Carotid cave aneurysms of the internal carotid artery

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In a series of 32 surgical cases of carotid-ophthalmic artery aneurysm, seven of the lesions were located in the "carotid cave." This special type of aneurysm is usually small and projects medially on the anteroposterior view of the angiogram. At surgery, it is located intradurally at the dural penetration of the internal carotid artery (ICA) on the ventromedial side, appears to be buried in the dural pouch (carotid cave), and is often difficult to find, dissect, and clip. The aneurysm extends into the cavernous sinus space, and the parent ICA penetrates the dural ring obliquely. An ipsilateral pterional approach was used in all 32 cases, and ring clips were used exclusively because the aneurysms were located ventromedially. Clipping was successful in five cases. All patients returned to their preoperative occupation, although vision worsened postoperatively in two cases. The technical steps required for successful obliteration of this aneurysm are summarized as follows: 1) exposure of the cervical ICA; 2) unroofing of the optic canal and removal of the anterior clinoid process; 3) exploration of the ICA around the dural ring and opening of the cavernous sinus; 4) direct retraction of the ICA and optic nerve; and 5) application of multiple ring clips to conform to the natural curvature of the carotid artery; a curved-blade ring clip is especially useful. The relevant topographic anatomy is discussed.

KEY WORDS • carotid cave • aneurysm • carotid-ophthalmic aneurysm • internal carotid artery • aneurysm clip

Among these, 19 were of the ventral type, six were dorsal, six were medial in the operating field, and one was fusiform. Seven of the 19 ventral aneurysms formed the special subgroup known as the "carotid cave" aneurysm, and are the subject of this report (Table 1). Five of the seven patients were male, and five were in their 6th decade of life. Only two patients presented with subarachnoid hemorrhage, caused by rupture of the aneurysm; the aneurysms in the others were incidental findings. Three patients had multiple aneurysms.

Surgical Technique

An ipsilateral pterional approach is used in all cases, after the carotid artery is exposed in the neck. The sylvian fissure and carotid cistern are opened and the ICA is visualized. Usually the aneurysm is not seen at this stage. Next, the roof of the optic canal and anterior clinoid process are drilled carefully. Unroofing of the optic canal and opening of the dura propria facilitate mobilization and safe retraction of the optic nerve. The distal side of the aneurysm can now be visualized arising from the ventromedial wall of the ICA if the aneurysm extends beyond the carotid cave. It is impossible to visualize the aneurysm when it is in the carotid cave (Fig. 1 left). The ophthalmic artery is dissected along
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Fig. 1. Intraoperative illustrations of a representative case of carotid cave aneurysm as approached pterionally. 1: optic nerve; 2: carotid artery; 3: ophthalmic artery; 4: carotid dural ring; 5: carotid cave; 6: aneurysm; 7: axilla. The arrowhead points to the superior hypophyseal artery. Left: Exposure of the carotid cave region with the optic nerve unroofed and anterior clinoid process removed. Right: The aneurysm is visualized when the carotid dural ring is opened. The aneurysm is sketched slightly proximally to stress the carotid cave.

TABLE 1
Summary of seven cases treated surgically for carotid cave aneurysm

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Symptom*</th>
<th>Multiplicity</th>
<th>Clipping</th>
<th>Postop vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56, F</td>
<td>rt MCA†</td>
<td>2</td>
<td>failure</td>
<td>normal</td>
</tr>
<tr>
<td>2</td>
<td>42, M</td>
<td>tumor†</td>
<td>1</td>
<td>failure</td>
<td>worse</td>
</tr>
<tr>
<td>3</td>
<td>44, M</td>
<td>TIA†</td>
<td>1</td>
<td>success</td>
<td>normal</td>
</tr>
<tr>
<td>4</td>
<td>58, M</td>
<td>SAH</td>
<td>1</td>
<td>success</td>
<td>normal</td>
</tr>
<tr>
<td>5</td>
<td>56, F</td>
<td>SAH</td>
<td>2</td>
<td>success</td>
<td>normal</td>
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<tr>
<td>6</td>
<td>59, M</td>
<td>TIA†</td>
<td>1</td>
<td>success</td>
<td>normal</td>
</tr>
<tr>
<td>7</td>
<td>58, M</td>
<td>ACA†</td>
<td>2</td>
<td>success</td>
<td>worse</td>
</tr>
</tbody>
</table>

