Interposition saphenous vein grafts for advanced occlusive disease and large aneurysms in the posterior circulation

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The authors report their initial experience with the use of interposition saphenous vein grafts between the external carotid artery and the proximal posterior cerebral artery. The indications, results, and technical aspects of the operation are reviewed. All patients accepted for surgery were at high risk for a posterior circulation infarct, and all patients with ischemic symptomatology had continued to progress while on anticoagulant drugs or anti-platelet agents. Thus, all patients were at high risk, and 11 of the 14 patients operated on were confined to bed before surgery. Intraoperative graft flows varied from 35 to 170 ml/min, and postoperative graft flows ranged from 75 to 311 ml/min in the patent grafts. There were three early graft occlusions and two late graft occlusions; these all occurred in patients with relatively low flows at the time of surgery (40 ml/min or lower). Subdural hygroma was the next most frequent complication to graft occlusion. It was thought to be caused by the pulsating graft anastomosed to a major vessel through a small opening in the basal arachnoid, which provided a new path for cerebrospinal fluid flow in patients with a degree of preexisting atrophy. One patient with a large aneurysm in the posterior circulation underwent proximal intracranial clipping of the vertebral artery and bypass grafting simultaneously. There were seven excellent results and two good results in nine patients in whom the graft remained patent. In the five patients with graft occlusion, there were two minor strokes, two major strokes, and one death.

KEY WORDS  saphenous vein graft □9 anastomosis □9 occlusive disease □9 basilar artery □9 vertebral artery aneurysm □9 posterior circulation

We report here our initial experience with the use of interposition saphenous vein grafts between the external carotid artery and the proximal posterior cerebral artery (PCA). These procedures were initially undertaken to provide an immediate large volume of flow to patients with impending brain-stem infarction from stenoses or occlusions of the basilar artery. However, we have extended the use of these grafts to one patient with a large aneurysm of the vertebral artery and believe that these grafts will have a role, combined with vertebral or basilar artery ligation, in the management of large or giant aneurysms of the posterior circulation which are not amenable to direct clipping.

Clinical Material

This operation was performed in 13 patients for a variety of ischemic symptomatology attributable to occlusive disease of the basilar artery, and in one patient with a large aneurysm of the vertebral artery in which the parent artery was ligated because the aneurysm could not be repaired by direct clipping. The symptoms of occlusive disease included: progressing stroke, transient ischemic attacks (TIA's), minor brain-stem infarcts, and postural orthostatic cerebral ischemia. Each patient usually suffered from more than one symptom complex, and all patients had persisting symptomatology in spite of anticoagulants or anti-platelet agents. Patients considered disabled preoperatively were either hospital-bound or non-ambulatory and confined to bed. Pertinent data regarding each of these patients are summarized in Table 1.

