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James I. Ausman

Fernando G. Diaz

R. A. de los Reyes

Carl Shrontz

Jeffrey Pearce

See next page for additional authors

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James I. Ausman, MD, PhD,* Fernando G. Diaz, MD, PhD,*
R.A. de los Reyes, MD,* Carl Shrontz, MD,* Jeffrey Pearce, MD,*
and Manuel Dujovny, MD*

The surgical management of patients with cerebrovascular disease is reviewed. Our approach to the management of extracranial cerebral vasculature is discussed first, and increasingly more complex areas are then presented. Our discussion reviews the applications of carotid endarterectomy, extracranial-intracranial bypass procedures, and vertebral extracranial reconstruction.

The surgical management of patients with cerebrovascular disease is extremely controversial (1-6). Multiple approaches have been designed for different problems in the carotid and the vertebrobasilar circulation, but, to date, no randomized control study has shown that the surgical procedures indeed produce any definite benefit for the patients. The symptomatic relief many patients have experienced and numerous nonrandomized surgical studies indicate that surgery has some potentially beneficial applications in the management of patients with cerebrovascular disease (1,6-11).

The incidence of cerebral infarction following the onset of ischemia of the anterior or posterior circulation is believed to approximate 35% within the first four years (3,12,13). The incidence is greatest during the first year and especially during the first month after the onset of symptoms (3,12,13). Cerebral infarctions developing in the anterior or the posterior circulation occur with a similar frequency (12,13). Once a cerebral infarction has developed, over 90% of these patients will either die or be left with a permanently disabling condition (4,6,12-17).

Clinical Presentation

Patients who develop cerebral ischemia present with a stereotyped set of symptoms, usually referred to as transient ischemic attacks (TIA). These attacks are generally short (usually under 30 minutes long), recurring, usually resolve completely, and follow the same pattern of distribution (4,5,8,12,14-18).

Transient ischemic attacks of the anterior circulation are characterized by episodes of transient loss of vision (amaurosis fugax), generally of one eye. They are described as the closing of a shade over the eye or progressive dimming of the vision (19). In some cases, loss of vision is complete and sudden. Episodes of contralateral hemiparesis or hemisensory deficits may occur at the same time or independently (4,12,14,16,18). When ischemia occurs in the left hemisphere, it is frequently associated with loss of speech (4,12,14-16).

Vertebrobasilar TIAs of the posterior circulation are generally mixed and complex and present with a combination of symptoms, including cranial nerve abnormalities, crossed sensory or motor changes, bilateral visual disturbance, and dizziness (7,10-12,19). Patients with vertebrobasilar insufficiency (VBI) frequently complain of diplopia, dizziness, vertigo, imbalance, blurring of vision of both eyes, and dysarthric speech. Their sensory and motor findings are generally contralateral to the cranial nerve abnormalities; often the sensory and motor findings occur in opposite sides of the face and body. A minimum of two of these symptoms, at least one of which must involve the axial nervous system, is generally required for the designation of vertebrobasilar insufficiency (7,9,11,12).

The clinical presentation of patients with cerebral ischemic events generally will not permit accurate prediction of the specific site of vascular pathology (21). Various sources of problems must be ruled out, including: 1) cardiac causes such as dysrhythmia, emboli, valvular abnormalities, or, occasionally, atrial myxoma; 2) hematologic causes, including blood dyscrasia, coagulopathies, leukemia, and some hemoglobinopathies such as sickle

cell anemia; 3) vascular abnormalities, which can be encountered from the aortic arch to the small intracranial vessels and include occlusive ulcerated and stenotic atherosclerotic plaques, inflammatory angiopathies, fibromuscular hyperplasia, and Moya Moya disease (2,8,15,17, 18,21-23). We believe that selective cerebral angiography is the only means currently available by which a precise anatomical and topographical vascular diagnosis can be established; it should be advised for all patients in whom causes other than vascular have been excluded (3,7,24).