* MCA = middle cerebral artery aneurysm; tumor = pituitary adenoma; TIA = transient ischemic attack; SAH = subarachnoid hemorrhage; ACA = anterior cerebral artery aneurysm.
† Carotid cave aneurysm was an incidental finding.

Operative Results

All seven patients underwent craniotomy (Table 1). In two early cases (Cases 1 and 2) the aneurysms could not be exposed due to lack of knowledge about the carotid cave at that time. Two patients exhibited decreased vision after the operation. In one of them (Case 2), three pieces of Bemsheet (cellulose fabric) were wrapped around the proximal ICA at the origin of the ophthalmic artery including a suspected portion of the aneurysm. Postoperatively, vision in the ipsilateral eye was limited to light perception only, which improved to finger-counting following immediate removal of the Bemsheets. In the other case (Case 7), postoperative ipsilateral vision deteriorated to hand motion. This patient had previously undergone craniotomy at which a ruptured anterior communicating artery aneurysm had been obliterated. On reopening for treatment of the incidental carotid cave aneurysm, the optic nerve was found to be tightly adherent to the head of the clip and to the piece of sponge which had been placed between the clip head and optic nerve. Dissection of the adhesion was necessary to reach the aneurysm; in addition, the optic nerve was retracted, although mini-
mally, in the course of obliterating the aneurysm. In all other cases vision and visual fields were unchanged and normal. One patient (Case 2) developed cerebrospinal fluid rhinorrhea which required reopening the craniotomy for closure of an ethmoidal sinus, which had been entered when drilling the optic canal at the first operation. Postoperative angiography showed that the clipped aneurysms had all been completely obliterated. No patients developed neurological symptoms other than the decreased vision in the aforementioned two cases.

Illustrative Cases

Case 3

This 44-year-old man suffered a transient ischemic attack. A computerized tomography (CT) scan showed a small low-density area in the left basal ganglion. Left carotid angiography showed an aneurysm of the carotid-ophthalmic type (Fig. 2 left), and he was referred to us for surgery. Neurological examination at admission was normal, and he did not develop any neurological deficits on the preoperative balloon Matas test for 25 minutes.

At surgery, the optic canal was unroofed and the anterior clinoid process was removed, then the axilla was exposed. A right-angled ring clip was then used to clip the aneurysm. The patient awoke from anesthesia without any deficit. Left carotid angiography 2 days later showed incomplete obliteration of the aneurysm (Fig. 2 center). Immediate reoperation was undertaken. At reoperation, the clip blades were found to fall just short of completely occluding the aneurysm neck in its proximal portion. The dural ring was cut circumferentially to expose the genu, and the cavernous sinus was opened further. The previously placed ring clip was removed and a newly designed ring clip with curved blades was applied to the neck of the aneurysm, resulting in complete obliteration (Fig. 2 right).

This was one of our earlier cases in which the operation was performed when we were not well aware of the detailed anatomical correlations. The dural ring had not been cut at the first operation, which led to incomplete clipping. The newly designed curved-blade ring clip was better suited for this type of aneurysm.

Case 5

This 56-year-old woman suffered two subarachnoid hemorrhages, 5 and 3 weeks prior to her presentation. Surgery for a right carotid-posterior communicating artery aneurysm was undertaken on the day of the second event, and the intraoperative findings suggested that the aneurysm had not ruptured. The angiogram also showed a left carotid cave aneurysm pointing medially.

