A COMBINED MICROSURGICAL SKULL-BASE AND ENDOVASCULAR APPROACH TO GIANT AND LARGE PARAACLINOID ANEURYSMS

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BACKGROUND
The treatment of giant and large paraclinoid aneurysms remains challenging. To improve exposure, facilitate the dissection of aneurysms, assure vascular control, reduce brain retraction and temporary occlusion time, enable simultaneous treatment of associated lesions, and achieve more successful treatment of "difficult" (atherosclerotic and calcified) aneurysms, we combined the skull-base approach with endovascular balloon occlusion of the internal carotid artery (ICA) and suction decompression of the aneurysm.

METHODS
Sixteen female patients were treated, eight with giant aneurysms and eight with large aneurysms. Eight aneurysms occurred on the right side and eight on the left. Eight patients had an additional aneurysm; five were clipped during the same procedure. Three patients had infundibular arterial dilation. One patient had an associated hemangioma of the ipsilateral cavernous sinus. The cranio-orbital-zygomatic approach was used for all patients. The anterior clinoid was drilled, and the optic nerve was decompressed, dissected, and mobilized. Transfemoral temporary balloon occlusion of the ICA in the neck was followed by placement of a temporary clip proximal to the posterior communicating artery. Suction decompression was then applied. All aneurysms were then successfully clipped, except one that had a calcified neck and wall that could not be collapsed. Intraoperative angiography performed in 13 of 15 patients with clipped aneurysms confirmed obliteration of the aneurysm and patency of the blood vessels.

RESULTS
Postoperative results were good in 14 patients. One patient had right-sided hemiplegia and expressive aphasia, which improved after rehabilitation. One patient with an additional basilar tip aneurysm clipped simultaneously died on the fifth postoperative day because of intraventricular hemorrhage. The origin of bleeding could not be determined on autopsy. Surgical difficulties and morbidity stemmed mainly from a severely calcified or atherosclerotic aneurysmal neck.

CONCLUSION
The combination of skull-base approaches and endovascular balloon occlusion coupled with suction decompression is a successful option for the treatment of these challenging aneurysms. © 1998 by Elsevier Science Inc.

KEY WORDS
Endovascular techniques, giant aneurysm, large aneurysm, paraclinoid aneurysm, skull base surgery, suction decompression.

Paraclinoid aneurysms can arise from many points on the circumference of the intradural internal carotid artery (ICA), proximal to the origin of the posterior communicating artery. In the anterior circulation, these aneurysms are most likely to become giant [15,30,42,43,45]. Their treatment is more difficult than that of other aneurysms of the anterior circulation. Significant advancements that facilitate their treatment include: detailed microsurgical anatomical studies of this area [10,13,18,33]; the development of skull-base approaches to this area [2,3,12,13,23,26,31,32,39]; surgical advancements, including drilling of the anterior clinoid, unroofing the orbital canal, opening the falciform fold of the optic nerve, and opening the distal ICA ring [1–3,7,10,12,13,20,24,31,33,39,41,43,45]; distal control by temporary clipping and various methods of proximal control with or without suction decompression [6,10,13,16,17,20,35,38,42,43,45]; microsurgical dissection techniques of the subarachnoid cisterns [45–47]; the refinement of clips and clipping techniques [14,40,45–47]; and various methods of
cerebral protection during temporary occlusion [6–9,30,34,42,44].

Nevertheless, the successful treatment of paraclinoid aneurysms remains a neurosurgical challenge. In an attempt to further refine their treatment, we integrated all these achievements. We herein report the results of a series of 16 patients with giant or large paraclinoid aneurysms treated through the cranio-orbital-zygomatic approach combined with endovascular, transfemoral, balloon occlusion with suction decompression. In addition, we present difficulties we encountered and the causes of complications associated with the surgical management of these lesions. Finally, we reviewed the results of operative treatment of giant and large paraclinoid aneurysms to determine a state-of-the-art treatment and to evaluate our results.

**Operative Technique**

Our surgical strategy for patients with giant or large paraclinoid aneurysms can be summarized in three points: 1) the cranio-orbital-zygomatic approach; 2) drilling of the anterior clinoid; and 3) proximal control through transfemoral endovascular balloon occlusion, followed by distal control with a temporary clip, and suction decompression to deflate an aneurysm.

Before the approach began in each patient, electrodes were placed for intraoperative monitoring as follows: a) somatosensory evoked potentials (SSEP) with median nerve stimulation; b) electroencephalography (EEG); c) brainstem auditory evoked responses (BAER); and d) oculomotor nerve monitoring. The patient’s temperature was kept at mild hypothermia level (range, 32.5–34°C).