Surgical Procedures for the Anterior Circulation

The indications for surgical intervention have not been completely accepted (1,3,12,16,25,26). However, most would agree that patients with transient ischemic attacks who have a significant vascular lesion corresponding to the involved cerebral hemisphere should be considered for surgical intervention (1,3,4,16,27-30). Patients who have suffered a cerebral infarction and recovered considerable function are also considered to be candidates for surgical treatment (1,3,6).

Two types of vascular lesions are important in the development of cerebral ischemia. These are hemodynamically significant stenosis located at the common carotid bifurcation of the internal carotid arteries and ulcerated plaques (1,3,16,18,21,23,25). Hemodynamically significant lesions should involve more than 80% of the cross-sectional lumen of the vessel; in biplane angiography, any involvement greater than 50% of the opacified vessel lumen corresponds to 80% of the cross-sectional diameter of the vessel (3,24). Patients who present with ulcerative lesions in the internal carotid artery, with or without a concomitant carotid stenosis, are considered to have a significant lesion.

The mechanisms involved in producing symptoms in these two situations are different. Patients with hemodynamically significant lesions present a flow problem in which the corresponding hemisphere is receiving insufficient blood through the corresponding carotid circulation (8,16). Those patients with ulcerative lesions in the internal carotid artery generally have symptoms secondary to emboli (18,25,31). Fibrin, cholesterol, or platelet emboli can originate from these ulcerative lesions and lodge in the intracranial cerebral circulation.

Patients with ulcerative lesions of the carotid artery may benefit from antiplatelet agents or anticoagulants. In the Canadian Cooperative Study, aspirin was reported to be beneficial in decreasing the incidence of transient ischemic attacks and cerebral infarction in men (20). However, in the American Aspirin Study (32), no differ-

ence was found in the incidence of infarction among men, and only symptomatic benefit was seen. Neither study found any evidence that aspirin provides protection for women. Anticoagulation has been suggested to treat patients with ulcerative lesions (33). While symptoms improve for individual patients, no definite randomized study has shown that full anticoagulation treatment decreases the incidence of infarction. Some reports have indicated that anticoagulation may in fact increase the risk of embolization by preventing the development of normal endothelium over the ulcerated area (25). In those cases in which a pure hemodynamic lesion contributes to the transient ischemic events, it is unlikely that anticoagulation could offer any significant benefit, since there is no embolic source.

To date, no well-controlled randomized study has demonstrated that carotid endarterectomy decreases the frequency of cerebral infarction when patients are compared to an untreated population (2,4,8). However, numerous large studies have shown that in nonrandomized populations, the incidence of cerebral infarction is lower among patients who had a carotid endarterectomy than among patients who refused the operation or who were not operated upon for different reasons (1,3,5, 27,28,30). Acceptable surgical risks for mortality from carotid endarterectomy are generally under 3%, and for neurological morbidity, including TIAs and cerebral infarction, the risks are under 2-3% in most series (Fig. 1) (1,3,5,27,28,30). The long-term stroke rate in carotid endarterectomy patients is 2% per year. When the risks
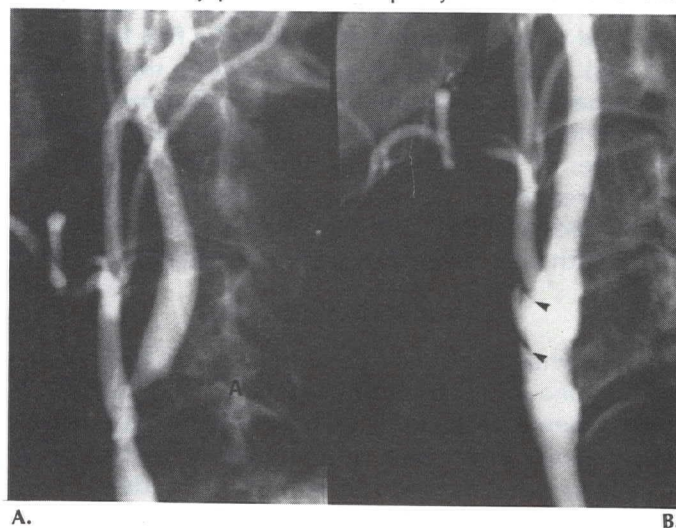

