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Cerebral Angiography in Posterior Fossa Revascularization

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With advances in microsurgical techniques and refinement of cerebral angiography, many new surgical approaches for the treatment of vertebrobasilar insufficiency (VBI) have been developed. Detailed selective cerebral angiography is essential for confirming the clinical diagnosis, for demonstrating the exact anatomical and topographical vascular pathology, and for deciding on the best surgical procedure. Angiography

The surgical management of patients with vertebrobasilar insufficiency (VBI) is a relatively new development made possible by the advances in microsurgical techniques (1) and the refinement of cerebral angiography (2). The first extracranial to intracranial bypass procedure for posterior fossa revascularization was performed by Ausman in 1975 (3). In this patient, the occipital branch of the external carotid artery (OA) was anastomosed to a branch of the posterior inferior cerebellar artery (PICA) to bypass bilateral distal vertebral artery occlusion. Since then, different surgical approaches to the problem of posterior fossa ischemia have been reported (4-16). This paper reports a five-year experience with cerebral angiography in patients with vertebrobasilar insufficiency who underwent various types of surgical procedures to reconstruct or bypass the vascular obstruction to the posterior fossa circulation. Our technique of cerebral angiography in these cases is presented in detail with few illustrative cases. This is followed by a discussion of the role of cerebral angiography and its value in candidates for posterior fossa revascularization procedures both preoperatively and postoperatively.

Materials and Methods

Patient selection

This report is based on our experience with 175 patients who underwent various surgical procedures for posterior fossa revascularization at Henry Ford Hospital in the period 1980-1984.

All patients in this report had the clinical diagnosis of vertebrobasilar insufficiency according to the criteria of Whisnant et al (17-18). This requires the presence of two or more of the following symptoms: 1) motor or sensory symptoms or both occurring bilaterally in the same attack, 2) ataxia of gait or clumsiness of both extremities, 3) diplopia, 4) dysarthria, 5) bilateral homonymous hemianopsia. Additional symptoms compatible with this syndrome are vertigo, tinnitus, and multiple cranial nerve palsies that are usually contralateral to the major motor or sensory deficit. Patients with dizziness as their only complaint were not included in this group. Syncope, drop attacks, and transient global amnesia were not accorded much weight in establishing the diagnosis of VBI. Whenever any of these symptoms occurred singly, other causes besides VBI were considered. Many of our patients had four or five symptoms or signs consistent with VBI.

The patients included in this report presented with transient ischemic attacks (TIA) referable to the posterior circulation and were neurologically intact. Less than 5% had a completed stroke with a fixed neurological deficit. Clinically these patients were categorized as unstable or stable according to whether or not they required intravenous anticoagulant therapy.

The workup of these patients was designed to exclude other conditions which could mimic vertebrobasilar disease: 1) cardiac disorder such as dysrhythmias, myocardial insufficiency, emboli from valvular disease or old infarction, 2) blood hypercoagulability, 3) bleeding disorders, 4) demyelinating disease, 5) intracranial neoplasms in the cerebellopontine angle region or in the cerebellum, 6) Meniere’s syndrome. Laboratory examinations included a complete blood count with a blood smear and coagulation profile. A 12-lead electrocardiogram and Holter monitoring for 24 to 36 hours were done if dysrhythmia was suspected. Computerized axial tomographic scan (CAT scan) was obtained with thin sections for the posterior fossa and the brainstem in most cases. Preoperatively all patients underwent four-vessel selective cerebral angiography. A second angiogram of the reconstructed vessel or the bypass was obtained in most patients either before discharge or during follow-up.

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follow-up angiogram was usually obtained about a year postoperatively or whenever symptoms recurred.

**Angiographic technique**

The population group of VBI patients presents a special challenge to neuroradiologists. Often in the older age group, these patients have many associated risk factors and are sometimes clinically unstable with recurrent TIA requiring intravenous anticoagulation. Meticulous care and attention to detail are the keys to success in the care of this vulnerable group. The following guidelines were followed strictly in the conduct of the angiographic examination:

1. Preangiographic preparation included adequate hydration and mild sedation. Some unstable patients were given low molecular weight dextran before angiography to prevent rouleaux formation.

2. Maintenance of adequate blood pressure. Patients with significant basilar stenosis or occlusion may develop signs of brainstem ischemia if a usually high blood pressure is tightly controlled (19). On the other hand, unduly elevated blood pressure increases the risk of postangiographic bleeding and hematoma. The blood pressure must be observed closely to minimize both risks.