**Surgical Approach**

The details of the cranio-orbital-zygomatic approach, which we used in this series, and its utilization have been described previously [2,3,32,39]. We herein present a brief description. The patient is placed supine. The head is rotated 30 to 40 degrees toward the opposite side, dropped toward the floor, tilted 5 to 10 degrees, and fixed in the Mayfield head rest (Figure 1). The axis of visualization can be changed by turning the table from side to side or vertically. The surgical field at the ipsilateral frontotemporal orbital region and the left femoral region (for the interventional neuroradiologist) are prepared in the usual manner.

A skin incision is made 1 cm in front of the tragus, at the level of the zygomatic arch, and carried behind the hairline to the level of the contralateral superior temporal line. This incision spares the branches of the facial nerve and the parietal branch of the superficial temporal artery. Particular attention is paid to the dissection of the superficial and deep fascia of the temporalis muscle to prevent injury to the facial nerve and maintain the arterial vascularization of the temporal muscle. After the zygomatic arch is cut obliquely at each end, the temporalis muscle is reflected downwards. A large pericranial flap is preserved to repair the floor of the frontal fossa and for closing the frontal and ethmoidal sinuses, if necessary. The supraorbital nerve is dissected away, or freed, from its foramen.

The craniotomy is performed with three holes and a high speed bone drill. The first hole is the keyhole, made just behind the zygomatic process of the frontal bone, at the frontosphenoidal junction. The lower half of this hole opens into the orbit; the upper half opens into the frontal fossa (Figure 2, right inset). The second hole is placed posteriorly at the floor of the temporal fossa. The third hole, which is small, is made in the frontal bone, just above the supraorbital incisura and lateral to the nasion to avoid, if possible, encountering the frontal sinus. If the sinus is opened, the mucosa is removed, and the sinus is packed with a piece of the temporal muscle. The holes are connected with the craniotome, and the final cut is made in the orbital roof between the keyhole and the frontal hole. During this process, the contents of the orbit are protected with a spatula (Figure 2).

After the flap is removed, the dissection is continued extradurally along the floor of the middle fossa. The ICA is exposed in its horizontal intrape-
The cranio-orbital-zygomatic approach: the position of the burr holes and craniotomy. The pericranium is reflected anteriorly. After the zygoma is cut, the temporalis muscle is reflected downwards. (Right inset) The keyhole with adjacent bone incisions. (Left inset) The remaining portion of the orbital roof and the lateral wall are removed in one piece.

Removal of the anterior clinoid. (Top) Extradural drilling (O, orbita; C, anterior clinoid; D, dura). (Bottom) Intradural drilling (A, aneurysm; C, anterior clinoid; FL, frontal lobe).

DISSECTING THE ANEURYSM

After the dura is opened, splitting the sylvian fissure brings the ICA and the aneurysm into view. The bridging veins of the temporal lobe are preserved. The subarachnoidal cisterns, including the ICA cistern, are opened in order, revealing the first few millimeters of the posterior communicating and anterior choroidal arteries. Just proximal to the posterior communicating artery, a space is created for later placement of the temporary clip. Opening the dura propria of the optic nerve from the falci-form fold along the entire length of the optic canal longitudinally allows slight but significant lateromedial mobilization of the nerve and dissection away from the aneurysm. Intermittent retraction of the optic nerve is preferred over single, protracted retraction.

The origin of the ophthalmic artery is carefully dissected away from the aneurysm. Opening the distal dural ring anchoring the ICA reveals the proximal portion of the aneurysmal neck. This opening is extended toward the third cranial nerve, and any resulting venous bleeding is easily controlled with packing. Stepwise dissection of the aneurysm from the surrounding structures follows. Papaverine is routinely applied to the ICA and its branches early in the surgical procedure and is repeated as necessary.
Combined Approach to Paraclinoid Aneurysms