A.   B.

Fig. 1

Left lateral carotid angiograms of a 56-year-old white woman with repeated episodes of expressive dysphasia and right hemiparesis. A. Preoperative angiogram showing marked internal carotid artery stenosis. B. Postoperative angiogram showing reconstitution of internal carotid artery with minimal postoperative changes.

from anticoagulation therapy and aspirin are compared to the risks of no treatment, no treatment (29) and anticoagulation (28) have a 35% stroke rate, aspirin 17% (7), and carotid endarterectomy 11%. These data come from multiple studies and compare possibly different groups of patients. All patients had TIAs, but only the surgical group was further selected by angiography.

In our experience with 375 procedures performed from October 1978 through September 1982, we found an incidence of 0.8% TIAs, 2.4% permanent neurological deficits, and 2% mortality in the immediate postoperative period. Our patency rate is 204 of 214 patients (95%) who had postoperative angiograms.

Extracranial-to-Intracranial Anastomosis

The recent development of microsurgical techniques has permitted the application of these principles to the intracranial reconstruction of small vessels. The surgical principle used for bypass reconstruction for the cerebral circulation is the microvascular anastomosis of an extracranial-to-intracranial vessel (EC-IC) (7,10,11,20,34). The superficial temporal artery and, on a few occasions, the occipital artery have been used as donor vessels (Figs. 2,3). In some cases, radial artery and saphenous vein grafts have been placed between the carotid or the subclavian artery and the middle cerebral circulation (34). Synthetic grafts have also been used (35).

Clinical indications for the application of EC-IC arterial anastomosis have not been generally accepted (9,16,34). In our clinic, those patients who present with episodes of transient cerebral ischemia referable to the anterior circulation or who have had a completed infarct, with suffi-

cient recovery of neurological function, are considered suitable cases. The radiographic findings which provide the most common indications are inaccessible lesions in the carotid artery. These include complete obstruction of the internal carotid artery, complete obstruction of the common carotid artery, and high grade stenosis of the carotid artery in the petrous portion, cavernous portion, or supraclinoid area. Middle cerebral artery lesions, either stenotic or occlusive, are also included. In occasional patients, occlusion of a middle cerebral artery by tumor, especially meningiomas, has been treated by an EC-IC arterial anastomosis before tumor resection. In some patients, giant aneurysm of the cavernous carotid artery, or of a supraclinoid carotid artery, or middle cerebral artery which cannot be surgically excised, has been treated with simultaneous occlusion of the internal carotid artery in the neck and EC-IC anastomosis (34).

At present, an international randomized clinical trial is underway to help establish the value of EC-IC bypass surgery in selected patients who have specified symptoms and radiographic lesions. Final answers from the study will not be available for three more years. In the meantime, our institutional criteria for selection include symptomatic patients who have appropriate internal carotid occlusion, carotid siphon stenosis, or middle cerebral artery stenosis or occlusion. Patients with incidentally detected but angiographically significant (more than 50%) carotid siphon or middle cerebral stenosis have prophylactic bypasses, since these are dangerous
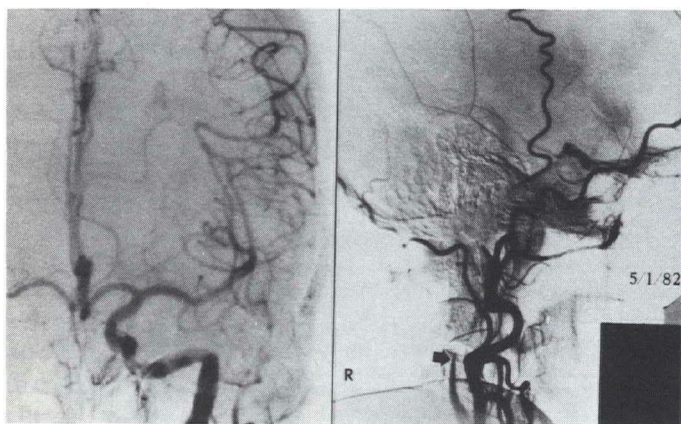

