Treatment of carotid-cavernous fistulas by cavernous sinus occlusion

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The author reports the occlusion of 33 carotid-cavernous fistulas in 31 patients using thrombogenic techniques. In one patient the carotid artery had been occluded previously, in one it was occluded deliberately, and with 31 fistulas it was preserved. There was no mortality and virtually no morbidity.

KEY WORDS - carotid-cavernous fistula - aneurysm - thrombosis - thrombogenic occlusion

CAROTID-Cavernous fistula carries a high risk of danger to vision, estimated by Hamby in his superb 1966 monograph to amount to visual loss in 25% of cases and visual impairment in a further 20%. On the other hand, the mortality and cerebral morbidity are both very low. Arterial occlusion, universally condemned at other sites of arterial venous fistula (for example, the leg), has been grudgingly accepted here, because for many years there has been no better alternative, and because the end organ (unlike the leg) has three remaining arteries to supply it collectively. Nevertheless, as documented by Stern, et al., and Morley, the operative mortality and cerebral morbidity have been distressingly high in this condition which offers virtually no spontaneous risk of either. As foreseen by Hamby, a method that closes the fistula without sacrificing the artery has been required. Our own thrombogenic efforts and Parkinson’s direct surgical approach have their origins in the early 1960’s. The occlusive balloon techniques of Serbinenko and Debrun are more recent. Our approach, based on occlusion of the venous segment of the fistula, would also be inapplicable for the leg but fortunately it presents no problem to cerebral or facial drainage. In the fistulous condition, those veins which have long been carrying blood in the wrong direction may all be sacrificed without functional loss.

Anatomical Considerations

A look at the anatomy of the cavernous sinus shows us that the simplified quadrilateral space is traversed by a tortuous carotid artery that passes from its posterior inferior lateral corner to its anterior superior medial corner. This effectively divides the quadrilateral cavity into two, a larger anterior inferior portion, and a smaller posterior superior one (Fig. 1). Although the external appearance of the fistulous sinus presents a smooth continuous bulge laterally, superiorly, and posteriorly, the internal arrangement conforms to these two anatomical spaces. The multiple interconnected veins, which Parkinson has shown to be typical of the normal sinus in corrosion casts and which he has actually observed at operation, do not as a rule appear as functional barriers to thrombogenic packing of the clinical fistula. Presumably distension of a main channel obliterates lesser channels. These two cavities may connect very freely, forming, in fact, only one cavity. Occasionally they may be quite separate, giving rise to an exclusively anterior or a predominantly posterior fistulous sac. No specific radiological effort has been made to verify whether the connection lies lateral to the artery, medial to the artery, or on both aspects of the artery. It is probable that all three mechanisms exist. Occasionally the anterior compartment is seen (radiologically) to be subdivided by one or two septae.

Veins of the Anterolateral Sac

The middle cerebral veins and the sphenoparietal sinus enter the anterosuperior portion of the cavernous sinus. Although we have used the middle cerebral vein as a site of entry into the sinus, both of these structures are, in fact, quite close to the third and fourth nerves. The main vein of clinical symptomatology and of surgical use is the opthalmic vein (Fig. 2). Classical anatomical accounts describe a superior ophthalmic vein that enters the cavernous sinus through the superior fissure, and an inferior
ophthalmic vein that enters through the inferior orbital fissure. The common arrangement is, however, different. The large distended superior ophthalmic vein bends laterally and inferiorly at the apex of the orbit and then posteriorly to enter the cavernous sinus through the inferior orbital fissure. Here it may, or may not, be joined by a smaller inferior orbital vein. This position in the inferior orbital fissure offers an ideal surgical approach, because there are no other structures in the inferior orbital fissure. The important structures, the optic nerve, the ophthalmic artery, the third nerve, the sixth nerve, and the nasociliary nerve all lie within the musculo-tendinous origin of the ophthalmic muscles, and are protected by them. The superior orbital fissure, which carries the lacrimal and frontal nerves and the fourth nerve, need not be considered from a surgical point of view (Fig. 3). The pterygoid veins are quite variable and drain through the floor of the middle fossa. They are not surgically accessible (Figs. 2 and 8).

Veins of the Posterior Superior Sac

The two important veins in the posterior superior sac are the superior petrosal sinus, which runs in the tentorium at its attachment to the petrous bone, and the inferior petrosal sinus, which connects the cavernous sinus with the jugular bulb. Both are surgically accessible, the former by direct surgical approach and the latter by a transjugular balloon catheter (Figs. 2 and 11).

A large vein may exist in the roof of the cavernous sinus but its proximity to the entering third nerve makes this approach undesirable surgically. It may connect to the vein of Rosenthal. An occasionally expressed belief that the fistulous sinus is surrounded by many unnamed distended veins has not in our experience had any valid basis.

Lateral Surface of the Anteroinferior Cavity

The lateral surface of the anteroinferior cavity is covered by the first division of the fifth nerve superiorly and the second division inferiorly. The sixth nerve lies medial to the first division. In the fistulous sac, as these are separated out, a significant interval develops anteroinferiorly, free of nerves and of any underlying carotid artery. It provides an excellent site for surgical access. The total lateral surface is, however, accessible to needle insertion insofar as nerve damage is concerned. Multiple penetrations of this wall by the fine needles employed appear to be easily tolerated. In one patient in whom 26 needles were
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FIG. 3. Diagrams of the superior orbital fissure. Note isolation of the ophthalmic vein from neighboring nerves.

used, only a temporary sixth-nerve palsy occurred. The posterior and superior aspects of the anterolateral sac are, however, occupied by the carotid artery, and needles can only be inserted into that portion of the sac which is radiographically free from underlying artery.

