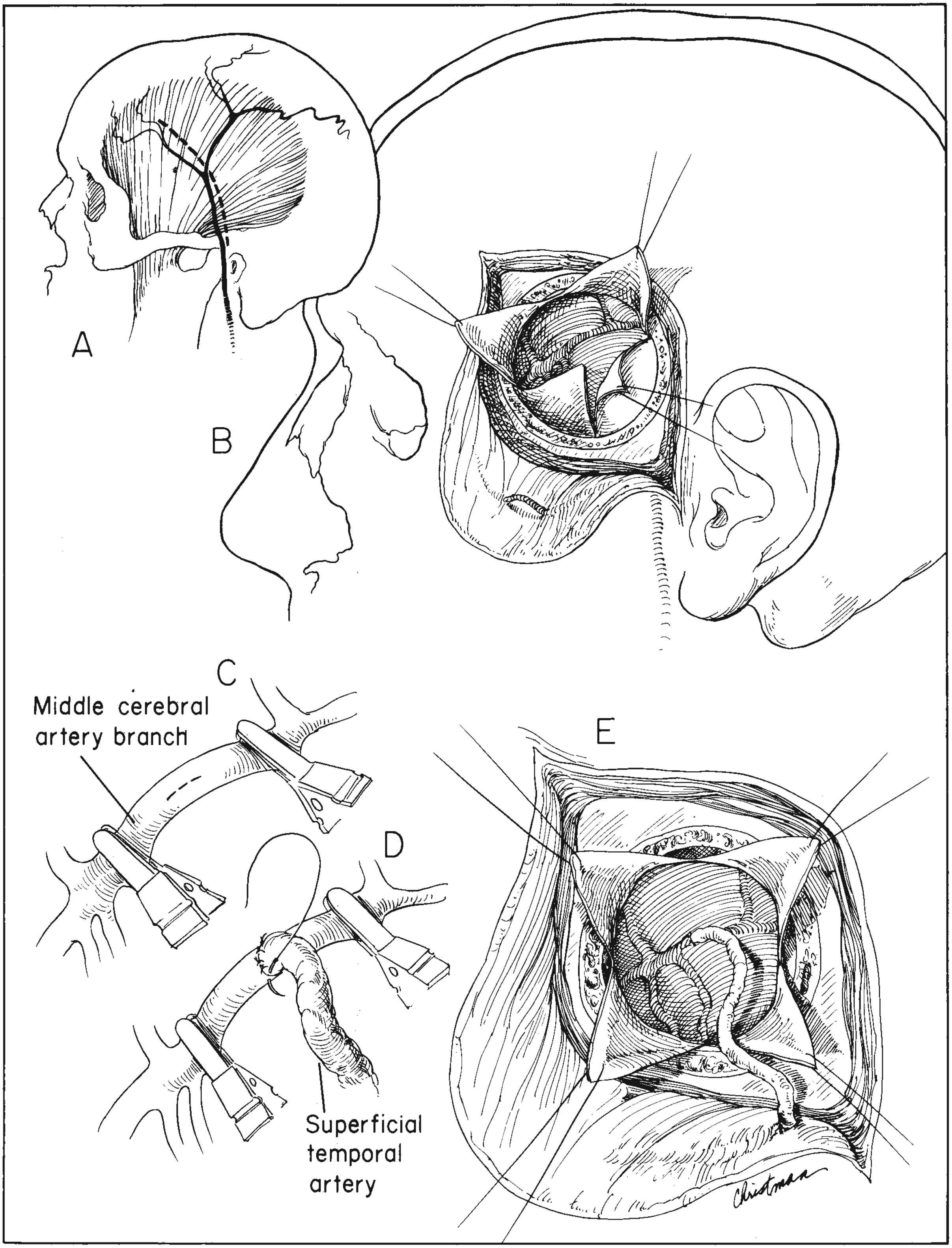

The Superficial Temporal Artery-Middle Cerebral Artery Branch Anastomosis (STA-MCAB). *A*. Placement of skin incision for exposure of STA. *B*. 4 cm craniotomy performed to expose the sylvian vessels. *C*. Isolation of MCAB. *D*. Microsuturing of STA-MCAB. *E*. STA-MCAB anastomosis.

can be observed by the pulsating vessels. Using electromagnetic flow meters, Crowell found that the anastomosis provided 20 to 40 cc/min of blood.[9]