BALLOON OCCLUSION AND TEMPORARY CLIPPING

At this point, the neuroradiologist uses fluoroscopic guidance from a portable OEC Diasonics digital radiographic unit (OEC-DIASONICS, Salt Lake City, Utah) to introduce a 5-French, 100-cm arterial catheter through a 6-French left femoral arterial sheath into the appropriate ICA. After the catheter is correctly positioned, it is exchanged for a 5-French double-lumen balloon catheter with a 300-cm exchange guide wire. The tip of the balloon catheter is positioned 2 cm above the carotid bifurcation (Figure 4a) and is tested for proper intraluminal placement. Test inflation of the balloon with isotonic contrast is performed under fluoroscopy to determine the proper volume necessary to completely occlude the ICA. Usually, 0.1–0.15 mL is adequate. To prevent clotting, a pressure drip infusion of normal saline is started to the distal arterial lumen. Cerebral protection is attained with an ultrashort barbiturate (Pentobarbital; 4–8 mg/kg body weight) until burst suppression is achieved. The anesthesiologist then elevates the mean arterial pressure (10–20 mm Hg above the baseline levels), and the balloon is inflated. Then, a temporary clip is placed just proximal to the posterior communicating artery. Gentle and continuous hand retrograde suction through the luminal end of the catheter is used to decompress the aneurysm and empty the backflow from the ophthalmic and superior hypophyseal arteries.

CLIPPING THE ANEURYSM

The wall of the aneurysm, which is thick and often atherosclerotic, differs from that of the parent artery, which is thin. This difference allows the aneurysmal sac to be gently compressed, as the aneurysm occasionally must be lifted to establish a plane between it and the ICA. At this stage, the aneurysm collapses and is carefully separated from
the ICA. The neck of the aneurysm is dissected and permanently clipped (Figure 4b).

In nine of our patients, more than one clip was needed to exclude the aneurysm from the circulation and to prevent the circulation pressure from opening or pulsating the clip blades. In these cases, placing the other clip(s) parallel to or in the opposite direction and away from the parent artery was sufficient. Bipolar coagulation of the aneurysmal sac did not have an effect in some patients because either the aneurysmal wall and neck were thick with prominent atherosclerosis or the aneurysm was thrombosed. To eliminate the existing mass effect of the giant aneurysm after clipping, the aneurysmal dome was punctured or excised. In patients with severe atherosclerosis or thrombosis, the dome of the aneurysm was opened, and the contents were evacuated. In the case of the dome being attached to the hypothalamus, the pituitary stalk, or the chiasm, that portion of the aneurysm was left in situ. After clipping the aneurysm, the blood flow was re-established and angiography was done through the existing catheter to confirm the obliteration of the aneurysm and the patency of the blood vessels (Figures 5 and 6).

**CASE MATERIAL**

During a period of 44 months (September 1993–April 1997), 16 patients with giant or large paraclinoid aneurysms were referred to our institution. Eight of the aneurysms were giant (>25 mm) and eight were large (15–24 mm). Eight aneurysms were on the right side; eight were on the left side. Neuroradiologic investigation included four-vessel angiography, computed tomography (CT), and magnetic resonance imaging (MRI). Follow-up ranged from 1–44 months. The clinical data are summarized in Table 1.

Eight of our patients (50%) had an additional aneurysm elsewhere; five were clipped during the same procedure. Three patients also had infundibular arterial dilations. One patient (Case 9) had a rare clinical presentation—a large paraclinoid aneurysm associated with a hemangiona of the ipsilateral cavernous sinus. The patient, whose operation was delayed 56 days after initial bleeding, first underwent surgery at another facility and was referred to us after the initial clipping failed (Case 7). Table 2 shows the final outcome in our series. Outcomes are based on the grading scales described earlier [6,20,46]; 14 of our patients (88%) had good outcomes, enabling them to return to their usual preoperative activities.

Four of our patients (25%; Cases 8, 12, 13, and 11) had evidence of severe atherosclerosis and calcified plaque at the aneurysmal neck or intraneurysmal thrombosis. The first three were successfully clipped. In one patient (Case 8), the calcified plaque at the aneurysmal neck was removed, and adequate dissection and clipping were performed. Postoperatively, she developed a neurologic deficit, which improved after 2 months of rehabilitation. At the time of this report, the patient was still in fair condition, but her neurologic status was improving, and she is walking. In the second patient (Case 12), the calcified portion of the aneurysmal neck was torn (“fractured”) during the clipping. After the plaque was removed, the tear was sutured, and the blood flow was re-established. Interestingly, the vascular anatomies and preoperative medical conditions of these two patients were similar. They were the same age, and had undergone the same cerebral protection regimen, but only one developed ischemic deficit. The third of these four “difficult” cases (Case 13) had a partially thrombosed aneurysm that could not be completely collapsed (see Figure 10). An appropriate neck was created by stepwise coagulation, the thrombosed sac was divided, and the aneurysm was consequently clipped.