Walls of the Posterosuperior Cavity

Although the normal cavernous sinus cavity does not project extensively posterosuperior to the carotid artery, there may be a reasonably large projection in the fistulous sinus. Inferiorly, this projection is covered by the upper fibers of the fifth nerve. The main problem here is the underlying carotid artery. Since the sixth nerve lies deep to the upper portion of the fifth nerve as it winds laterally around the carotid artery, a needle insertion that avoids the artery should also avoid the sixth nerve.

Superiorly, the fourth nerve enters the edge of the tentorium and its position in the roof of the sinus must be guessed at, rather than identified. It lies lateral to the third nerve. The third nerve is easily identified as it enters about the midpoint of the roof of the sinus. It too runs forward in the roof. The surface area immediately behind the third nerve is freely accessible to needle entry. In fact, as the sinus bulges posteriorly into the posterior fossa, this bulge may also be entered over the edge of the tentorium by means of a curved needle.

The interconnection between the two cavernous sinuses posterior to the posterior clinoids may be seen, sometimes very distended, but it is not readily accessible.

Surgical Techniques

The technique or combination of techniques chosen depends upon detailed preoperative angiography. If the fistulous connection is identified, it can be thrombosed by inserting thrombogenic needles (copper-clad steel) through the lateral wall of the cavernous sinus into the connection. If the fistulous neck cannot be identified but the flow is clearly into one or other sac, then that sac is thrombosed. If the site is not determined and both sacs fill simultaneously, then both sacs are thrombosed. Thrombosis is induced by the insertion of conventional thrombogenic material (Gelfoam, oxidized cellulose, or cotton) in a retrograde fashion through the ophthalmic vein or through the superior petrosal sinus. Thrombosis may also be induced by transcutaneous placement of an occlusive balloon into the posterior sac through the jugular vein, the jugular bulb, and the inferior petrosal sinus. The double bend of the ophthalmic vein has not permitted us to catheterize the anterior sac transcutaneously, although we have attempted this on two occasions. Peterson, et al., have succeeded in doing this. Thrombosis may also be induced by inserting thrombogenic wire (phosphor bronze) into those aspects of the lateral and superior walls that are radiographically free from underlying carotid artery and which, in the case of the superior wall, are posterior to the entry of the third nerve.

There are in all seven techniques available (Table 1): 1) anterior extradural (transophthalmic vein) packing; 2) anterior transdural packing; 3) use of lateral stereotaxic needles; 4) use of lateral thrombogenic wire; 5) posterosuperior transsuperior petrosal sinus packing; 6) posterosuperior transjugular balloon occlusion; and 7) posterosuperior thrombogenic wire (not basically different from (6)). To these are added one more technique: 8) intraoperative angiography. These techniques will be described in detail.

Intraoperative Angiography

The problems with catheterization of the superficial temporal artery are that the artery is small, goes into spasm easily, turns acutely medially below the zygoma, and may be tortuous. After its identification and ligature, 1 ml of papaverine solution, injected into its lumen and around it, will dilate it, and will greatly simplify the procedure. Its lumen can be held open by micro-stay sutures. Its lumen may be further iden-

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FIG. 4. Angiograms of a 61-year-old man 1 year after the spontaneous onset of a fistula. Despite the small size of the fistula, ophthalmoplegia, proptosis, and chemosis were very severe. There was no adequate posterior or inferior drainage. Left: Preoperative radiogram. Right: Massive array of clips in this, our first anterior Gelfoam occlusion, represent the anxiety of the surgeon rather than the vascularity of the problem. A remarkable resolution of symptoms occurred within 2 weeks.

If the initial angiogram does not clearly show the artery because it is obscured by the rapidly filled sinus, then it should be recognized that a small amount of anteroinferior packing can be done safely even without arteriography. As this reduces the venous flow considerably, the artery then usually stands out.

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<table>
<thead>
<tr>
<th>Radiographic Findings</th>
<th>Therapeutic Options</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fistulous Neck Visualized</strong></td>
<td>transpetrosal balloon occlusion</td>
<td>Gelfoam, oxidized cellulose, cotton</td>
</tr>
<tr>
<td>all cases</td>
<td>stereotaxic needling</td>
<td>Gelfoam, oxidized cellulose, cotton</td>
</tr>
<tr>
<td>all cases</td>
<td>other options listed below</td>
<td>Gelfoam, oxidized cellulose, cotton</td>
</tr>
<tr>
<td><strong>Primary Filling Sac Visualized: Neck Not Clearly Seen</strong></td>
<td>transspht. vein packing</td>
<td>phosphor bronze wire, diam. 2 mils</td>
</tr>
<tr>
<td>small anterolateral sac</td>
<td>anterior transfacial packing</td>
<td>phosphor bronze</td>
</tr>
<tr>
<td>large anterolateral sac</td>
<td>transspht. vein packing</td>
<td>Gelfoam, oxidized cellulose, cotton</td>
</tr>
<tr>
<td></td>
<td>anterior transfacial packing</td>
<td>Gelfoam, oxidized cellulose, cotton</td>
</tr>
<tr>
<td></td>
<td>lateral thrombogenic wire</td>
<td>Gelfoam, oxidized cellulose, cotton</td>
</tr>
<tr>
<td>small posterolateral sac</td>
<td>transspht. retrofacial sac packing</td>
<td>phosphor bronze</td>
</tr>
<tr>
<td>large posterolateral sac</td>
<td>superior transfacial sac (difficult)</td>
<td>phosphor bronze</td>
</tr>
<tr>
<td></td>
<td>superior transfacial wire</td>
<td>phosphor bronze</td>
</tr>
</tbody>
</table>