Fig. 2

Preoperative angiograms of a 44-year-old black woman with sudden left hemiparesis. AP (left) and lateral carotid angiograms (right) demonstrating complete right internal carotid occlusions with some crossed filling of right MCA via anterior communicating artery.
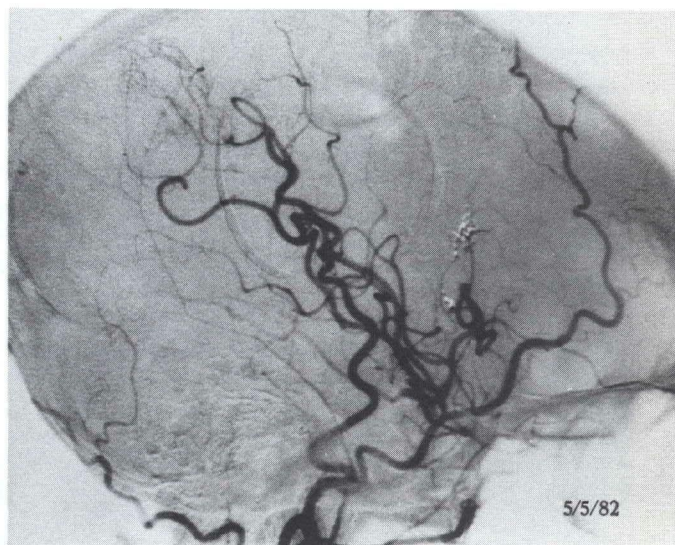

Fig. 3

Postoperative angiogram of a 44-year-old black woman with left hemiparesis showing filling of right MCA tree through a patent STA-MCA anastomosis. (See Fig. 2 for preoperative angiograms.)

lesions. For patients who have a single event and an appropriate internal carotid occlusion, the decision is not clear. Those patients under 55 years old are offered a bypass; the incidence of cerebral infarction ipsilateral to a carotid occlusion is 3% per year, and at a young age this can represent significant potential morbidity. Cerebral blood flow studies are also used to select those with an appropriate perfusion deficit for bypass surgery.

Acceptable surgical risks, including any type of neurological morbidity and mortality, are about 2% for each. In our series of 425 patients, we have no mortality for intracranial procedures of the anterior circulation and 2% permanent neurological deficits immediately after surgery. Our patency rate is greater than 97%.

Intracranial Reconstructions

Intracranial vessels frequently have selective lesions located at the origins of the trunks of the anterior or middle cerebral arteries. In these cases, or in cases in which a large aneurysm is present at the origin of one of these vessels with involvement of a major branch originating from the aneurysm itself, other surgical alternatives are frequently necessary. In these cases, we have found it necessary to proceed with reimplantation of a main trunk of the middle cerebral artery or with a middle cerebral artery endarterectomy. In selected cases of an

embolus to the middle cerebral artery, an embolectomy has been done successfully. These three procedures are still in an elementary developmental stage, and we have not been able to determine their clinical indications or the frequency of complications. Technically, we have been able to complete these procedures successfully, but further investigation will be required before a final conclusion can be reached.