The fourth of these patients (Case 11) had an aneurysm with a calcified neck and wall. The lesion could not be clipped and clamped. Thin-section CT angiography with helical or spiral techniques can usually detect calcification along the aneurysmal wall; however, in this patient, the calcification was considered a part of the enlarged and heavily calcified anterior clinoid (Figure 7a and b). After drilling the anterior clinoid, we realized that the calcification was a part of the aneurysmal neck and wall. The aneurysm would not collapse and could not be clipped. This intraoperative finding was confirmed on the postoperative CT scan (Figure 7c). The patient subsequently was referred for a coiling procedure.

In our six patients with visual field deficits (38%), two aneurysms produced bitemporal deficit, two had a superior temporal field cut, and two involved the nasal half of the visual field. Two of these patients experienced visual field improvement postoperatively, whereas four retained the deficit. There were no postoperative visual field deteriorations in our series.

Eight of our patients (50%) had postoperative complications (Table 3). In seven of them, the complications were overcome with surgical or medical treatment and their outcomes were good. One patient (Case 2) died after a sudden deterioration on
Case 4. (a) Preoperative angiogram demonstrating the right large paraclinoid aneurysm. (b) Preoperative MRI (coronal view) demonstrating the aneurysm, (A), and its origin (arrowhead) from the subclinoid ICA. (c) Intraoperative angiogram confirming the successful clipping and patency of the adjacent blood vessels.
Case 6. (a) Preoperative angiogram demonstrating the right giant paraclinoid aneurysm. (b) Intraoperative photo (A, aneurysms; ICA, internal carotid artery; large arrow, location for placement of the temporary clip; arrowhead, origin of the posterior communicating artery; small arrow, origin of the anterior chorioidal artery) (c) Intraoperative angiogram confirming the successful clipping and patency of adjacent blood vessels (arrow indicates the positions of three parallel clips).
Combined Approach to Paraclinoid Aneurysms

Distribution of Patients According to Age, Clinical Presentation, Presence of Associated Lesion (Aneurysm or Tumor) and Their Simultaneous Treatment, Clinical Grading Scales for Subarachnoid Hemorrhage, Time Elapsed After Bleeding, and Clinical Outcomes

<table>
<thead>
<tr>
<th>CASE NO.</th>
<th>AGE (YEARS)</th>
<th>CLINICAL PRESENTATION</th>
<th>ASSOCIATED LESION</th>
<th>HUNT-HESS GRADE</th>
<th>YAŞARGIL GRADE</th>
<th>TIME AFTER BLEEDING</th>
<th>OUTCOME</th>
</tr>
</thead>
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<tr>
<td>1 (G)</td>
<td>37</td>
<td>SAH, CH</td>
<td>A (ICA, S, c)</td>
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<td>2 (L)</td>
<td>59</td>
<td>SAH, CH, VFD</td>
<td>A (BT, L, +)</td>
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<td>Ia</td>
<td>3 days</td>
<td>Death</td>
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<tr>
<td>3 (G)</td>
<td>42</td>
<td>SAH, CH</td>
<td>ID (MCA, i)</td>
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<td>IIa</td>
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<td>Good</td>
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<tr>
<td>4 (L)</td>
<td>33</td>
<td>CH, PS</td>
<td>ID (PCoA, c)</td>
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<td>0a</td>
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<td>Good</td>
</tr>
<tr>
<td>5 (L)</td>
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<td>SAH, CH</td>
<td>A (MCA, S, i, +)</td>
<td>III</td>
<td>IIIa</td>
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</tr>
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<td>6 (G)</td>
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<td>0b</td>
<td>56 days</td>
<td>Good</td>
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<tr>
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<td></td>
<td>II</td>
<td>Ia</td>
<td>48 h</td>
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<td>A (ICA, G, c)</td>
<td>I</td>
<td>Ia</td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>9 (L)</td>
<td>49</td>
<td>CH, VFD</td>
<td>T (i, +)</td>
<td>0</td>
<td>0b</td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>10 (G)</td>
<td>47</td>
<td>CH, VFD</td>
<td></td>
<td>0</td>
<td>0b</td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>11 (G)</td>
<td>45</td>
<td>CH, VFD</td>
<td>A (ICA, L, c)</td>
<td>0</td>
<td>0b</td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>12 (L)</td>
<td>51</td>
<td>CH, VFD</td>
<td>A (ACoA, S, +)</td>
<td>0</td>
<td>0a</td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>13 (G)</td>
<td>50</td>
<td>AS</td>
<td>A (ICA, S, i, +)</td>
<td>0</td>
<td>0a</td>
<td></td>
<td>Good</td>
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<tr>
<td>14 (L)</td>
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<td>0</td>
<td>0a</td>
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<td>Good</td>
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<tr>
<td>15 (L)</td>
<td>43</td>
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<td>0</td>
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<tr>
<td>16 (L)</td>
<td>37</td>
<td>SAH</td>
<td>A (ICA, S, i, +)</td>
<td>I</td>
<td>Ia</td>
<td>24 h</td>
<td>Good</td>
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</tbody>
</table>

*Modified Hunt-Hess [22], and Yaşargil [45].