3. Continuous monitoring of vital signs during and after the procedure.

4. Frequent and repeated evaluation of the patient’s neurological status after each injection.

5. Obtaining detailed demonstration of the circulation and mild sedation. Some unstable patients were given low molecular weight dextran before angiography to prevent rouleaux formation.

6. Routinely examining the carotid circulation bilaterally to a combinatorial the anatomical configuration of the selected vessel, a relatively small volume of contrast material.

**Route**

The majority of our patients are examined by the transfemoral route (right or left) provided that adequate femoral pulses and distal circulation are present.

The transaxillary approach (mostly right and rarely left) is utilized when both femoral pulses are weak, distal pulses are absent or barely palpable, or the vertebral arteries are the most vulnerable. The transaxillary route may be used to supplement the transfemoral approach.

Retrograde brachial angiography by percutaneous needle or catheter injection is rarely necessary. It can be used as a supplemental procedure to provide specific information not obtained by other routes.

**Catheters**

The most commonly used catheters in this series are the HN4 (5 French) and the Sidewinder 3 (6 French). The HN4 catheter is preferred for patients under 60 years, and the Sidewinder, in older patients. Occasionally, the use of Head Hunter 2 or 3 was successful when others failed. Initial catheter introduction is usually achieved over a 0.032 J-shaped guidewire. In all cases, it must not impede the circulation in the selected vessel. This is particularly important in selective vertebral catheterization because the two vertebrae are frequently misshapen in size and variable in their distal distributions (20). Frequently, the catheter tip can be engaged just at the origin of the vertebral artery so that the whole length of the anatomical course of the vessel can be covered by one injection of a relatively small volume of contrast material.

**Radiographic positions**

In addition to the standard AP Towne and lateral projections for the head and neck, a biplane oblique projection with the head turned 20° to 30° to the contralateral side is found extremely useful for visualizing the origins and the distal cervical and intracranial segments of both vertebral arteries. This position avoids the foreshortening of that segment inherent in the standard projection. An en face projection is used for better display of distal vertebral arteries and the basilar artery, the origins and course of its branches.

**Contrast injection**

We use 7 to 9 mL of Conray 60 at a rate of 5 to 7 mL/sec and 450 p/si pressure for selective vertebral injections. For subclavian injections, 15 to 20 mL are used at an injection rate of 10 to 12 mL/sec. A blood pressure cuff is temporarily inflated around the upper arm for the subclavian injection. If the catheter position was felt to be somewhat unstable due to the anatomical configuration of the selected vessel, a slower initial rise was chosen for the mechanical injection to minimize the risk of catheter displacement. The position of the catheter and the neurological status of the patient must
Fig 1
Preoperative left subclavian (A) and left common carotid (B) arteriograms. Postoperative left common carotid arteriogram (C) following left vertebral-carotid transposition and left carotid endarterectomy.
be checked after each injection, and the catheter should be withdrawn from the selected vertebral artery, unless it is clearly shown to be safe by fluoroscopy.

**Magnification and subtraction**

Magnification and subtraction techniques are implemented by means of a small-focus X-ray tube with an efficient head-holding mechanism. Selected films from each run are subtracted before interpretation. Uneasy patients have to be sedated before the injection in order to obtain an adequate subtraction image. Digital subtraction following intraarterial injection, a very useful technique, has not as yet been widely used for technical reasons.

**Postoperative and follow-up studies**

An angiogram was obtained 10 to 15 days after each posterior fossa revascularization procedure. Since the purpose was to check for the patency of the reconstructed vessel or the bypass, a limited selective study of the vessel in question was performed (e.g., the common carotid in vertebral-carotid transposition [VCT], the external carotid in superficial temporal to superior cerebellar, or the OA to anterior inferior cerebellar artery [AICA] or PICA bypass). On the other hand, long-term follow-up studies in either symptomatic or asymptomatic patients included complete four-vessel cerebral angiography with special emphasis on the operated vessels.

Intravenous digital subtraction arteriography is adequate for the postoperative evaluation of the patency of VCT but not for the evaluation of bypasses. In the latter cases, a steep 40° to 50° oblique projection is necessary to profile the end-to-side anastomosis. The filling of the basilar artery can be ascertained in a lateral or slightly off-lateral position of the intracranial circulation.