Vertebrobasilar Insufficiency

The clinical indications for surgical intervention in patients with vertebrobasilar insufficiency relate directly to the occurrence of repeated episodes of symptoms referable to the posterior circulation. Since it is not possible to localize clinically the pathological source of symptoms in the vertebrobasilar territory (21), it is important to obtain detailed angiography, including the origins of the vertebral arteries and their entire course through the vertebrobasilar junction and basilar artery. Lesions at any one of these levels, or in the subclavian artery, can lead to vertebrobasilar insufficiency (2,7,10,11,20,36). The symptoms of patients with vertebrobasilar insufficiency are believed to derive from hemodynamic causes. If this hypothesis is correct, and since antiplatelet agents and anticoagulants do not correct hemodynamic problems, mechanical correction of the perfusion deficit is the preferred therapeutic alternative.
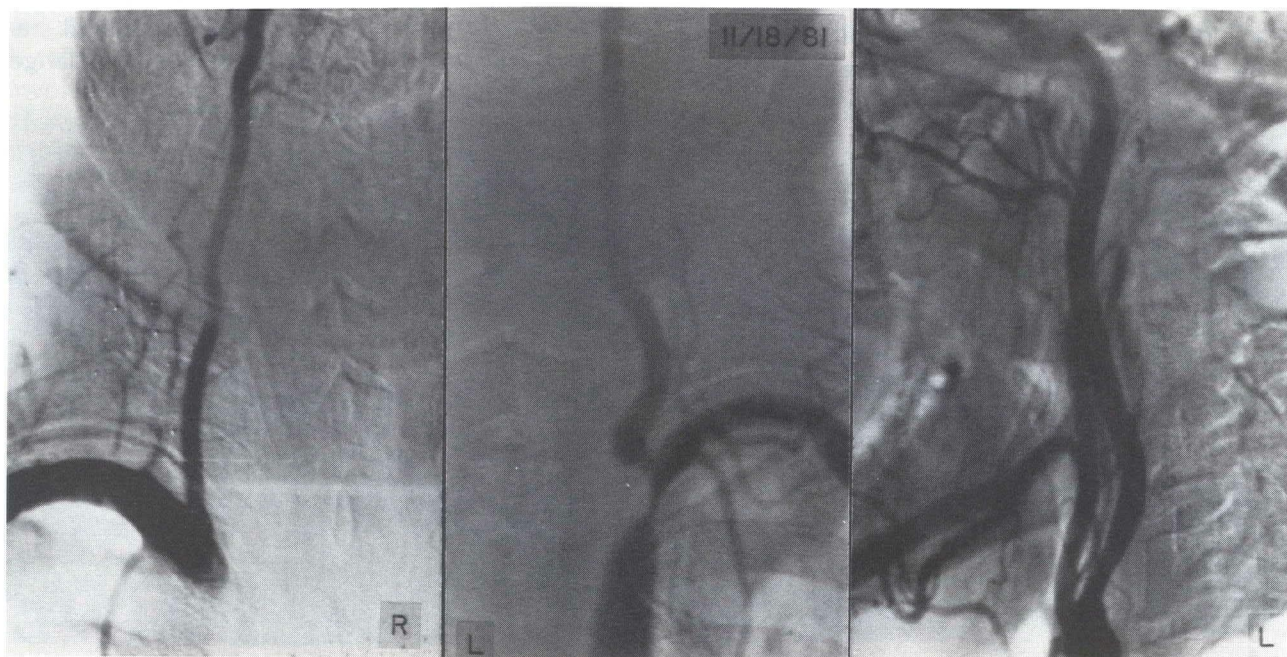

Fig. 4

Preoperative angiograms of a 62-year-old white man with repeated episodes of vertigo and bilateral visual blurring: Preoperative right and left subclavian and left carotid arteriograms revealing complete right subclavian occlusion, marked left subclavian and moderate left internal carotid artery stenosis.
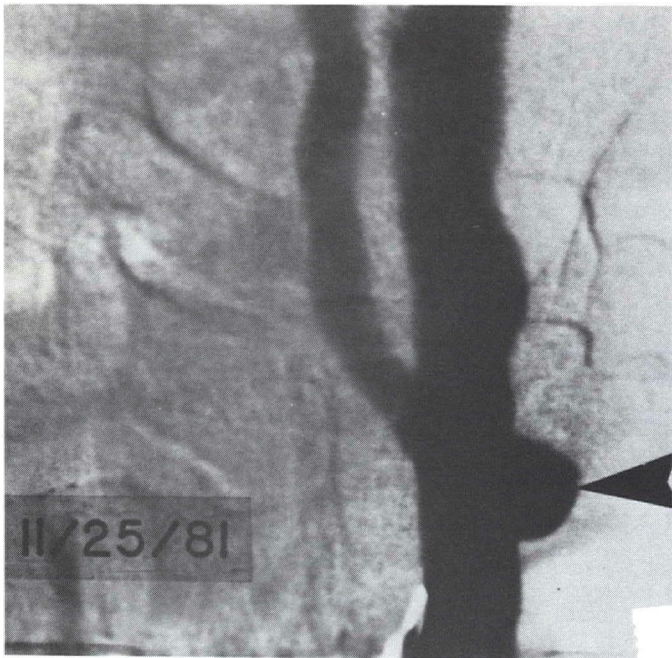
Fig. 5