**Abbreviations: A, aneurysm; ACoA, anterior communicating artery; AS, asymptomatic; BT, basilar tip; T, cavernous sinus hemangioma tumor; CH, chronic headache; c, contralateral; G, giant; ID, infundibular arterial dilation; ICA, internal carotid artery; i, ipsilateral; L, large; MCA, middle cerebral artery; PS, pituitary symptoms; S, small; (+), simultaneous surgical clipping or excision; SAH, subarachnoid hemorrhage; VFD, visual field deficit; PCoA, posterior communicating artery.

*a, no neurologic deficit; b, with neurologic deficit.

"aneurysm not clipped.

The fifth postoperative day. She had undergone simultaneous clipping of two large aneurysms, one paraclinoid and the other at the basilar tip. Intra-ventricular hemorrhage was diagnosed on a CT scan, and external ventricular drainage was performed immediately, but without improving the patient's clinical condition. At autopsy, the aneurysms appeared to be correctly clipped and the site of bleeding could not be determined.

**DISCUSSION**

**TREATMENT**

Treating giant or large paraclinoid aneurysms is more difficult than other anterior circulation aneurysms and demands particular operative technique. The risk of treatment is higher and is associated with greater operative hazards. Various techniques for conservative or indirect treatment have been advocated, including carotid occlusion, arterial extracranial-intracranial bypass and subsequent ligation of the ICA with heparinization, wrapping, and intramural thrombosis. Drake et al [14] reported an 84% success of proximal Hunterian ligation of the ICA, which was performed in 21% of their giant paraclinoid aneurysms.

Most neurosurgeons agree that the best treatment for giant or large paraclinoid aneurysms is direct clipping [5,6,10,12,18,20,21,29,30,35,38,40,42,43,45]. The goals should be to eliminate the risk of primary or recurrent subarachnoid hemorrhage, prevent further visual loss by decompressing the optic apparatus, and secure the hemodynamics by maintaining the patency of the ICA and its branches. Optimally, all aneurysms should be clipped simultaneously. The frequency of multiple aneurysms also justifies an aggressive surgical approach.

Perhaps the greatest technical difficulties are gaining proximal control and relieving the tension within the aneurysm to allow dissection and suc-
Case 11. The left giant paraclinoid aneurysm that could not be collapsed and clipped on account of its calcified neck and wall. (a, b) Preoperative CT angiogram (axial view and coronal view) depicting the large, heavily calcified anterior clinoid that could not be distinguished preoperatively from the en bloc calcified aneurysmal neck and wall (arrows). (c) Postoperative CT scan (axial view) after the removal of the anterior clinoid (arrows indicate remaining calcification of the aneurysmal neck and wall).
cessful clipping. To temporarily control the blood flow and prevent rupture of the aneurysm during the clipping, Yaşargil and colleagues [45-47], described the technique of trapping these aneurysms followed by puncture or excision of the aneurysmal dome, suction of the contents, deflation and coagulation of the sac, and finally clipping. A similar technique for decompression was used by Flamm [16]. Dolenc [13] has emphasized proximal control of the subclinoid ICA by a combined epidural and subdural approach. Batjer and Samson [7] and Tamaki et al [43] used endovascular suction decompression through the exposure of the carotid artery in the neck. Sinson et al [38] reported the usefulness of intraoperative endovascular surgery to treat difficult, large cerebral aneurysms with intraluminal thrombus, a broad neck, plaque at the neck, the potential to compromise perforators, or a combination of these features. Albert et al [1] have advocated the transfemoral route for the endovascular catheter using the Seldinger technique, which avoids puncturing the wall of the carotid artery. Ausman et al [5] used extracranial microvascular reconstruction in three cases in their series of giant paraclinoid aneurysms, raising the upper limit of their operability.