**Representative Cases**

**Case 1**

A 63-year-old man had episodic vertigo, ataxia, left arm paresis, and bilateral visual blurring. The preoperative angiogram showed marked stenosis (more than 80%) of the proximal left subclavian artery (Fig 1A) extending to the left vertebral origin, which was narrowed by about 30%, followed by post-stenotic dilatation. The right subclavian artery in this patient was completely occluded (not shown). The left internal carotid artery (Fig 1B) was narrowed by 60% in its proximal portion. Combined left carotid endarterectomy and left VCT was performed. The postoperative left common

**Fig 2**

Preoperative left vertebral angiogram (A). Postoperative right external carotid angiogram (B) following right occipital artery to posterior inferior cerebellar artery and right occipital artery to anterior inferior cerebellar artery anastomoses.
carotid angiogram (Fig 1C) shows a widely patent anastomosis and left internal carotid artery bulb. The left external carotid artery is occluded.

Case 2
A 63-year-old man presented with dysphasia, diplopia, syncope, and left visual blurring, as well as right 5th and left 7th cranial nerve palsy. He also had right arm and leg weakness and sensory impairment. Preoperative angiogram (Fig 2A) revealed severe narrowing (more than 90%) of the distal portions of both vertebral arteries above the level of C-1, proximal to the origin of their PICA branches. There was rich collateral circulation to the vertebrobasilar junction and the proximal basilar artery through retrograde flow in the anterior spinal artery. Both PICAs and AICAs filled, with the right PICA being the largest branch. The distal basilar artery filled retrogradely from the carotid circulation. Right side-to-side occipital to PICA and end-to-side occipital to AICA anastomoses were performed. The postoperative angiogram (Fig 2B) showed a widely patent anastomosis with excellent antegrade filling of the basilar artery up to its terminal branches.

Case 3
A 66-year-old man was admitted following a four-week history of multiple transient ischemic attacks involving the vertebrobasilar circulation. His symptoms included dizziness, dysarthria, dysmetria, syncope, nystagmus, bilateral sensory impairment of arms and legs, and motor weakness of both legs. The preoperative angiogram (Fig 3A) showed a patent left vertebral artery which was the sole supply to the basilar artery since the right vertebral was congenitally hypoplastic. A segment of severe stenosis (more than 90%) involved the basilar artery proximal to the origin of its AICA branches. Right superficial temporal end-to-side anastomosis to the superior cerebellar artery was performed. Postoperative angiograms (Figs 3B, C) showed patent anastomosis with excellent filling of the basilar artery, both antegrade and retrograde, through the anastomosis and all its major branches.

Case 4
A 64-year-old man had a three-month history of dizziness, diplopia, tinnitus, and left visual blurring. Preoperative angiogram (Fig 4A) showed a localized segment of severe stenosis involving the left vertebral artery extracranially at the level of C-1. Left vertebral endarterectomy was performed, and the postoperative angiogram (Fig 4B) showed a widely patent artery in the area of previous stenosis.

Discussion
The management of patients with VBI has been controversial since Kubick and Adams (21) first described the clinical syndrome of basilar thrombosis in 1946. No specific form of treatment was used in such cases until Millikan et al (22) recommended systemic anticoagulation in 1955. Since then, the beneficial effects of this treatment modality in reducing the mortality rate (23) and the incidence of stroke have been reported (18). However, many study groups were not systematically evaluated by cerebral angiography; other possible causes of the symptoms were not ruled out, and the diagnosis was largely based on clinical grounds. Even extensive clinical evaluation of patients with vertebrobasilar ischemic events cannot indicate reliably the site or nature of the vascular pathology. Caplan and Rosenbaum (2) cited six major types of vascular pathology in occlusive disease of the posterior circulation. The variation in the site and nature of vascular changes has also been demonstrated in postmortem examination (24). Analysis of the correlation between the presumptive clinical diagnosis and the angiographically proven pathology in the 11 cases of VBI reported by Caplan and Rosenbaum (2) revealed the fallacy of basing the diagnosis and management on clinical grounds alone. Two patients presented with grave neurological signs and symptoms that were thought clinically to be caused by large vessel occlusion. However, the angiogram did not show significant large vessel disease; therefore, both were spared long-term anticoagulation. On the other hand, angiography verified severe basilar artery obstruction in four other patients. They were treated by anticoagulants in spite of being a poor risk for that type of treatment. Angiography revealed the vascular occlusive etiology in three other patients in whom either a metabolic disturbance or a space-occupying lesion had been the presumptive cause of the patient's clinical symptoms.