*After occluding primary sac, secondary sac should be occluded if it persists. If no preferential filling of either sac is noted, the anterolateral sac should be attacked first, as it is responsible for the main symptoms and is easier to occlude. With better radiography this problem should be eliminated.
Carotid-cavernous fistulas radiographically, facilitating further thrombosis. Direct cavernous venography may also be of value.

**Anterior Extradural Approach**

The anterior extradural approach is suitable as the initial stage of packing of the anterolateral sac. In fact, the entire anterolateral sac may be packed from this approach even if it is large. For small anterolateral sacs that drain exclusively anteriorly, this packing obliterates the fistula entirely (Fig. 4).

Through a small temporal bone flap (in some situations a craniectomy might suffice) the dura is retracted from the anterior wall of the middle fossa. The use of mannitol facilitates this retraction. The foramen rotundum is located at the anteroinferior corner of the anterior wall (Fig. 5), and immediately above and medial to it are the inferior and superior orbital fissures. The thin triangular area of bone between the superior and inferior orbital fissures is drilled out, revealing the apex of the lateral wall of the orbit. Immediately beneath the periorbita, the greatly distended ophthalmic vein can be seen. This vein makes a further posterior bend as it enters the dura of the cavernous sinus immediately above the foramen rotundum. At this point it narrows into the fixed dura which is the site of surgical access (Fig. 6). A linear incision is then made in the dura of the middle fossa. The anterior temporal lobe is retracted slightly, and the anterior inferior corner of the lateral wall of the cavernous sinus is identified. If any difficulty is experienced in identifying the exact point of entrance of the vein, the point may be identified by aspirating blood through a tuberculin syringe and a very fine needle.

A sucker is prepared with a small pack of loose cotton applied to its tip. An incision, no more than 3 mm in length, is made at the point of entry of the vein into the sinus, and the incision is immediately occluded by the cotton applied to the sucker (Figs. 5 and 7). Small, previously prepared strips of Gelfoam, oxidized cellulose, or cotton are then inserted into the anteroinferior aspect of the cavernous sinus. Between each insertion the sucker covers the opening so that external bleeding is minimal. Gelfoam is somewhat too soft and initially may blow out again. A few strands of cotton attached to the Gelfoam make it firmer and permit an easier insertion. The pressure of packing of the anteroinferior cavity is that which the operator estimates would cause no damage to the sixth nerve should the pack come in contact with that nerve posteriorly. This is a subjective judgment. If the incision is made into the orbital vein distal to the precise point of entry, packing may move in a retrograde direction toward the orbit rather than into the cavernous sinus. Although the vein looks large and perhaps simple to deal with, it is, in fact, extremely difficult to pack where it is situated in the loose tissues of the orbit. Pressure cannot be applied because of the risk of damage to nerve structures. Dandy has previously

FIG. 5. Diagram showing the anterior extradural technique. Upper: The foramen rotundum is located. Center: The bone between fissures is drilled out. Lower: An incision is made at the point of entry into the sinus.

FIG. 6. Angiogram, transorbital view, of a posttraumatic anterior compartment fistula in a 46-year-old woman. Note the narrow point of entry into the sinus (left orbital view), the importance of which was not recognized at the time. An intraorbital mobilization of the vein resulted in delayed resolution of proptosis 3 months after occlusion (unlike the 2-week resolution in the patient shown in Fig. 4). *Single arrow* indicates the sinus, *double arrow* shows the ophthalmic exit.
commented upon this difficulty. The fixation provided by the rigid dura and the freedom from adjacent nerves make the point of entry of the vein into the sinus the only real point of surgical access.

Anterior Intradural Approach

If the large vein is not visible upon unroofing the apex of the lateral wall of the orbit, then a strictly intradural approach is used. The dural opening should be wider and the temporal lobe is retracted slightly further. The anteroinferior corner of the lateral wall of the cavernous sinus is clearly visualized. A tuberculin syringe needle is inserted immediately above the foramen rotundum to verify the position of the sinus. If doubt exists as to whether the needle is in the artery or not, then contrast injection will quickly clarify the issue (Fig. 9 right). An incision is now made into the dura of similar length but of considerably greater depth. The anterior inferior sinus is then similarly packed.

Lateral Approach: Stereotaxic Needles

Through a large dural incision the brain is further retracted. The park bench position of the head* and the use of mannitol facilitate this. Large portions of wet Gelfoam beneath any retractor blade will distribute the pressure and keep the brain moist. They can easily be removed at the end of surgery. About six small identifying needles, 5 mm long and fashioned from the stilette of a No. 18 or No. 20 lumbar puncture needle, are inserted into the dura along the presumed course of the artery. These penetrate the wall of the sinus to 3 mm or more. Arteriography through the superficial temporal catheter then identifies the course of the artery, and these needles are moved so that two will outline the upper and lower margins of the fistulous connection. A confirmatory angiogram is made. Copper-clad steel thrombogenic needles of appropriate length are then inserted transdurally across the fistulous connection between these two markers. They are closer than 1 mm apart. Occlusion is rapid. No electric current is used, as this could injure underlying nerves or cause spasm. It appears that these needles offer no hazard to the fifth or sixth nerve, which they are presumed to transverse (Fig. 8).