**TRANSFEMORAL ROUTE FOR PROXIMAL CONTROL**

The use of the transfemoral catheter eliminates the necessity of a separate neck incision to isolate the cervical carotid and avoids puncture of the ICA in the neck. Furthermore, the use of this catheter creates more working space for the surgeon. Placing the balloon catheter at the cervical ICA occludes the blood flow should the aneurysm inadvertently rupture. In addition, back suction through the catheter, aside from decompressing the aneurysm, removes accumulated clots in the ICA and any backflow from its branches. Finally, intraoperative angiography through the existing balloon catheter can be done immediately. This procedure was carried out in 13 of our 15 patients with clipped aneurysms. As reported by Dardeyn et al [11], it carries a risk rate of 1.5% of complications (stroke). Postoperative dysphasia occurred in Case 15. Although CT scan did not reveal any abnormality and the patient clinically improved 1 week after the surgery, we suspect that this complication was embolic. One patient (Case 7) developed intimal dissection and occlusion of the right ICA at the balloon site (Figure 8), but responded well to medical treatment and recovered completely after 4 days. This complication, which results from the balloon compression, was reported to occur in 3.7% of patients and seems to be related to the duration of balloon occlusion of the artery and the degree of compression. Most patients, however, have no symptoms or recover spontaneously after a few days if symptoms exist [28].

**TEMPORARY OCCLUSION**

Through the clinical experience, much new information has been obtained on the subject of temporary arterial occlusion [6–9,34,44]. However, the “safe” occlusion time, the optimal regimen and drug...
for cerebral protection, and the choice between single or multiple episodes of temporary occlusion remain at the discretion of the surgeon. During the temporary occlusion (done in 15 of 16 of our patients), changes that denoted a compromise of cerebral blood flow and function appeared on neither the SSEP nor the BAER. A single, uninterrupted occlusion was done in all but three patients, each of whom had two repeated occlusions. In one of these three patients with two temporary occlusions, the second occlusion was used for clipping of the associated middle cerebral artery (MCA) aneurysm. The mean duration time of temporary occlusion was 10.7 minutes.

CRANIO-ORBITAL-ZYGOMATIC APPROACH

The use of the skull-base approach was a vital element of our surgical strategy [2,3,23,32,39]. Despite the thorough diagnostic preoperative work-up, the extent of obstruction by bony elements and the amenability of these aneurysms to dissection from the surrounding adherent structures cannot be predicted until the aneurysm is actually dissected. But our strategy is such that, by the time we begin dissecting the aneurysm, any bony and fibrous elements obstructing the way have been removed. The cranio-orbital-zygomatic approach also provided us with additional points for proximal ICA control (at the horizontal intrapetrous ICA and at the subclinoideal ICA).

The clip could be placed at a low angle, parallel to and even below the removed anterior clinoid, when the situation required (Figure 9). In addition, this approach further minimized the need for brain retraction and provided both extra- and intradural axes for drilling the anterior clinoid, for unroofing the optic canal, and for “opening” the superior orbital fissure. It also gave good cosmetic results. Finally, by using this approach, we were able to successfully treat six patients (38%), each of whom had another lesion associated with the paraclinoid aneurysm. In five of eight patients with multiple aneurysms, we clipped additional aneurysms during the same procedure. In one patient we clipped a large paraclinoid aneurysm and totally removed a hemangioma of the ipsilateral cavernous sinus. As mentioned by Lawton and Spetzler [25] this approach “…increases the superior limits of the angle of exposure and thereby improves the transsylvian access to aneurysms…”

VISUAL FIELD DEFICIT

Visual field deficit is characteristic of giant and large paraclinoid aneurysms. It arises from focal compression of the optic nerve and chiasm. It primarily involves the nasal half or the nasal inferior quadrant of the visual field. This deficit increases over time because the aneurysm progressively enlarges. After operative decompression, visual status has been reported to improve in up to two-thirds of patients [4,10,12,13,15,19,21,30,31,41–43]. Dolenc [12] outlined the difficulty of preserving the ophthalmic artery during the surgery of these aneurysms. According to our experience, preservation of the ophthalmic artery is feasible and very important for visual maintenance.

RESULTS OF THE OPERATIVE TREATMENT

Series of giant and large paraclinoid aneurysms in general have been reported less frequently than series of the same types of aneurysms at other locations; numbers of cases are not large, and numbers of directly “attacked” aneurysms are even smaller (Table 4). A comparison of these series is certainly biased by various differences among
them; differences in rates of direct surgery of aneurysms and successful clipping; differences between patients; numbers of cases included in each series; times of treatment; referrals; treatment protocols; timing of surgery; preoperative grades of patients; aneurysm sizes, subtypes, and other aneurysmal features; follow-up periods, etc. Some series are cumulative, and include cases from two or more authors. Furthermore, important data in some reports are missing, incomplete, or unclear. Nonetheless, some relationships can be established, conclusions reached, and certain general trends noticed.