A left pterional approach was made to the carotid cave aneurysm. On exploration, the aneurysm was found behind and medial to the ICA. The proximal part of the aneurysm neck could not be visualized until the optic canal was unroofed, the anterior clinoid process drilled, and the anterosuperior part of the cavernous sinus opened. After dissecting the aneurysm, the cervical ICA was temporarily occluded with a clip for 4 minutes. An oblique-angled ring clip was placed with a multijoint clip applier, whereby as the blades were being closed the direction of the clip blades could be changed stepwise according to the curvature of the ICA. On examination, the proximal part of the aneurysm neck on the medial side of the ICA was not completely occluded and, when the cervical carotid artery occlusion was released, the clip blades became detached from the aneurysm. The clip was replaced, and a second clip of the same type was positioned proximally in tandem fashion for reinforcement.

The curvature of the ICA at and around its exit varies in individual cases; in this case, the curvature was greater in the intracavernous portion and the carotid artery was relatively straight in the intradural segment. The use of two ring clips was better than using a single
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clip in order to conform to the natural curve of the carotid artery and to reinforce the occluding force.

Discussion

Carotid-ophthalmic artery aneurysms arise from the ICA between the origins of the ophthalmic artery and the posterior communicating artery. Many reports in recent years have discussed successful clipping of these aneurysms; however, some of these aneurysms still present considerable surgical difficulty. Aneurysms arising from the ventral wall of the ICA have been grouped separately by some authors as paraclinoid or ventral aneurysms. Nutik stated that paraclinoid aneurysms arise from the surface of the ICA opposite the origin of the ophthalmic artery. In his cases, the site of origin was partly intradural and partly intracavernous. Surgical obliteration of these aneurysms has been difficult: Nutik's attempted surgery for paraclinoid aneurysms resulted in a high mortality rate (four of his five patients died). At times the surgeon had to resort to wrapping the aneurysm, as clipping was not possible.

The small subgroup of ventral ICA aneurysms poses problems at surgery. These aneurysms are in the carotid cave and mainly proximal to the origin of the ophthalmic artery; they are small, grow ventromedially, and extend into the cavernous sinus. Angiographically, most of the aneurysms lie below the level of the anterior clinoid process. In the anteroposterior view, they project medially and in the lateral view posteriorly, confirming a ventromedial origin from the ICA (Fig. 3). It is not certain why these aneurysms arise at these unusual locations unrelated to a branching site of an intracranial artery. However, at surgery the aneurysm was found to arise close to the origin of a small, medially running artery in three of the seven cases (Fig. 1). It is possible that the aneurysm may have developed in relation to the superior hypophyseal artery.

FIG. 3. Tracings of the lateral (left) and anteroposterior (right) angiograms from the seven cases of carotid cave aneurysms (black areas). The numbers correspond to the case numbers in Table 1.
Problems at clipping in our first two cases led us to study the anatomy of this area more thoroughly. The dura forms an oblique ring around the carotid artery as it emerges from the cavernous sinus, adhering firmly to the adventitia of the artery. The dural adherence is strongest from the dorsal to the lateral wall of the carotid artery. On the medial side of the artery there is some redundant dura that forms a small recess or pouch with its apex toward the cavernous sinus. This dural pouch lies in the 1 to 6 o'clock position medial to the carotid artery as seen in the left pterional approach, and is usually empty. On the medial side this recess is bounded by bone, the sphenoid body (carotid sulcus). We have called this dural pouch the "carotid cave," as it lies between the carotid artery and carotid sulcus (Fig. 4), and believe that the availability of this potential space on the medial aspect of the carotid artery facilitates the aneurysm's growth. Since the aneurysm arises just cranial to the genu of the ICA, the hemodynamic thrust and the turbulence of flow caused by the changing course of the ICA contribute to the growth of the aneurysm. The aneurysm cannot grow very large since it is limited by bone medially and the carotid artery laterally. A small aneurysm can lie buried in this cave, posing problems of localization at surgery. We believe that the aneurysm arises intradurally from the ICA but extends to the cavernous sinus space during its growth, because we have not found any cases in which the distal aneurysm neck or dome was covered with dural tissue. It is likely also that the dural ring or the covering dura may be weak or partially deficient on the medial side, allowing easy growth of the carotid cave aneurysm into the cavernous sinus.