Lateral Approach: Thrombogenic Wire

In the lateral approach, the carotid artery is outlined by steel markers in an identical procedure (Figs. 9 center and 10 upper right). Wire is then inserted posterosuperior or anteroinferior to the course of the

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*The head dependent without support, as when resting in the lateral position on a park bench or other firm flat surface.
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FIG. 8. Angiograms of a patient with a spontaneous fistula and a sixth-nerve palsy without proptosis. Left: The fistula drains exclusively into the pterygoid plexus (single arrow). There is no filling of the ophthalmic vein or of the petrosal sinus, although there is a massive posterior bulge (double arrow). The site of the fistula is not evident. Center: At six frames per second the fistulous point was identified posteriorly rather than inferiorly as anticipated (arrow). Right: Intraoperative angiogram. Note temporal lobe retractor. Top and bottom needles are markers (arrows). The fistula is sealed.

Carotid artery. This is the treatment of choice for very large fistulas of long duration. These may require 50 or 100 feet of very fine phosphor bronze wire. The No. 31 introducing needle has an external diameter of about 10 mil (1 mil = 1/1000 in.), and an internal diameter of about 5 to 7 mils. The wire used is 2 mils in diameter. These needles are about 6 in. long. A short segment of No. 22 needle tubing (internal diameter about 14 mils) is essential to pump the wire in. The tubing fits over the distal end of the introducing needle and slides up and down a short distance with each insertion. The wire and the distal end of the pump are held together by the operator's fingers. As the pump advances, the wire is channelled by the pump's internal surface into the narrow introducing needle. If the pump is not used, the wire simply kinks as the operator attempts to feed it manually into the introducing needle. The distal portion of the wire has a short curl in its end which facilitates an initial curling of the wire as it enters the sinus. A stopper composed of a silk ligature 2 mm from the distal end of the introducing needle prevents the needle plunging deeper into the sinus. A similar stopper on the proximal shaft of the introducing needle prevents the pump from sliding too far down. The mechanism of introduction has been described previously. Sometimes only a few inches of wire will pass before a kink occurs, sometimes many feet. For most large fistulas about 10 or 12 separate needle insertions may be necessary. The operator recognizes that the fistula is becoming completely occluded when wire kinking occurs more frequently and more readily. Intraoperative arteriography and cavernous venography may also be used as indicators (Figs. 9 and 10).

FIG. 9. Angiograms of a traumatic aneurysm and fistula in a 22-year-old man following a boating accident. Left: Preoperative angiogram. Center: Progressive enlargement of aneurysm 3 weeks later as shown by intraoperative retrograde superficial temporal angiography. Note initial dural markers to outline the presumed course of artery (arrows). Right: Intraoperative venography to verify that the thrombogenic wire did not enter the artery. Some markers have been removed having served their purpose.
FIG. 10. Angiograms of a severe bilateral (independent) fistula in a 21-year-old man following a serious car accident. Upper Left: Left side. The site of the leak not seen. Upper Right: Intraoperative angiogram suggesting that the fistula is occluded. Note markers to indicate line of artery. Insertion of lateral wire was safely centered on the anterior inferior marker. Some contrast material is seen in the upper wire (arrow). A subtotal carotid clamp for a few days might have made the occlusion complete at this stage but was not used. Lower Right: A slow increase of ophthalmoplegia occurred. Initial lateral wire has been compressed anteroinferiorly (arrows). An “aneurysm” with some residual posterior drainage has formed. A second operative wire insertion obliterated the “aneurysm.” A third sealed the contralateral fistula.

Posterosuperior Approach

The posterosuperior approach requires a considerably greater degree of retraction and is therefore considerably more difficult. Excessive strain on the vein of Labbé is an ever-present danger. The third nerve is easily seen and avoided, but the course of the fourth nerve must be estimated. Wire insertion in a line directly behind the third nerve should be clearly medial to the fourth nerve. As a rule it is possible to use the superior petrosal sinus as a site of entry for packing. Occasionally it is absent, usually it is bulging, and it can be identified, if not clearly seen, by aspiration of blood. It is entered quite close to the bulging sinus. Packing is relatively simple. If it is opened far behind the bulging sinus, then the operator has little measure of the pressure with which he is packing the sinus and this could be hazardous to the sixth nerve.

Posterior Transjugular Approach

The posterior transjugular approach requires little description. A No. 5 Fogarty catheter is introduced into the jugular vein through a larger introducing catheter, and both are inserted up to the jugular bulb. The catheter will easily enter the lateral sinus; manipulation of its introducing sleeve guides it anteromedially toward the presumed origin of the inferior petrosal sinus. In two occasions we have succeeded in entering the posterior cavernous sinus, but in one patient the neck of the aneurysm was subsequently shown to be in the anterolateral sac. In one child we could only insert the catheter half way up the clivus, and in a fourth patient it would only enter the lateral sinus. Inflation of the balloon will seal the fistula if the balloon happens to be placed against it. In our single successful case, deflation 5 days later because of some trigeminal pain did not result in return of the fistula (Fig. 11).