Illustrative Cases

Case 2

This 69-year-old retired salesman was admitted to his local hospital on August 7, 1980, with a 1-week history of intermittent attacks of vertigo, light-head-
TABLE 1
Clinical data in 14 patients with interposition saphenous vein grafts*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Date of Surgery</th>
<th>Disabled Preop</th>
<th>Symptom Complex</th>
<th>Angiography Findings</th>
<th>Intraop Graft Flow</th>
<th>Postop Graft Flow</th>
<th>Operative Complications</th>
<th>Operative Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48, M</td>
<td>Nov 1, 1979</td>
<td>yes</td>
<td>daily TIA's, POCI</td>
<td>basilar artery stenosis</td>
<td>35 ml/min</td>
<td>occluded 3 mos postop</td>
<td>none</td>
<td>excellent, required transluminal dilatation</td>
<td>excellent</td>
</tr>
<tr>
<td>2</td>
<td>69, M</td>
<td>Aug 22, 1980</td>
<td>yes</td>
<td>TIA's, POCI</td>
<td>basilar artery occlusion</td>
<td>140 ml/min</td>
<td>311 ml/min</td>
<td>none</td>
<td>poor, then lost to follow-up</td>
<td>excellent</td>
</tr>
<tr>
<td>3</td>
<td>62, M</td>
<td>Sept 16, 1980</td>
<td>no</td>
<td>TIA's</td>
<td>basilar artery stenosis</td>
<td>40 ml/min</td>
<td>occluded 1 day postop</td>
<td>small thalamic infarct</td>
<td>excellent</td>
<td></td>
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<tr>
<td>4</td>
<td>69, M</td>
<td>Oct 10, 1980</td>
<td>yes</td>
<td>progressing stroke, POCI</td>
<td>basilar artery occlusion</td>
<td>100 ml/min</td>
<td>150 ml/min</td>
<td>subdural hygroma</td>
<td>excellent</td>
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<td>5</td>
<td>64, M</td>
<td>Nov 3, 1980</td>
<td>yes</td>
<td>TIA's, infarct, POCI</td>
<td>basilar artery occlusion</td>
<td>40 ml/min</td>
<td>75 ml/min</td>
<td>venous infarct</td>
<td>poor, then lost to follow-up</td>
<td>excellent</td>
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<td>6</td>
<td>53, M</td>
<td>Jan 9, 1981</td>
<td>yes</td>
<td>POCI, infarct, progressing stroke</td>
<td>basilar artery occlusion</td>
<td>55 ml/min</td>
<td>109 ml/min</td>
<td>none</td>
<td>excellent</td>
<td></td>
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<tr>
<td>7</td>
<td>44, M</td>
<td>Jan 14, 1981</td>
<td>yes</td>
<td>infarct, slow stroke, TIA's</td>
<td>basilar artery stenosis</td>
<td>40 ml/min</td>
<td>occluded 1 mo postop</td>
<td>subdural hygroma</td>
<td>poor</td>
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<tr>
<td>8</td>
<td>55, F</td>
<td>March 20, 1981</td>
<td>yes</td>
<td>POCI, TIA's, dementia</td>
<td>basilar artery occlusion</td>
<td>60 ml/min</td>
<td>80 ml/min</td>
<td>none</td>
<td>excellent</td>
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<td>9</td>
<td>56, M</td>
<td>March 27, 1981</td>
<td>no</td>
<td>TIA's, infarct, POCI</td>
<td>basilar artery stenosis</td>
<td>40 ml/min</td>
<td>occluded</td>
<td>brain-stem infarct</td>
<td>death</td>
<td></td>
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<td>10</td>
<td>41, M</td>
<td>April 1, 1981</td>
<td>yes</td>
<td>TIA's, infarct, POCI</td>
<td>basilar artery stenosis</td>
<td>120 ml/min</td>
<td>130 ml/min</td>
<td>temporal lobe swelling, homonymous field defect, 3rd nerve palsy</td>
<td>good</td>
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<td>11</td>
<td>62, M</td>
<td>April 21, 1981</td>
<td>yes</td>
<td>TIA's, POCI</td>
<td>basilar artery stenosis</td>
<td>60 ml/min</td>
<td>80 ml/min</td>
<td>myocardial infarct, perforated colon (diverticulum)</td>
<td>excellent</td>
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<td>12</td>
<td>62, F</td>
<td>April 12, 1981</td>
<td>no</td>
<td>SAH</td>
<td>vertebral artery aneurysm</td>
<td>140 ml/min</td>
<td>150 ml/min</td>
<td>transient 7th nerve palsy, subdural hygroma</td>
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<td>13</td>
<td>47, F</td>
<td>May 5, 1981</td>
<td>yes</td>
<td>POCI, TIA's</td>
<td>basilar artery stenosis</td>
<td>35 ml/min</td>
<td>80 ml/min</td>
<td>none</td>
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<td>14</td>
<td>48, M</td>
<td>June 1, 1981</td>
<td>yes</td>
<td>POCI, TIA's</td>
<td>basilar artery stenosis</td>
<td>170 ml/min</td>
<td>100 ml/min</td>
<td>subdural hygroma, transient dysplasia</td>
<td>excellent</td>
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* Abbreviations: TIA = transient ischemic attack; POCI = postural orthostatic cerebral ischemia; SAH = subarachnoid hemorrhage.

edness, diaphoresis, dysarthria, right hemiparesis, right hemisensory deficits, and occasional diminution or loss of consciousness. These attacks were particularly associated with sitting up or standing up from the supine position, and lasted 30 to 45 minutes. He had no previous history of cerebral vascular insufficiency. He was not a diabetic. He had undergone a successful two-vessel coronary bypass procedure 7 years previously.

Examination. A computerized tomography (CT) scan on admission was normal. The patient was placed on a course of heparin and at bed rest. He continued to have 2 to 3 episodes per day consisting of several or all of the above symptoms. On at least one occasion he was noted to have left hemiparesis rather than right hemiparesis. The extreme orthostatic nature of his problem was noted on at least two occasions when he sat up for one reason or another in bed and promptly had an ischemic attack. Angiograms on August 18, 1980, identified total occlusion of the left vertebral artery up to the level of a small posterior inferior cerebellar artery. The right vertebral artery was small and ended in a large posterior inferior cerebellar artery. The carotid systems were essentially normal.