Postoperative angiogram of a 62-year-old white man with repeated episodes of vertigo and bilateral visual blurring showing anastomosis of left vertebral artery to left common carotid artery.
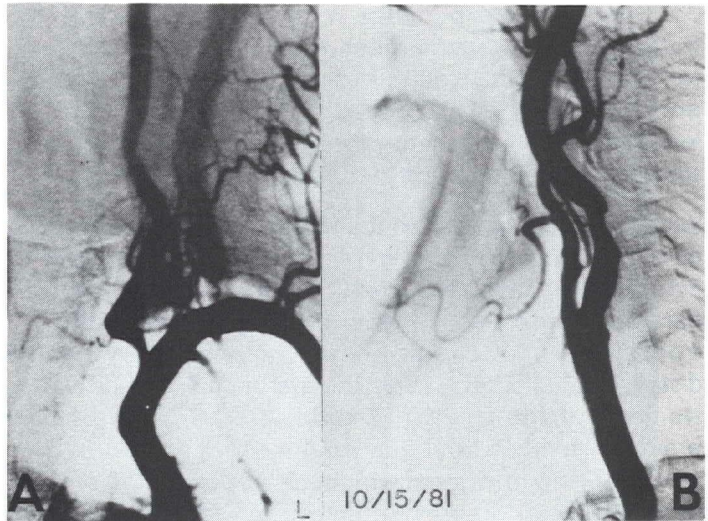

Fig. 6

Preoperative angiograms of a 63-year-old white woman who presented with one episode of right hemiparesis. A. Preoperative left subclavian angiogram revealing marked left vertebral artery stenosis; right vertebral artery was occluded. B. Preoperative left carotid angiogram showing markedly stenotic and ulcerated left internal carotid artery distal to the carotid bulb.

The surgical procedures which can be performed vary according to the location of the pathologic lesion. In patients with subclavian artery stenosis, a reversal of flow in the vertebral system caused by a "steal" of blood with reversal of flow into the arm produces ischemic compromise of the vertebrobasilar territory (19,36). In these patients, available corrective measures include ligation of the vertebral artery at its origin, with transposition of the vessel to the common carotid artery (Fig. 4,5), or transposition of the subclavian artery to the common carotid artery. Other methods, such as a subclavian endarterectomy or a subclavian-to-subclavian graft have been used, but these are much more extensive procedures that require a thoracotomy or clavicular removal (19).

Many surgical approaches have been used for lesions originating in the vertebral artery. The vertebral-to-carotid transposition offers the simplest means by which the stenosis can be bypassed (19). In this procedure, the vertebral artery is ligated at its origin, is reanastomosed end-to-side, and sutured by section to the lateral wall of the carotid artery (Figs. 6,7). Other methods include vertebral endarterectomy (which has not been uniformly successful), a saphenous vein graft from the subclavian to the vertebral artery, and transposition of the vertebral artery to either the thyrocervical trunk or the subclavian artery itself (36). All of these procedures have less favorable results than the vertebral-to-carotid trans-

Fig. 7

Postoperative angiograms of a 63-year-old white woman who presented with one episode of right hemiparesis showing transposition of vertebral artery to the common carotid artery and complete restitution of internal carotid artery lumen following carotid endarterectomy.

position. In our experience with 46 vertebral-carotid transpositions, there has been no mortality, and symptomatic relief occurred in over 95%, with limited temporary morbidity. This procedure represents an excellent therapeutic alternative for symptomatic subclavian steal and vertebral origin stenosis.

Vertebral artery lesions in the midcervical area may also be approached in several ways. Local vertebral endarterectomy, which we performed on one occasion, is not a common approach. Saphenous vein graft interposition from the common carotid or the subclavian artery to the distal vertebral artery is another method (36), while anastomosis of the external carotid artery or one of its branches to the distal vertebral artery has also been reported (37). In cases in which the stenosis is the result of osteophytic compression of the vertebral artery, decompression of the vertebral canal has been satisfactory.