Clinical Presentation

This report deals with 33 consecutive fistulas in 31 patients, two of whom had separate bilateral fistulas. Another had separate bilateral fistulas but one side had been treated 2 years previously in another institution. Six patients had unilateral fistulas that also drained into the opposite cavernous sinus. Three of these drained further into the opposite superior ophthalmic vein. One produced mild visual symptoms on that side and one produced more serious symptoms on that contralateral side than on the ipsilateral side (Fig. 11).
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Fig. 11. Angiograms of a 52-year-old man who developed moderate proptosis of right eye 2 days after a fight, but by 5 days the left eye was involved and soon became proptosed and chemotic. Drainage was mostly posteriorly, crossing over the midline to fill the left cavernous sinus and cause more severe symptoms on the contralateral side. Left: Preoperative angiogram showing no filling of the cerebral arteries. Right: The fistula is occluded by transjugular balloon. After 5 days the balloon was deflated because of mild trigeminal pain. There has been no return of the fistula for over 2 years.

There were 18 males and 13 females, with ages ranging from 12 to 81 years. Eighteen of the fistulas were right-sided. Trauma was held responsible for the fistulas in 19, aneurysms in three, dural arteriovenous malformations in three, and arterial fibromuscular dysplasia in one. In seven patients there was no clearly evident cause, although aneurysm was suspected in most. The previous medical history was good, or reasonably good, in 27 patients; of the remaining four, one had widespread arterial fibromuscular dysplasia, one had a long history of hypertension and an admission blood pressure of 220/160 mm Hg, one had a lesser hypertension and two coronary occlusions, and one had senile changes and a single contemporaneous coronary occlusion. Fifteen patients could not tolerate unilateral carotid compression, 14 because of hemispheric problems, and one because of ipsilateral visual loss. One 15-year-old patient with large independent bilateral fistulas could tolerate occlusion of either carotid. Four patients had previous surgical attempts to close the fistulas.

The presenting symptoms were overwhelmingly visual (Table 2). Five patients were already blind in the affected eye. One of these had his eye enucleated. A further 10 had some degree of loss of visual acuity, one of them was almost totally blind. Proptosis with total ophthalmoplegia was present in 13 patients (including the four who were blind and retained their eye). Proptosis with diplopia but without total ophthalmoplegia was present in eight patients. Proptosis without diplopia was recorded in a further eight, but four of these eight had a decrease in visual acuity. Thus, a total of 29 had proptosis; one had an eye enucleated; and the remaining three had diplopia without proptosis. Of the total 33 fistulas, only four were associated with neither visual loss nor diplopia, although all four were related to proptosis.

Proptosis and visual symptoms were severe when the sinus drained predominantly anteriorly, and were very severe when it drained exclusively anteriorly, even though the volume appeared to be small. They were mild when the drainage was predominantly posteriorly, even though the volume appeared fairly large. They could be mild or severe when drainage was in both directions and the degree depended upon the volume of the leak. Visual symptoms were severe only in one patient with a predominantly posterior drainage. She had a blood pressure of 220/160 mm Hg, indicating, as expected, that the retro-orbital pressure was the predominant factor. Chronic pressure in the sinus, as distinct from retro-orbital pressure, seemed to cause sixth rather than third nerve palsy.

A history of headache could be elicited at some time...
TABLE 2
Presenting symptoms and results in 31 patients

<table>
<thead>
<tr>
<th>Presenting Symptoms</th>
<th>No. of Cases</th>
<th>Results</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>blind, eye enucleated</td>
<td>1</td>
<td>blind</td>
<td>1</td>
</tr>
<tr>
<td>blind</td>
<td>4</td>
<td>blind</td>
<td>4</td>
</tr>
<tr>
<td>presumed blind but too confused for absolute certainty</td>
<td>1</td>
<td>20/80 vision</td>
<td>1</td>
</tr>
<tr>
<td>decrease in visual acuity</td>
<td>9</td>
<td>complete recovery</td>
<td>9</td>
</tr>
<tr>
<td>proptosis &amp; total ophthalmoplegia</td>
<td>13</td>
<td>complete resolution</td>
<td>13</td>
</tr>
<tr>
<td>proptosis &amp; diplopia</td>
<td>8</td>
<td>proptosis completely resolved</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>diplopia on fast movement only</td>
<td>2</td>
</tr>
<tr>
<td>decrease in vision acuity</td>
<td>29</td>
<td>complete resolution</td>
<td>29</td>
</tr>
<tr>
<td>headache</td>
<td>15</td>
<td>complete cessation</td>
<td>15</td>
</tr>
<tr>
<td>subarachnoid hemorrhage, mild</td>
<td>1</td>
<td>complete resolution</td>
<td>1</td>
</tr>
<tr>
<td>lateralizing hemispheric signs, very mild</td>
<td>1</td>
<td>complete resolution</td>
<td>1</td>
</tr>
<tr>
<td>pre-fistula senile changes</td>
<td>1</td>
<td>worse</td>
<td>1</td>
</tr>
</tbody>
</table>

in virtually all of the patients. Headache, or more particularly a retro-orbital pain, was considered to be of some significance at the time of presentation in 15 patients. In two it was absolutely distressing and was the symptom that initiated surgical treatment, in one instance 26 years after development of the fistula. Bruit was present in 29 and in one instance was the symptom which, after 6 years, initiated treatment.