On August 19, the patient was transferred by air
Saphenous vein grafts for posterior circulation occlusion

Fig. 1. Case 2. Postoperative series of angiograms, subtraction technique. **Upper:** Lateral view revealing good flow through the bypass graft, with retrograde filling of the basilar artery to the point of its origin from the junction of the vertebral arteries. **Lower:** Anteroposterior projection indicating the contour and shape of the saphenous vein bypass graft. There is filling of the opposite posterior cerebral artery.

Ambulance to St. Mary's Hospital, a distance of some 300 miles, without incident. However, it was necessary to keep him in the supine position on arrival, because his attempts to sit on the edge of the bed or assume the upright position resulted in ischemic events. The neurological examination revealed no major fixed deficit.

**Operation.** On August 22, surgery was performed under general anesthesia through a modified pterional approach. The right saphenous vein, which had been harvested between the groin and the knee, was anastomosed end-to-end between the resected stump of the right ECA and the proximal PCA just distal to the third nerve. This graft was brought through a tunnel in the neck and ran from the carotid bifurcation in the subcutaneous tissue anterior to the ear and then through the lower margin of the craniotomy in the inferior aspect of the temporal fossa just superior to the zygoma. The intracranial anastomosis was completed using a running 7-0 Prolene suture, and the proximal anastomosis was constructed using interrupted 5-0 Prolene sutures. Blood flow through the graft was recorded at 140 ml/min.

**Postoperative Course.** The patient awoke from the operative procedure with no neurological deficit and had an uncomplicated postoperative recovery. He was discharged from the hospital on September 3, 1980.

Postoperative angiograms (Fig. 1) demonstrated excellent flow through the bypass graft. He has remained well since discharge, and is taking aspirin and dipyridamole.

**Case 8**

This 55-year-old woman was referred for a chief complaint of difficulty in mentation and loss of vision while she was in the upright position. Her symptoms began 2 years before admission, at which time she had noted a gradual loss of balance. A "kink" in the right vertebral artery was identified on angiography, and she underwent saphenous vein grafting between the right carotid artery and the distal vertebral artery at her local hospital. She remained stable for 1 year after the operation. Thereafter, she developed progressive difficulty in balance, slurred speech, visual and auditory hallucinations, and major problems with short-term memory and cerebration. She would frequently lose her vision on assuming the upright position and had become confined to her bed 3 weeks prior to referral.

**Examination.** The patient's medical problems included obesity, diabetes mellitus, and an old small anterior myocardial infarction. Angiography revealed occlusion of the bypass graft in the neck and a basilar artery occlusion.
FIG. 2. Case 8. Postoperative angiograms, subtraction technique. Left: Lateral view indicates good perfusion of the posterior circulation to the midpoint of the basilar artery. Right: Anteroposterior view indicating the path of the saphenous bypass graft into the posterior cerebral artery, with filling of both posterior cerebral arteries through the graft and perfusion of the upper two-thirds of the basilar artery.

Operation. An interposition saphenous vein graft was placed between the right ECA and the proximal PCA on March 20, 1981. Blood flow measured in the graft with an electromagnetic flowmeter was recorded at 60 ml/min.

Postoperative Course. Except for a period of transient hallucinations on the 4th postoperative day, the patient had no postoperative complications. Angiography on the 6th postoperative day (Fig. 2) demonstrated good flow through the graft. The patient was discharged 8 days after the operation; she was ambulatory and had a marked improvement in cerebration and vision. Her ataxia was unchanged. Correspondence with her referring physician in June, 1981, indicated she was continuing to do well.

Case 12

This 62-year-old woman was admitted 10 days after having sustained a subarachnoid hemorrhage. Angiograms at her local institution had demonstrated a large aneurysm (Fig. 3) arising from the distal left vertebral artery. The right vertebral artery was small and not visualized intracranially.

Examination. The patient was Botterell Grade 1 at the time of admission to the hospital, and was without neurological deficits except for lower motor neuron findings in both lower extremities which were the result of polio as a child.

Operation. The aneurysm was exposed along the posterior margin of the petrous bone through a left posterior temporal craniotomy on April 12, 1981. The base of the aneurysm was quite thick, and clips placed across it were displaced onto the parent artery. The aneurysm arose just distal to the origin of the anterior inferior cerebellar artery. It was apparent that any procedure directed toward protection of the aneurysm would have to preserve the blood supply to this very critical artery which took origin, in fact, from the base of the aneurysm. The dome of the aneurysm was quite thin, and we considered it unlikely that a wrapping procedure would provide the protection required for this lesion, which had arisen from the apex in the curve of the vertebral artery and was apparently in the direct line of the ejection stream from a proximal loop of the vessel (Fig. 3).