The series of direct surgical treatment of paraclinoid aneurysms (among them giant and large ones) reported some 2 decades ago had relatively high mortality rates, ranging from 20–60% [15,19,21,25,36]. Nonetheless, these authors should be credited for being the first to directly attack these difficult lesions. The postoperative mortality and morbidity decreased markedly over time, and the rate of direct surgical approaches to these lesions increased, as did the rate of successful clipping of these giant and large aneurysms [5,6,10,12,14,20,27,37,41,42,45]. In the recently reported series of giant and large paraclinoid aneurysms [5,6,12,14,27,37], the mortality rates of direct surgery are lowered to 8%, 5%, 7%, 6%, 8%, and 11%, respectively. Furthermore, in their series, Ausman and associates [5] reported 92% good outcomes, as did Levy et al [27]. Batjer et al [6] reported 59% good, 23% fair, and 14% poor outcomes, as well as permanent ICA occlusions in 14%; Drake et al [14] reported 79% direct surgeries, 97% rate of successful clipping, 88% good and 6% poor outcomes; whereas Shibuya and Sugita [37] reported 84% good and 5% poor outcomes. In his series, which also included small paraclinoid aneurysms, Day [10] reported a 96% rate of successful clipping, with 87% good and 7% poor outcomes, and a 6% mortality rate. Overall, the direct surgery of these aneurysms has recently increased as has the rate of successful clipping. Furthermore, good outcomes range from 59–92%, and the number of patients with poor and fair outcomes is decreasing (Table 4). Surprisingly, the time of temporary occlusion has been reported only twice [6,42].

Surgical difficulties and morbidity in our series stemmed mainly from the severely calcified and atherosclerotic aneurysmal neck. Thus, care should be used in the presence of radiological or clinical suspicion of atherosclerosis, thrombosis, and/or calcification at the aneurysmal site. The time of temporary occlusion may need to be extended, and the clipping of such an aneurysmal neck itself carries the risk of tearing (fracture). In cases of severe calcification of the aneurysmal neck and wall (6% of our cases), the aneurysm is not amenable to collapsing and clipping despite direct surgery. This fact was also noted by Batjer et al [6] in four of the cases in their series.

**CONCLUSION**

A combination of the cranio-orbital zygomatic approach and endovascular transfemoral balloon occlusion with suction decompression proved to be a
Results of Operative Treatment of Giant and Large Paraclinoid Aneurysms