Lateralizing hemispheric changes were absent except in one patient who had a minimal pronator drift.

TABLE 3
Methods and results of treatment of 33 carotid-cavernous fistulas

<table>
<thead>
<tr>
<th>Type of Fistula</th>
<th>No. of Fistulas</th>
<th>Method</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outmoded Methods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>neck visualized</td>
<td>1</td>
<td>copper electric needles</td>
<td>asymptomatic arterial spasm</td>
</tr>
<tr>
<td>sac correctly presumed</td>
<td>1</td>
<td>transorbital needle</td>
<td></td>
</tr>
<tr>
<td>sac not identified</td>
<td>1*</td>
<td>stereotaxic copper needles in vein</td>
<td>temporary 6th-nerve palsy</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>stereotaxic copper needles in artery</td>
<td>artery deliberately occluded</td>
</tr>
<tr>
<td><strong>Presently Acceptable Methods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>neck identified</td>
<td>3</td>
<td>&quot;stereotaxic&quot; needles</td>
<td></td>
</tr>
<tr>
<td>sac identified</td>
<td>3</td>
<td>superior ophthalmic vein pack</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>superior ophthalmic vein pack &amp; arteriovenous feeders</td>
<td></td>
</tr>
<tr>
<td>sac correctly presumed</td>
<td>1</td>
<td>phosphor bronze wire into ethmoidal &quot;false aneurysm&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>superior ophthalmic vein pack</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>anteroinferior transdural pack</td>
<td>one developed temporary</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>superior petrosal pack</td>
<td>asymptomatic carotid narrowing</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>transjugular balloon</td>
<td>temporary 6th-nerve palsy</td>
</tr>
<tr>
<td>sac not identified</td>
<td>10†</td>
<td>lateral phosphor bronze wire</td>
<td>temporary worsening of ophthalmic paresis</td>
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<td></td>
<td>1‡</td>
<td>anteroinferior pack &amp; superior petrosal pack</td>
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<td>1</td>
<td>superior ophthalmic pack &amp; posterior superior wire</td>
<td>temporary worsening of ophthalmic paresis</td>
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<td>1</td>
<td>superior ophthalmic pack &amp; lateral wire &amp; posterior superior wire</td>
<td>temporary worsening of ophthalmic paresis</td>
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<td>1‡</td>
<td>superior ophthalmic pack &amp; superior petrosal pack &amp; lateral wire</td>
<td>temporary worsening of ophthalmic paresis</td>
</tr>
</tbody>
</table>

*Unsuccessful attempt to enter the cavernous sinus through the frontal (ophthalmic) vein.
†Successful entry of cavernous sinus through a jugular vein (inferior petrosal sinus).
‡Unsuccessful attempt to enter the cavernous sinus through the jugular vein (inferior petrosal sinus).
Carotid-cavernous fistulas

FIG. 12. Angiograms of a fistula persisting in a 26-year-old woman 2 years after a car accident, despite carotid ligature, and muscle embolization (note clip on embolus in sac). Left: Preoperative angiogram. The fistula fills from the vertebral artery via the posterior communicating artery. Center: Under local anesthesia the internal carotid and ophthalmic arteries were clipped intradurally. The fistula continues to fill from a reticulum around the internal carotid artery in the neck. Right: Subtracted radiograph showing occlusion by 27 ft of phosphor bronze wire (arrows). The middle cerebral artery is supplied by the posterior communicating artery and by external carotid anastomosis.

Senile changes in one patient antedated her fistula, and the relation of this steal to her continued deterioration is not exactly clear. One patient had a mild subarachnoid hemorrhage at the onset of her symptoms without demonstration of any vascular abnormality other than the fistula.

Patients presented for treatment at intervals ranging from immediately to 26 years after the initial symptom. Most appeared within 6 months.

Treatment

The first seven cases have been reported previously. During the period of the total series our concepts of management developed. In two patients who were already blind we used an electric current to induce thrombosis (Table 3). This is no longer recommended for two reasons: it may induce arterial spasm, and it may injure a nerve. In one patient we deliberately occluded the carotid by stereotaxic needle insertion. Although successful in relieving symptoms this was conceptually unwise. One patient had already undergone carotid occlusion by previous treatment. All others have had their carotid artery preserved. We have employed stereotaxic needle occlusion when the fistulous connection was radiographically evident, and packing of the ophthalmic vein entrance, or the adjacent anteroinferior corner, or the superior petrosal vein exit when the predominantly filling sac was evident. Wire thrombosis was used when the origin was obscure, when the fistulous sac was quite large, and when the area to be thrombosed was distant from either the anteroinferior or posterosuperior corner.

In nine patients, the site of the fistula was correctly identified. In three the neck was seen to lie in the anterolateral sac. Two of these were occluded by insertion of stereotaxic copper needles into the neck, and one by insertion of copper electric needles. In one, the neck was seen to lie clearly in the posterosuperior sac, and it was occluded by stereotaxic needles (Fig. 8), supplemented (perhaps unnecessarily) by insertion of wire into the distended apex of the posterosuperior sac. In three patients, the fistula was confined to the anterior sac even though a fistulous neck was not seen. These were packed through the ophthalmic vein exit of the sinus (Fig. 4). Two were fed by distinct external carotid vessels and were in addition sealed by direct obliteration of the connection.