In the fourth portion of the vertebral artery, areas of segmental stenosis up to the distal vertebral artery near the vertebrobasilar junction can be approached directly. In three cases, we have completed vertebral artery endarterectomy, but we have insufficient experience to predict its ultimate applicability (Fig. 8).

Many other procedures have been used to bypass lesions in the distal vertebral or in the basilar arteries. The occipital artery has been anastomosed to the posterior inferior cerebellar artery (PICA) in its immediate retromedullar portion (10). These anastomoses have generally been successful but are also extremely difficult to accomplish. The procedure is indicated exclusively for those cases with symptomatic occlusion or stenosis of one or both vertebral arteries proximal to the origin of PICA. When occlusion or stenosis is proximal to the origin of the first major basilar artery branches (the anterior inferior cerebellar arteries [AICA]), we have performed a unilateral anastomosis of the occipital artery to the anterior inferior cerebellar arteries with satisfactory results (20). When the basilar artery is stenotic or occluded in its midportion between AICA and the superior cerebellar artery (SCA) origins, we have anastomosed the superficial temporal artery to the superior cerebellar artery (7) with satisfactory results in 19 cases (Fig. 9). Others have reported good results following anastomosis of the superficial temporal to the posterior cerebral artery or with a saphenous graft anastomosis from the external carotid to the posterior cerebral artery (11).

In general, procedures that require intracranial reconstruction of the posterior circulation are very time consuming, taxing for the patient and surgeon alike, and require a coordinated team approach. These procedures are all carried out with barbiturate anesthesia in the recumbent patient (7,20,38). Sustaining normal blood pressure is mandatory, and extreme care is required during surgery to maintain a supple brain minimally subjected to retraction.
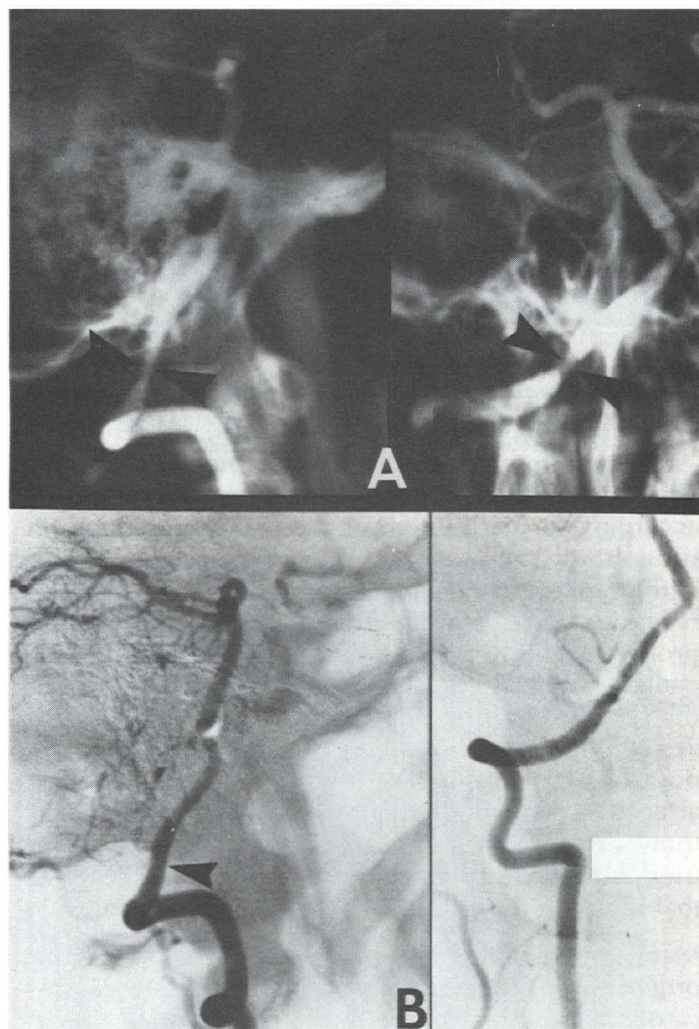