Some technical considerations are important for successful obliteration of these aneurysms. We recommend an ipsilateral pterional approach in all these cases. The contralateral approach is not satisfactory for anatomical and technical reasons. Routinely, ipsilateral cervical carotid arteries are exposed in preparation for temporary occlusion if necessary. Unroofing the optic canal and drilling the anterior clinoid process are necessary to facilitate exposure of the aneurysm. Lateral retraction of the carotid artery to visualize the aneurysm and/or to clip it before these procedures are completed would likely result in premature rupture of the aneurysm. The ophthalmic artery is mobilized along its course. The dural ring around the carotid artery should be freed and the intracavernous carotid artery should be mobilized up to the genu and axilla. This is necessary since the aneurysm neck lies buried in the carotid cave and the opposite wall of the parent artery is extradural or lies in the cavernous sinus. Without these procedures it is impossible to apply a ring clip. Extreme care should be taken to prevent rupture while dissecting the adhesion on the aneurysm.

Ring clips are preferred for aneurysm clipping. Two points are important when applying the clip: one is that the clip should be applied to conform to the curve of the carotid artery. Because the working space is limited by the optic nerve, the clip is first applied along the course of the intracranial portion of the carotid artery and is then rotated along the curve of the genu while closing the blades. The second is that the clip blade should pass as far as the axilla of the artery; otherwise, the clip might obliterate the carotid artery. Use of two clips with short blades (5 mm) is often better than using...
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one with longer blades in order to conform to the natural curve of the carotid artery. We have recently designed a new type of ring clip with curved blades. This design enables easier complete occlusion of the carotid cave aneurysm with a single clip, as illustrated in the second operation in Case 3 (Fig. 2 right). Direct retraction of the optic nerve is useful when dissecting and clipping and is effectively performed by a retraction system such as the Sugita system. It is important to follow the principle of intermittent retraction, preferably for 10 minutes or less with 10 minutes of release. In two cases in the present series, vision on the side of the aneurysm worsened. The normal optic nerve will tolerate intermittent retraction with moderate pressure up to 20 torr. Direct retraction of the optic nerve can be effectively performed by cutting the optic nerve sheath at its lateral border with the anterior clinoid process; the magnitude of safe retraction is roughly the same as the diameter of the carotid artery (that is, about 5 mm). Observing vessels on the surface of the optic nerve is important; blanching of the vessels may be a dangerous sign. The Doppler flowmeter should be used intraoperatively to confirm adequacy of blood flow through the carotid and ophthalmic arteries.

Perhaps some of the paraclinoid aneurysms reported by Nutik and some of the unclipped aneurysms described by Yasargil, et al., belong to this group. Fox, in his recent paper on ventral ICA aneurysms, highlighted the difficulties of clipping certain aneurysms, particularly the small ones. These cases are probably carotid cave aneurysms. Carotid cave aneurysms arise closer to the origin of the ophthalmic artery along the circumference of the ICA than do paraclinoid aneurysms, which arise on the opposite side of the ICA. Another difference is that the aneurysm sac is ventromedial to the ICA and not beside the anterior clinoid process as is seen in paraclinoid aneurysms. In view of the unusual site of origin, small size, intradural growth with occasional intracavernous extension, and special surgical tactics required for their clipping, this special type of aneurysm should be grouped separately from carotid-ophthalmic aneurysms and we propose calling them “carotid cave” aneurysms.

Although aneurysms genuinely located in the cavernous sinus require different techniques, the basic methods for clipping a carotid cave aneurysm (such as opening the cavernous dural ring, securing the genu and axilla of the ICA, and conforming the clip to the carotid curve) are also important for large intradural carotid artery aneurysms which are located ventrally and proximally, because they likely extend into the carotid cave.

References

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