Although no preparations had been made for a saphenous vein interposition graft, we elected to employ this type of bypass procedure in combination with a proximal clipping of the vertebral artery. The patient was redraped and the ECA was exposed in the neck. A saphenous vein, harvested from the left thigh, was then sewn end-to-side to the external left PCA by a 7-0 running Prolene suture. The proximal graft was brought through a tunnel in the subcutaneous tissue, which ran deep to the parotid gland, and the vessel was sewn end-to-end to the ECA. There was a very strong pulse through the graft after flow was restored,
Saphenous vein grafts for posterior circulation occlusion

The patient awoke from the operative procedure rather slowly but with no major neurological deficits.

Postoperative Course. The next morning the patient was disoriented but she had no gross motor findings. Forty-eight hours after the operative procedure, she developed a peripheral left seventh nerve palsy, and thereafter the eye was protected with an eye shield. She was transferred from the intensive care unit to the neurosurgical floor 4 days postoperatively. At that time her medications included antihypertensive agents, aspirin, and dipyridamole. She made an excellent recovery until the 10th postoperative day, when she developed symptoms related to a subdural hygroma. This was successfully shunted into the peritoneal cavity, whereupon she made a swift recovery. At the time of discharge from the hospital, her seventh nerve function was recovering and the family considered her condition normal.

Surgical Technique

Two surgical approaches have been used to expose the posterior cerebral artery for the intracranial anastomosis procedure (Figs. 5 and 6). Initially, we used the approach illustrated in Fig. 5, as it is similar to the exposure we routinely use for repair of basilar aneurysms (the Sylvian fissure is not opened in this exposure as suggested in the illustration). It has the advantage of positioning the surgeon a considerable distance away from bridging veins in the region of the vein of Labbé, and the disadvantage of greater retraction on the tip of the temporal lobe along with a greater amount of surgery required for elevation of the craniotomy. The advantages that this approach has seemingly offered to us in terms of exposure of the basilar artery have not been as important in operations exposing the PCA at the site of the anastomosis. For this reason, when we had acquired greater experience we returned to Drake's subtemporal approach (Fig. 6). We routinely use both mannitol and cerebrospinal...
Fluid drainage to achieve good exposure of the PCA, so that there is a very minimal amount of brain retraction. The Yaşargil self-retaining retractor is essential (one blade is sufficient). The inferior aspect of the temporal lobe is covered with one large square of Surgicel before the cottonoids are placed for the brain retractor. This Surgicel is left in place, and has prevented small bleeding points from developing when the cottonoid is removed from the wound. This is important, as the 4000 to 5000 units of heparin given just prior to PCA occlusion is not reversed. Heparin is given in an effort to prevent thrombus formation in the PCA during the period of stagnated flow. In one case early in the series, before we used heparin routinely, thrombus formed in the vessel during a 20-minute occlusion time. Just prior to temporary occlusion of the PCA the patient is also given 250 mg of pentobarbital.

The PCA is dissected free from the arachnoid as it courses around the peduncle (the P₁ segment of the PCA). The P₁ segment of the PCA is not exposed, and it is not necessary to disturb the third nerve. There is no need to identify the posterior communicating artery, which in these cases is always very small. The portion of the vessel that is isolated for temporary occlusion has been referred to by Zeal and Rhoton as the anterior half of the P₂ segment of the PCA. It measures approximately 25 mm long. Fortunately, in most instances, long and short circumflex thalamoperforating arteries arise either from the P₁ segment or the portion of the P₂ segment very close to the posterior communicating artery, and it is possible to place the first temporary clip distal to these branches. The hippocampal, peduncular perforating, and medial posterior choroidal arteries also seem to arise most commonly from the very anterior portion of this segment. The anterior temporal artery often arises in the field of occlusion, but bleeding from this vessel can be controlled readily with the self-retaining retractor. The posterior choroidal and posterior temporal branches of the PCA arise distal to the site of the anastomosis. We have found considerable variation in the distribution of these branches along the segment that has been isolated for temporary ligation. Invariably, however, one is able to select a portion of vessel about 1.5 cm in length free of perforating vessels, which is suitable for receiving the anastomosis. The PCA at the point of the anastomosis has appeared to be slightly smaller than a middle cerebral trunk, and we estimate that the diameter approaches 3 to 3.5 mm in most instances. This compares favorably with the measured diameter in fixed specimens reported by Zeal and Rhoton.

After the PCA has been exposed, the self-retaining retractor is partially removed from the wound and the saphenous vein graft, which has been previously exposed in the thigh, is harvested. A No. 8 or No. 10 French catheter is placed in the proximal end of the graft and secured firmly with ligature. Ice-cold heparinized saline is intermittently injected during graft placement through this catheter. The final step in graft preparation includes distention of the graft under pressure to break the mechanically induced spasm, which results in a marked constriction of the graft. Once this spasm has been “broken,” the graft assumes its original distended diameter, and spasm is no longer a major problem during the remainder of the operation.