In six patients, the site of the fistula was correctly presumed to lie in the anterolateral sac. One fistula was occluded by an electric needle inserted through the orbit. (The eye had been previously enucleated; this electrical method is not now recommended). Another was thrombosed by 40 feet of wire inserted into a false aneurysm which progressed toward the ethmoid cavity (Fig. 9). Two were occluded by packing through the site of exit of the ophthalmic vein, and two by opening into and packing the anteroinferior corner of the anterior sac. In one patient, the fistula was presumed to lie in the posterosuperior sac and it was occluded by an intravenous balloon inserted transcutaneously into the posterosuperior sac (Fig. 11), and in another it was occluded by a superior petrosal pack.

In 16 patients, the site of the fistula was not precisely identified preoperatively, although in retrospect the identification was not always difficult (Fig. 12). In two early cases, occlusion was carried out by multiple stereotaxic needles. In 10 patients, occlusion was effected by inserting wire into the lateral
aspect of the anterolateral sac. One fistula was occluded by packing the anteroinferior corner and the superior petrosal sinus, and one by packing the ophthalmic exit and inserting wire into the posterosuperior sac. In one patient, the ophthalmic exit was packed and the lateral and posterosuperior surface treated with wire (Fig. 10). In the final patient, occlusion was accomplished by packing the ophthalmic vein exit and the superior petrosal sinus and by wiring the lateral aspect.

Technical Problems

Those fistulas in which the connection could not be identified provided a specific problem in four instances. Complete or partial occlusion of the exits without sealing the fistula simply converts the fistula into an aneurysmal sac (Fig. 10). One case was asymptomatic; in two, partial ophthalmoplegia became complete, and in one, complete ophthalmoplegia and further proptosis developed. The first three patients were treated by reoperation and occlusion of the remaining sac, using wire in two, and packing in one. In the last patient, partial carotid occlusion (internal) was maintained in the neck by a Seldinger clamp for 2 weeks. Symptoms in this patient promptly receded but a faint bruit persisted for 3 months; after which angiography confirmed absence of the fistula and patency of the internal carotid. Septate subdivision of the anterior compartment might have been present in these patients, although it was not visible radiologically.

In two patients a temporary sixth-nerve palsy appeared. One patient, who was treated early in the series, was treated with 26 stereotaxic needles. The other had packing through the superior petrosal sinus.

One patient in whom the electric current was used developed asymptomatic spasm of the carotid artery in the syphon. Another patient, in whom packing was accomplished through the anteroinferior corner, developed a very localized asymptomatic narrowing of the adjacent carotid. At angiography 2 weeks later, there was a very small localized distension at that point. The appearance suggested bruising of the wall rather than the usual type of spasm.

Results

All five patients who had been totally unilaterally blind at the time of presentation remained blind in that eye. They presumably had sustained optic nerve damage at the time of trauma. All 10 who had diminished visual acuity made an excellent recovery. This included one who was thought to be blind but in whom total loss of visual acuity could not be confirmed because of extreme chemosis and mental confusion. She recovered visual ability to read enlarged print. Proptosis disappeared from all 29 patients who had that sign, although it took 3 months to disappear from those two in whom significant dissection of the ophthalmic vein was carried out within the orbit (Fig. 6). All 20 patients with double vision regained single vision except two who still see double during extreme movement, but have otherwise single vision. In one of these patients a third-nerve palsy persisted for 9 months and in the other a sixth-nerve palsy lasted for 6 months before surgery. The carotid artery is presumably intact in all except one in whom it was deliberately sacrificed and one who had a previous carotid ligation and embolization. Four patients, relieved of all symptoms, refused postoperative angiography. In three of these, the fistula was seen to be occluded on the intraoperative angiogram, but, in one, occlusion was not verified angiographically.

There was no mortality in the series. Occasional postoperative drowsiness and an occasional arm drift were considered to be secondary to cerebral retraction. Retro-orbital pain was frequently present for several weeks.

Follow-Up Review

The first of these operations was performed more than 16 years ago, the most recent 1½ years ago. One of the earliest patients in the series, who had severe hypertension and two coronary occlusions, died 2 years postoperatively from documented internal cerebral hemorrhage. The patient with widespread fibromuscular dysplasia died 2 years after treatment of his fistula following unrelated abdominal surgery. The senile patient in the series who had been initially refused operation later suffered coronary occlusion and developed complete ophthalmoplegia and loss of eye sight. Occlusion through the ophthalmic vein was then carried out to relieve her intolerable retro-orbital pain. At the end of her lengthy period of hospitalization she went to a nursing home that afforded more detailed care than the one from which she came.

The 12-year-old posttraumatic child developed an epileptic seizure 6 months after discharge. She was one of those patients whose fistula was temporarily converted into an aneurysm. The second operation and its more vigorous retraction may have contributed to cortical hyperirritability, or her seizure could have been related to her initial head injury. A delay in the onset of puberty raised similar questions as to the role of the antecedent trauma, pressure on the hypothalamus or even retrograde thrombosis into the pituitary or hypothalamus.