Angiography plays an essential role in the diagnosis and treatment of VBI (25). Prognosis is worse in patients with angiographic evidence of compromise (25). In a series of 280 patients, (25) reported a fatality rate of 5.2%. Other authors (26) reported a fatality rate of only 2%. The reported rate of permanent neurologic deficit is also lower than that reported for other ischemic vascular events.
had been suspected clinically. Our experience with this large group of thoroughly evaluated VBI patients confirms that selective cerebral angiography is the only means to determine precisely the location and nature of the vascular pathology. Angiographic evaluation of patients with cerebrovascular symptoms has been avoided by many clinicians and radiologists for fear of severe complications. The available literature on this subject is contradictory and difficult to analyze because of heterogeneous population groups, variable angiographic techniques, and different systems of classification of complications. For example, Faught, Trader, and Hanna (25) reported an overall cerebral complication rate of 12.2% in patients who underwent angiography for transient ischemia or stroke with permanent complications occurring in 5.2%. On the other hand, Eisenberg, Bank, and Hedgcock (26) reported a rate of transient cerebral complications of only 1.3% resulting from similar procedures. In recently reported and well-controlled large series, the incidence of permanent complications is less than 1% (27). Reliable evidence shows that patients who have had TIA or stroke are more vulnerable to complications than are patients with other indications for cerebral angiography, eg, brain tumor, subarachnoid hemorrhage, or seizures (27). Factors contributing to increased risk of neurologic complications are increased age, high serum creatinine, longer procedure time, larger volume of contrast material, larger and stiffer catheters, and the type of contrast material used. Hydration and constant monitoring are important to minimize complications. Meticulous care and attention to detail in performing the procedure are essential. The use of a small flexible catheter (5 French HN4) and its immediate withdrawal from the selected vessel after the injection are particularly helpful. We currently use the meglumine iotthalamate contrast agent Conray 60 for cerebral angiography. Because of the essential role that angiography has in confirming the clinical diagnosis and directing the management of patients with suspected vertebrobasilar insufficiency, its small risk is far outweighed by its benefits.

The population group reported presents many distinctive features worth noting. First, strict clinical criteria were used to establish the clinical diagnosis of VBI. A minimum of two of the most commonly observed symptoms with at least one involving the central nervous system were required. In many patients, four or five symptoms were present. Adherence to...
these rigid selection criteria is essential for a meaningful comparison of different treatment modalities in various study groups. Second, since the differential diagnosis of vertebrobasilar disease includes cardiac, hematologic and other disorders, a complete battery of ancillary laboratory tests was applied in each case. Third, each patient was subjected to detailed four-vessel cerebral angiography prior to surgery. Clearly, a precise anatomical and topographical vascular diagnosis is a prerequisite for the rational choice of treatment.

Surgical treatment of vertebrobasilar insufficiency is based on the hypothesis that the basis of symptoms in the majority of cases is hemodynamic. Accordingly, the objective is to achieve mechanical correction of the perfusion deficit in the posterior circulation. This is accomplished either by bypassing the compromised vessels or by reconstructing the diseased segment. The type of operation suitable in each case is determined by the site of significant stenosis. Detailed cerebral angiography of the vertebrobasilar and carotid circulations from origins to terminal branches permits preoperative mapping of the posterior and anterior circulations as well as the circle of Willis. The degree of dominance and contribution of each vertebral artery to the basilar circulation is assessed along with the site, extent, and nature of the stenotic or occlusive lesions. The presence of tandem lesions and lesions involving the origins of the main vertebral and basilar branches is verified. Furthermore, the routes of collateral circulation and the degree of filling give an idea of the direction, if not the amount of adequacy of blood flow. The condition of the anterior circulation is an important element in the preoperative evaluation. Significant carotid stenosis or occlusion either unilaterally or bilaterally could be associated. The degree of collateral supply from the anterior to the posterior circulation, as well as the dependence of the anterior circulation on the available vertebrobasilar circulation must be assessed. Another important aspect of the angiographic evaluation is to determine the availability of suitable donor or recipient vessels for bypass surgery.

The early postoperative angiogram shows the patency of the anastomosis or the reconstructed segment and the presence of any complications such as arterial narrowing or hematoma. Both antegrade and retrograde filling of the recipient vessel is assessed. Later follow-up angiography serves to evaluate the long-term results of surgery in asymptomatic cases and to investigate the origin of symptoms in patients who have recurring problems.

Current reports of surgical management of VBI may be considered as phase I and II trials in the treatment of a problem for which there is no proven therapy. Well-controlled phase III randomized studies are needed to compare the results of medical vs surgical treatment of VBI. Detailed cerebral angiography must be an integral part of such investigations in order to establish a vascular etiology for the clinical problem. These studies should shed light on the natural history of the VBI syndrome and help elucidate the mechanism of the symptoms.

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References

Cerebral Angiography