A tunnel for the graft is created between the medial inferior surface of the temporalis muscle and the ECA in the neck. This tunnel for the graft crosses the zygoma anterior to the ear and then follows a fascial plane deep to the parotid gland. It enters the neck at the apex of the cervical incision which has been used to expose the ECA. A large suture is affixed to this clamp and brought through the tunnel for the graft. This suture is then tied to the French catheter, and the French catheter is pulled proximally through the tunnel where the ties are released so that the catheter can be intermittently irrigated with the heparin solution described above. The free length of the vein graft approximates 25 cm. This distal segment of the graft is allowed to remain redundant in the middle fossa as this facilitates the placement of the vein in various positions during the intracranial anastomosis. This is an important point, as it enables the surgeon to work relatively free from obstruction created by the vein.
Saphenous vein grafts for posterior circulation occlusion

FIG. 6. A: Operative sketches of the subtemporal approach currently used for exposure of the posterior cerebral artery for bypass grafting. This approach minimizes brain retraction and yet provides an adequate space for suture manipulation with a single blade of the self-retaining retractor. B: Diagram of the vein following completion of the proximal and distal anastomoses. The tunnel for the vein passes from the medial aspect of the temporalis muscle to the subgaleal space over the zygoma through subcutaneous tissue anterior to the ear, and then through a fascial plane deep to the parotid gland to join the external carotid artery (ECA) at the level of the digastric muscle. ICA = internal carotid artery.

itself. We have found that cotton balls work well to pack the vein into the anterior middle fossa during the initial part of the anastomosis. Before the vein is placed in the depths of the wound for the anastomosis, its end is prepared for the anastomosis by making a horizontal cut across the vessel proximal to the site of previous clamping. It is not necessary to “fishmouth” this vessel, as the distended saphenous vein in most cases approximates 7 mm.

The self-retaining retractor is then replaced, and the PCA temporarily occluded after barbiturates and heparin have been administered. The PCA is occluded with either the temporary Kees clip or miniature Mayfield clips. The vessel is then opened with a broken razor blade secured in a microholder. On occasion, it has been necessary to extend the suture line with microscissors. The apex suture is placed and the 7-0 Prolene suture cut to a length of approximately 3 cm. The final tie in the suture line is completed between the cut stump end of the first knot and the free end of the running suture, so an adequate amount of suture should be left on the knot for this final tie. Alternatively, a second interrupted suture can be placed on the opposite side of the suture line for securing the suture line. We have routinely closed the medial side initially and then reversed direction of the sutures at the opposite apex of the arteriotomy, using a single back-handed suture. The distal temporary clip is removed first, and then the proximal temporary clip on the posterior cerebral artery is removed. There is no back bleeding out of the vein graft because of the valves. At this point, the graft is thoroughly irrigated (it has intermittently been irrigated prior to this point to keep air from becoming entrapped in the lumen of the vein). The graft is then brought through the subcutaneous tunnel by traction on the French catheter in the neck. The French catheter not only provides a means of irrigating the graft but also serves to keep the graft from twisting as it is brought through this tunnel and placed in the neck.

The ECA is then doubly ligated distally and divided for the end-to-end anastomosis or, if an end-to-side anastomosis is preferred, it is only temporarily ligated distally with a vessel loop. A proximal ECA can be easily occluded with a McFadden clip or a small vascular clamp. The end-to-end technique employs approximately 14 interrupted 5-0 Prolene sutures. The end-to-side technique uses a running 5-0 Prolene suture. For the end-to-end anastomosis, the vein graft is fishmouthed; for the end-to-side anastomosis, the vein is cut on an oblique. It is not necessary to isolate the common or internal carotid arteries for this anastomosis. It is, however, necessary to dissect the ECA as far distally as possible in order to give adequate length to that vessel for the rotations that will be required for the placement of interrupted sutures in the end-to-end anastomosis, or for a long arteriotomy should an end-to-side anastomosis be selected. Distally, the tunnel through the temporalis muscle, prepared by splitting fibers of the temporalis muscle, is directed into a small subtemporal craniectomy at the anterior-inferior margin of the craniotomy. With the subtem-
poral approach, the temporalis muscle is reflected with the scalp flap so that the path for the vein is prepared by passing a large curved hemostat or similar instrument from the medial surface of the temporalis muscle over the zygoma and then into the neck. This track for the vein is routinely enlarged with a curved Kelly clamp.