Discussion

This series indicates that it is technically possible to effectively occlude carotid-cavernous fistulas while preserving the structure and function of the carotid artery and the nerves of the cavernous sinus. It is not necessarily technically simple. The multiplicity of the types of fistulas that present, of the approaches described here, and of the thrombogenic methods used may initially puzzle the reader. They represent an
Carotid-cavernous fistulas

evolution rather than the end point of a technique. The options available are summarized in Table 1.

In general, in fistulas of recent origin the sac is small. This makes them more difficult to handle. Traumatic fistulas are often recent, have a small sac and a large volume of shunted blood, and are the most difficult group. Fistulas arising from presumed aneurysmal rupture tend to be more chronic. They have a larger sac which makes entry of wire easy or may have an identifiable neck for direct copper needle occlusion. Those arising from dural arteriovenous malformations are often relatively small and may have feeding arteries or a section of resectable dura that permits one to aid the occlusion from the arterial side.

The surgical operative plan depends upon high-quality radiography. The general principle is to identify the fistulous neck if possible, and occlude it by copper needles or by a transjugular balloon if it is situated posterosuperiorly. If a neck is not seen, then the sac that fills first is occluded first in the belief that the neck lies within the sac. If occlusion of that sac does not terminate the fistula then the other sac is occluded.

Although in this series the initially filling sac was not always identified it should be possible to do so in the future. A six-per-second film changer will help. There are also newer techniques by which entry of blood into the fistula can be slowed for better visualization. In Debrun’s technique the carotid artery is compressed during vertebral injection and, in the presence of an intact posterior communicating artery, this permits a relatively slow filling of the fistula from above. Another technique involves a transcarotid wedge balloon catheter which slowly fills the carotid artery and the fistula from the port distal to the distended balloon. Both techniques will give the “site” of the leak but with large traumatic fistulas there may be no indication of a “neck.”

Occlusion of a sac is most easily accomplished by transdural wire, but if it is small it is best occluded through its key vein, the superior ophthalmic vein for the anterolateral sac and the superior petrosal vein for the posterosuperior sac. A direct transdural entry can be made anterosuperiorly if the superior ophthalmic vein is not seen. Occasionally the superior petrosal vein is absent and it should be technically possible to enter the posterosuperior sac directly, although we have not done it.

The technically most demanding step often lies in catheterizing the superficial temporal artery with a large enough catheter for radiography. When we have failed, we have used the superior thyroid artery, and on one occasion a greatly enlarged occipital artery. We have reluctantly punctured the carotid, lest we injure it. Further experience with the intraoperative intracavernous venogram might allow this method to substitute for, or complement, the arterial injection. Hemorrhage at the time of surgery has not been a problem, and blood transfusion has been rarely used. The induction of hypotension has not been employed. Surgical technique does not require a microscope but does require a good head light. Atraumatic retraction with mannitol is essential for the lateral and posterior approaches.

It is possible, in those who tolerate carotid occlusion, that a subtotal Selverstone clamp might be used to diminish carotid flow and thus enhance thrombosis. We have only explored this possibility in one patient. Since visual symptoms predominate, it should be possible, in poor risk patients who have good posterior drainage, to shut off the ophthalmic vein while preserving posterior drainage. This is a relatively simple, mainly extradural, procedure which is not much more complicated than an extradural trigeminal rhizotomy. The important thing in this option is to estimate that the posterior drainage is adequate, for, if it is not, a symptomatic intracavernous pressure build-up could occur with sixth-nerve paresis, retro-orbital pain, or both.

It would seem that the next step in the operative management of these fistulas consists in adhering to the principle of preserving the carotid artery in all instances while improving the techniques, both radiological and surgical, that make this possible. Further efforts to occlude the posterior sac by transjugular balloons is one such development. Since this present series was completed we have used Debrun’s technique of inserting transcarotid detachable balloons directly into the fistulous sac. This recent experience suggests that it is particularly suited to those large posttraumatic fistulas with large openings that capture the entire carotid flow. It probably would have been the preferable technique in the last four patients shown in Table 3 had it been then available. Whether it is always safe in those fistulas that have captured the entire carotid flow in patients who do not tolerate carotid compression is not certain. The duration (or degree) of intraoperative carotid occlusion (or restriction) would depend upon the skill of the operator.

A detachable balloon might also be inserted at craniotomy through the ophthalmic vein exit, the superior petrosal sinus, or indeed through the lateral or superior walls.

We do not have much enthusiasm for further attempts to catheterize the superior ophthalmic vein from the supraorbital region because of the three turns (down, out, and back) which it takes at the apex of the orbit. Although Peterson, et al., succeeded in this, we have failed twice. Our own experience, and our later study of Dandy’s account, would most strongly advise against attempted catheterization of the distended ophthalmic vein within the orbit.

Summary

Thirty-three carotid-cavernous fistulas were occluded in 31 patients using thrombogenic tech-
niques. In one early patient the carotid was stereotaxically occluded deliberately. In one it was occluded by previous treatment. In all others its patency was deliberately preserved. There was no mortality and virtually no morbidity. Visual symptoms were relieved in all who were not already blind. Recommended techniques include retrograde packing of the cavernous sinus at the ophthalmic vein and superior petrosal sinus exits, packing by direct entry into the sinus at its anterior inferior corner, transjugular insertion of an occluding balloon into the posterior end of the sinus, and transmural insertion of thrombogenic wire and thrombogenic needles. Intraoperatively angiography is essential. The use of an electric current to enhance thrombosis is not advised.

References


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