Fig. 8

Angiograms of a 60-year-old white man with repeated episodes of vertigo, bilateral visual blurring, dysarthria, and left hemiparesis. A. Preoperative right lateral and AP vertebral angiogram showing marked VA stenosis at atlanto-occipital membrane (arrowheads); left vertebral artery was occluded. B. Postoperative right lateral and AP vertebral angiogram demonstrating complete reconstitution of luminal diameter.
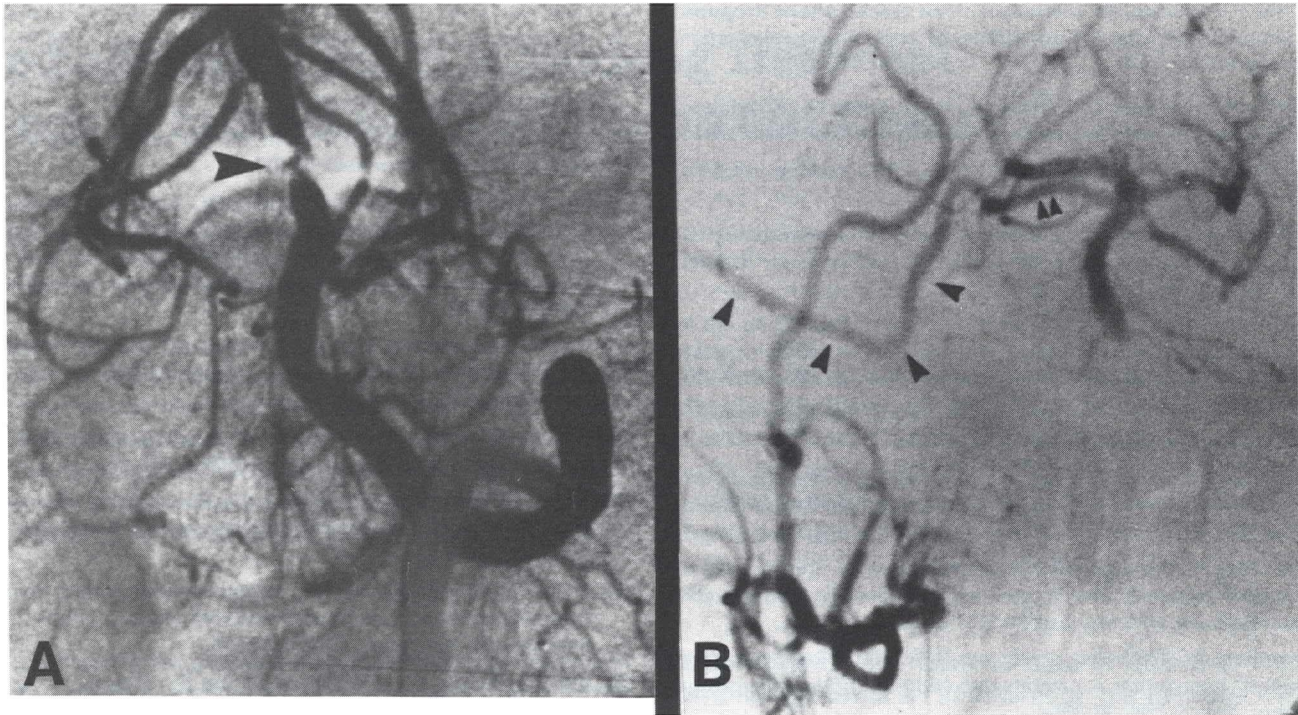
Fig. 9

Postoperative angiograms of a 63-year-old white man with repeated episodes of vertigo, diplopia, and dysarthria. Preoperative angiogram revealed high grade distal basilar artery stenosis. A. Postoperative lateral right external carotid angiogram showing filling of distal basilar artery branches including superior cerebellar and posterior cerebrals via patent STA-SCA anastomosis. B. AP angiogram showing distal basilar artery filling. Note the STA-SCA anastomosis (arrowheads).

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