Operative Results

Results of the operations in these cases are summarized in Table 1, and the complications of the operation are listed in Table 2.

Graft Patency

Graft patency can easily be determined in these cases by merely palpating the pulse of the saphenous vein. However, all patients with a patent graft have undergone postoperative angiography to delineate the vascular territory supplied by the graft.

Graft Blood Flow

Intraoperative graft blood flows have been determined using an electromagnetic flowmeter. Postoperative graft flows have been estimated from a determination of the diameter of the graft on angiography and a Doppler velocity probe which has indicated the velocity of flow through the graft. There have been five graft occlusions. Three of these occurred within 24 hours from the time of surgery, and two occurred 1 and 3 months after surgery, respectively. Each of these cases had relatively low flow volumes at the time blood flow was restored at surgery. The first occlusion can be attributed to our use of the anterior temporal branch of the PCA rather than the main trunk of the PCA itself as a recipient vessel. The second occlusion was attributed, at least in part, to diffuse atherosclerosis in the recipient vessel and to damage at the site of temporary occlusion of the PCA by the temporary occluding clip. The third occlusion was unexplained, but the patient's low cardiac output may have contributed to it. He was reexplored, and patency was maintained by a 24-hour infusion of heparin. The fourth occlusion (Case 7) occurred 1 month postoperatively and, in this patient, aspirin and Persantine (dipyridamole) had not been used because of complications related to his subdural hygroma. The fifth occlusion probably occurred 1 or 2 hours following the operation, and was thought to be related to thrombosis in the recipient vessel from the period of temporary occlusion. Low back-flow was found from the PCA before blood flow was restored, and the runoff and peripheral resistance seemed to be quite high when irrigating the graft. All patients in this series operated on after that case have received intraoperative heparin, which has not been reversed.

Complications

The complications are detailed in Table 2. The most frequent complication after graft occlusion was a subdural hygroma. Although this led to no permanent morbidity in itself, it was thought to contribute to the graft occlusion in Case 7 because the patient was not placed on aspirin and Persantine postoperatively. Only one patient in the series has had a permanent homonymous hemianopsia attributable to temporary occlusion of the PCA, and that same patient had an unexplained third nerve palsy, probably related to mobilization of the PCA near the third nerve. The transient seventh nerve palsy in Case 12 (the patient with a vertebral artery aneurysm) was the result of dissection of the aneurysm away from the seventh and eighth nerves in preparation for clipping. One patient developed a large infarction of a venous type in the temporal lobe related to temporal retraction (Case 5, reexplored). This patient was markedly disabled before surgery; he deteriorated following the operation and, although his long-term follow-up results are unknown, his neurological function was definitely worse than preoperatively and it is unlikely he ever achieved a good result.

Neurological Function

Seven patients immediately achieved an excellent result from the operation, with a relief of postural complaints and apparently the prevention of an impending brain-stem infarction. One patient, the first patient in whom the graft became occluded and in whom the anterior temporal branch of the PCA was used for the recipient vessel rather than the parent vessel itself, had an immediate excellent result. Three months postoperatively, he sustained a stroke that produced an inferior homonymous quadrant anopsia when the graft became occluded. He subsequently underwent a transluminal angioplastic dilatation procedure of the basilar artery with an excellent result and is now gainfully employed.

Discussion

Pathophysiology of Vertebral Basilar Disease

The cerebral circulation can be divided into two...
Saphenous vein grafts for posterior circulation occlusion

general components: 1) the conducting system including the carotid, middle cerebral, anterior cerebral, vertebral, basilar, and posterior cerebral arteries, along with their vast network of interlacing and anastomosing smaller branches on the brain's surface; and 2) the nutrient or penetrating arteries, which arise at right angles to the conducting vessels and which are, in fact, a system of regulatory arterioles. This latter system is responsible for focal autoregulation,9 and can be further subdivided into a relatively short palisade that supplies the cortical capillary bed and a longer palisade that supplies the white matter.13 Although atherosclerosis involves the conducting system in both the anterior and posterior circulation, there is a significant difference in the pattern of atherosclerosis in the two systems and in the manner in which this illness creates symptomatology.4,10 In the carotid system, symptomatic atherosclerosis is frequently extracranial or limited to the carotid siphon area.7 Although it may involve smaller branches in the conducting system, occlusions of these arteries are usually embolic in nature and most commonly originate from ulcerative plaques at the carotid bifurcation.7,11 Hemodynamic symptoms can occur from a very high-grade stenosis of the carotid artery or from occlusion of this vessel if there is impairment in the collateral circulation through the circle of Willis and if there has been no compensatory development of cortical collateral circulation.