Ideally, a large vessel should be used for establishing a bypass procedure. The superficial temporal artery to middle cerebral artery anastomosis has several disadvantages. The vessel diameters are small; about 1.5 mm ± .5 mm. With this small cross-sectional area, only a limited amount of blood is available (20 to 40 cc/min) which may not be sufficient to provide adequate flow. Middle cerebral artery flow is in the neighbornood of 120 cc/min. Therefore, flow through the anastomosis can account for only about 25% of the total arterial blood flow. It seems unlikely that superficial temporal artery-middle cerebral artery (STA-MCA) bypass flow of this magnitude will be able to sustain an entire human hemisphere, although it could provide functional improvement in cases of focal cerebral ischemia with focal deficits. It is conceivable, however, that with time the anastomosis could provide adequate flow, since flow is proportional to the fourth power of the radius, and increase in graft size with time has been observed. The limited size of the vessels poses a second problem. The chances for occlusion due to thrombus formation at the operative site are increased as the diameter of the vessels decreases. Meticulous surgery, however, can overcome this problem. Reichman has reported a 100% patency rate in 19 patients at the end of four years.[10]

Theoretically, the value of the STA-MCA anastomosis relates to the question of whether the pathogenesis of transient ischemic attack (TIA) and reversible ischemic neurologic deficit (RIND) is related to decreased total brain perfusion from inadequate collateral circulation in the presence of occluded or stenosed vessels, or secondary to emboli associated with ulcerated atheromatous plaques. Certainly there has been adequate documentation of the ulcerative, stenotic plaque at the carotid bifurcation discharging emboli during TIAs, that is, cholesterol emboli visualized in the fundus during an episode of amaurosis fugax. There are also some TIAs which result from transitory depression of cardiac output in patients who already have a significantly depressed cerebral blood flow (CBF) on the basis of a major vascular occlusion, cerebral small vessel disease, or a high stenosis. Evidence of this comes from Sengupta et al, studies in baboons following carotid ligation.[11,12] They showed that the cerebral vasculature cannot respond to stress (anoxia, CO_2 reactivity, and changes in BP) in a normal manner after ligation of a carotid artery. This suggests that when the blood flow is borderline, due to a basic lesion, further stress, such as a drop in pressure from decreased cardiac output may not be compensated for by the normal process of autoregulation and thereby provides the setting for the occurrence of TIA or stroke or both. A large group of workers have shown that a 25% to 40% reduction in gray matter blood flow is sufficient to produce the onset of symptoms.[13,14,15,16]

The volume of CBF cannot be accurately predicted on the basis of angiography alone; it must be measured directly. Patients with stenotic lesions often have both ipsilateral and contralateral decreased flow. Reichman studied 16 patients with carotid occlusion, and middle cerebral artery occlusion and stenosis, all of whom had globally reduced CBF.[17] Schmiedek and Gratzl have noted five different flow patterns in patients with severe cerebrovascular disease.[18,19,20] In these patterns regional CBF was:

1. severely reduced throughout (>50% reduction),
2. moderately reduced throughout,
3. generally reduced with an additional focus of relative ischemia,
4. normal in flow with focal areas of ischemia, and
5. generally normal.

Following STA-MCA anastomosis, Austin,[3] Reichman,[17] and Schmiedek[21,22] demonstrated a statistically significant increase in CBF both regionally and globally.

The world-wide clinical experience with STA-MCA bypass procedures has also been extremely encouraging in about 1,000 cases. Combining the overall results from several large reported series, about 85% of those operated upon for TIA or RIND or both were considered improved, while for strokes in progress or completed stroke, about 40% to 80% showed improvement.[3,23,17] There have been no reported deaths due to this procedure, although there has been a 3% to 5% mortality in this group of patients. The most common cause of death has been myocardial infarction. Some 6% of the patients were transiently worse following surgery, but only one case has been reported in which the increased neurologic deficit was permanent. This was probably due to the rupture of an aneurysm which was operated on at the same time. Scalp necrosis has occurred in about 3% of the cases.

The indications for microsurgical cerebral revascularization are quite specific. These procedures are to be considered *only* when conventional disobliterative vascular techniques are inappropriate, inadequate, or contraindicated in patients who are *symptomatic* from angiographically demonstrated lesions. Thus, the following are indications for STA-MCA anastomosis in *symptomatic* patients:

1. Complete long-standing obstruction of the internal carotid artery.
2. Fibromuscular hyperplasia where disease extends into the base of the skull.
3. Severe stenosis of the internal carotid artery at the base of the skull.
4. Lesions of the proximal middle cerebral artery.

Contraindications to the bypass procedures are similar to those for carotid endarterectomy.

1. Completed stroke with hemiplegia or aphasia or both.
2. Severe vascular disease of the external carotid artery.
3. Malignancy or any other process in which prognosis is extremely poor, that is:
   (a) Myocardial infarction within a six-month period of time.
   (b) Severe, unstable ischemia, or valvular heart disease.
   (c) Severe liver, pulmonary, or renal disease.

In summary, superficial temporal artery-middle cerebral artery anastomosis has been successfully performed in over 1,000 patients with a good patency rate and low morbidity. It appears to be successful in alleviating symptoms or improving neurologic function in a significant number of patients who have not responded to medical management and who are unsuitable for routine vascular surgery.

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