In the posterior circulation, although atherosclerosis at the origin of the vertebral artery is a common angiographic finding, these plaques are usually fibrous in character and seldom ulcerate.10,12,10 Furthermore, plaques at the origin of the vertebral artery are not frequently of hemodynamic significance because of the potential collateral circulation that can develop in the neck between this vessel and branches of the external carotid and thyrocervical systems. Several eloquent pathological studies have demonstrated that symptomatic large-vessel occlusive disease in the posterior circulation is usually intracranial in origin.4,7,8 These plaques can be distributed diffusely throughout the vertebral basilar system, but we have found that they are usually located proximal to the origin of the posterior inferior cerebellar artery, just distal to this vessel at the junction point between the two vertebral arteries and the basilar artery, and in the midportion of the basilar artery itself. Major congenital variations in this system make generalizations difficult and result in the wide spectrum of symptomatology.3

It is recognized that ischemic symptoms in both the anterior and posterior circulation can also result from involvement of the penetrating arteriolar system. These vessels can be occluded as a result of an athroma within the basilar artery itself occluding the lumen of the penetrating branch.26 They can also be occluded by an arteriopathy consisting of lipohyalinotic changes that destroy the vessel wall and that may be related to and accelerated by a hyperten-

sive disease. Penetrating branch occlusions produce lacunar infarcts, which are quite possibly the most common form of symptomatology in the posterior circulation. The relative frequency of this cause of brain-stem ischemia, in comparison with occlusion of larger vessels, has not been established. However, in our experience, patients suffering from only one or two ischemic events in the posterior circulation and who have not had a major postural component in their symptomatology, or who have not had multiple frequent events of ischemia, have had an apparently normal angiogram or an angiogram with very little obvious atherosclerosis.

The cause of TIA's in the posterior circulation is still unresolved.19 Two major causes have been proposed, namely, emboli from ulcerated plaques of large vessels to more distal arteries, and hemodynamic changes distal to the site of stenosis or occlusion of a large or small penetrating artery.18 The hemodynamic changes might result from variations in systemic perfusion pressure or from failure of collateral flow. Ischemic symptoms in the patients reported here were clearly hemodynamic in origin. Some of these patients were confined to their beds because of the severity of their symptoms, and virtually all patients could easily correlate the onset of their ischemic events with the upright position.

Analysis of Results

The patients we are reporting here represent a small minority of individuals suffering from occlusive disease in the posterior circulation. All patients reported here had a trial of anticoagulant therapy prior to the surgical procedure, and most patients were suffering from progressive symptoms or had disabling posturally related symptomatology. Thus, we are dealing with a group of patients who were acutely ill and at high risk for a major infarction in the posterior circulation.

Nevertheless, it is apparent that this operation cannot be undertaken lightly, and that there was a significant operative morbidity and mortality related to the operation. This was related in part to the neurological condition of the patient prior to surgery and in part to the surgical procedure itself (as in Cases 7 and 9). In patients in whom the graft remained patent, there was a very impressive improvement of symptoms and, in general, these patients did quite well.

Orthostatic symptoms of lightheadedness, syncope, and visual blurring have been relieved by operation in most patients with bilateral vertebral artery disease. In a group of cases undergoing occipital to posterior inferior cerebellar artery bypass surgery, these were the most common persisting neurological deficits following operation.17 Ataxia has not been as common in the group of patients reported here. Collateral circulation is more precariously balanced in the perfusion zone of the cerebellum and restiform bodies in...
patients with more proximal disease in the basilar
artery.

Analysis of Complications

There were two major complications in this series: graft occlusion and subdural hygroma. Causes for
graft occlusion appeared to be related to atherosclerosis in the recipient vessel with damage to athero-
sclerotic plaques from the temporary clips, distal oc-
closure in the PCA's during the period of temporary
occlusion (manifested by virtually no back-flow from
these vessels following release of the occluding clips),
and technical or surgical errors in the suture lines or
in procuring the saphenous vein graft. Although one
cannot minimize the contribution that surgical errors
or technical difficulties will make in an operation of
this magnitude, we were impressed that the particular
cases in which the graft became occluded were not
clearly related to technical difficulties in either the
proximal or distal anastomosis. We have concluded
that intraoperative heparinization is a risk that must
be accepted in these cases, as it appears that the PCA
is more likely to undergo spontaneous thrombosis
with stagnant flow than is a branch of the middle
cerebral artery during temporal artery to middle cere-
bral artery bypass grafting. We have never failed to
have a back-flow out of one of these vessels in the
middle cerebral distribution following a period of 20
to even 45 minutes of temporary occlusion. It is quite
possible that reaction to ischemia in the larger vessels
is more sensitive than that in the smaller artery, and
for this reason we strongly believe intraoperative hep-
arinization is necessary without need for reversal.

Subdural hygromas have been a frequent complica-
tion in this series, and have necessitated a subdural
to peritoneal shunt in four cases. Curiously, in one
patient who had both a subdural hygroma and a late
graft occlusion, the subdural hygroma resolved fol-
lowing the late graft occlusion. We believe that the
combination of a pulsating graft through a small
opening in the arachnoid at the base of the brain and
a preexisting degree of cerebral atrophy predisposed
these patients to this complication. Subdural hygro-
mas are our most common complication after tem-
poral artery to middle cerebral artery bypass proced-
ures, but symptomatic subdural hygromas are found
in only 1% to 2% of surgically treated patients. In the
group reported here, this complication has occurred
in 30% of the patients, but fortunately has thus far
responded well to subdural-peritoneal shunting.

Homonymous hemianopsia is a complication that
one might expect to find not infrequently in this group
of patients. It proved to be relatively uncommon. Two
patients had transient field defects that persisted for
approximately 24 hours, and one patient with a patent
graft had a permanent homonymous field defect. This
latter patient did not have evidence of a venous in-
farction on angiography or CT scanning. Drake has
previously commented on the collateral flow to
the distal PCA.

We have had one venous infarction with an associ-
ated intracerebral hematoma in this series. This
occurred in one of the patients with a graft occlu-
sion who underwent reoperation, and thereafter was
placed on a continuous infusion of heparin. In general,
venous infarction has been prevented by avoiding
damage to the vein of Labbé and selecting for surgery
the side in which venous perforators off the inferior
temporal lobe appear to be less prominent. Amazingly
enough, the patient with the vertebral artery aneurysm
had to have the vein of Labbé divided, as the aneu-
rysm was exposed by dividing the tentorium along the
posterior margin of the petrous bone. In this patient,
the vein of Labbé was quite prominent, and yet there
was virtually no swelling of the temporal lobe. Nev-
evertheless, we believe that in this instance we were
fortunate, and we strongly recommend that this vein
be preserved whenever possible.

Vein versus Artery for Grafting

Prior to using the saphenous vein for bypass graft-
ing, we had attempted a similar operation using the
superficial temporal artery as a pedicle donor. Over a
period of approximately 2 years before beginning the
series reported here, seven cases were operated on in
that group. Although the surgery was performed as a
desperation move in most instances, and five of these
seven cases had frankly progressing strokes, we were
very disappointed in the amount of the flow achieved
from that operation. Typically, the patients would
have a good pulse over the site of the anastomosis
which would persist for 1 or 2 days, and thereafter it
became progressively more difficult to palpate the
artery. Angiography in these patients revealed patency
of the graft but very minimal flow through the artery.
Angiograms were similar to those reported by Aus-
man, et al. The caliber of the temporal artery ap-
peared to be no larger than 100 to 200 µm. We do not
believe that this was related to a narrow or small
pedicle of tissue, as the arteries were routinely har-
vested with a wide pedicle and with considerable
surrounding soft tissue. It is possible that the long
suspension of the temporal artery in the subarachnoid
space results in a type of intimal hyperplasia, which
may possibly be related to differences in the cerebro-
spinal fluid pH and the pH of the interstitial fluid of
the scalp. In contrast, temporal artery to middle cere-
bral artery bypass procedures result in a suspension
of the temporal artery in subarachnoid fluid for a
section that is usually no more than 2 or 3 mm in
length. Furthermore, this short distance of vessel may
be covered and protected by a small amount of clotted
blood which later becomes organized and protects the
vessel from the cerebrospinal fluid. This is also true
in occipital to posterior inferior cerebellar artery by-
pass grafts.
Saphenous vein grafts for posterior circulation occlusion

Conclusion

It is premature to establish the role of this operative procedure in the management of posterior circulation occlusive disease. Thus far, the patterns of atherosclerosis in the posterior circulation are less well understood than those in the carotid system and, to date, little attention has been directed toward the management of patients with vertebral basilar symptomatology. Although the group we have operated on here represents only a small portion of the total group of patients seen with occlusive disease in this system, it is quite possible that large numbers of patients are not being referred for study and possible surgery because of the absence of a surgical approach to these problems. Results of our surgery have not been spectacular, but we believe there is reason for cautious optimism. Large amounts of flow can be delivered through these bypass grafts, and veins appear to have a role in extracranial to intracranial bypass surgery. However, this is a major operation with many opportunities for technical complications in patients who are already acutely ill.

References


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