<table>
<thead>
<tr>
<th>SERIES (REF.)</th>
<th>(YEAR)</th>
<th>NO. OF CASES (SIZE)</th>
<th>MEAN TEMPORARY OCCLUSION TIME (MIN)</th>
<th>DIRECT SURGERY OF ANEURYSMS NO./TOTAL (%)</th>
<th>SUCCESSFUL CLIPPING (NECK OCCL.) NO./TOTAL (%)</th>
<th>GOOD NO./ TOTAL (%)</th>
<th>FAIR NO./ TOTAL (%)</th>
<th>POOR NO./ TOTAL (%)</th>
<th>DEATH NO./ TOTAL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drake et al</td>
<td>(15) (1968)</td>
<td>14 (Incl. small)</td>
<td>*</td>
<td>10/14 (71)</td>
<td>5/10 (50)</td>
<td>4/10 (40)</td>
<td>6/10 (60)</td>
<td>2/10 (20)</td>
<td>6/10 (60)</td>
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<tr>
<td>Kothandaram et al</td>
<td>(25) (1971)</td>
<td>19 (Incl. small)</td>
<td>*</td>
<td>10/19 (53)</td>
<td>8/10 (80)</td>
<td>6/10 (60)</td>
<td>2/10 (20)</td>
<td>2/10 (20)</td>
<td>6/10 (60)</td>
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<tr>
<td>Guidetti and La Torre</td>
<td>(19) (1975)</td>
<td>26 (Incl. small)</td>
<td>*</td>
<td>25/26 (96)</td>
<td>13/25 (52)</td>
<td>17/25 (68)</td>
<td>2/25 (8)</td>
<td>6/25 (24)</td>
<td>4/25 (16)</td>
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<tr>
<td>Hosobushi et al</td>
<td>(21) (1979)</td>
<td>19 (All giant)</td>
<td>*</td>
<td>17/19 (90)</td>
<td>3/17 (18)</td>
<td>12/17 (71)</td>
<td>5/17 (29)</td>
<td>5/17 (29)</td>
<td>1/17 (6)</td>
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<tr>
<td>Heros et al</td>
<td>(20) (1983)</td>
<td>34 (25 Giant &amp; 9 large)</td>
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<td>26/34 (77)</td>
<td>22/26 (88)</td>
<td>21/23 (92)</td>
<td>1/23 (4)</td>
<td>3/23 (9)</td>
<td>1/23 (4)</td>
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<tr>
<td>Yaşargil et al</td>
<td>(1984)</td>
<td>17 (7 Giant &amp; 10 large)</td>
<td>*</td>
<td>16/17 (95)</td>
<td>12/16 (75)</td>
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<td>3/16 (19)</td>
<td>1/16 (6)</td>
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<tr>
<td>Symon and Vajda</td>
<td>(42) (1984)</td>
<td>6 (All giant)</td>
<td>14</td>
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<td>4/6 (67)</td>
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<td>1/6 (17)</td>
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<tr>
<td>Ausman et al</td>
<td>(5) (1990)</td>
<td>14 (All giant)</td>
<td>13/14 (93)</td>
<td>13/13 (100)</td>
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<td>1/13 (8)</td>
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<td>Day (10) (1990)</td>
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<td>*</td>
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<td>47/54 (87)</td>
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<td>Batjer et al</td>
<td>(6) (1994)</td>
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<td>Dolenec et al</td>
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<td>*</td>
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<td>*</td>
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<tr>
<td>Drake et al</td>
<td>(14) (1994)</td>
<td>110 (All giant)</td>
<td>*</td>
<td>87/110 (79)</td>
<td>84/87 (97)</td>
<td>77/87 (88)</td>
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<tr>
<td>Levy et al</td>
<td>(27) (1995)</td>
<td>44 (Giant &amp; large)</td>
<td>*</td>
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<td>26/26 (100)</td>
<td>24/26 (92)</td>
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<td>2/26 (8)</td>
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<tr>
<td>Shibuya and Sugita</td>
<td>(37) (1996)</td>
<td>19 (10 Giant &amp; 9 large)</td>
<td>*</td>
<td>19/19 (100)</td>
<td>16/19 (84)</td>
<td>1/19 (5)</td>
<td>2/19 (11)</td>
<td>2/19 (11)</td>
<td>2/19 (11)</td>
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<tr>
<td>This study</td>
<td>(1997)</td>
<td>16 (8 Giant &amp; 8 large)</td>
<td>10.7</td>
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<td>14/16 (88)</td>
<td>1/16 (6)</td>
<td>1/16 (6)</td>
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</tr>
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</table>

*Abbreviations: Data missing, incomplete, or unclear: -, no cases; incl., including; occl., occlusion.
successful and promising option for treating giant and large paraclinoidal aneurysms. We found these techniques particularly useful for raising the upper limit of the treatment of atherosclerotic, thrombosed, and partially calcified aneurysms and for simultaneous treatment of associated aneurysms and tumors.

The authors thank Ms. Julie Yamamoto and Dr. B. Lee Ligon for editorial assistance and Mr. Ron M. Tribell for original artwork.

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MG, Gasser JC, Hodosh RM, Rankin TV.

Intraoperative rupture should occur if the floor of the middle fossa is then opened, extradural dissection completely removes the anterior clinoidal ICA for additional proximal vascular control. The orbital rim and lateral wall of the orbit. After the temporal craniotomy free flap is elevated, including the zygomatic arch is then transsected and a fronto-temporal craniotomy opening is an interfascial soft tissue exposure. The origin of the ophthalmic artery often provides as reliable vascular control as other previously described standardized approaches to these lesions. Nine patients had unruptured lesions. All patients underwent surgical treatment of the aneurysm via a complex skull base approach that removed the orbital roof, exposing the sphenoid sinus and comprises the lateral inferior border of the optic foramen. Microsurgical resection of this optic strut is of paramount importance in visualizing the origin of the ophthalmic artery. The origin of the ophthalmic artery often demarcates the junction of the proximal aneurysm neck with normal ICA.

Giant proximal ICA aneurysms distort the anatomy and the expected course of the ICA to such an extent that preoperative conceptualization as to the type of aneurysm being treated is extremely valu-
Combined Approach to Paraclinoid Aneurysms

The question remains whether the additional treatment of giant proximal carotid aneurysms is necessary. The sacrifice of normal carotid artery from the aneurysm neck when the entire superior medial wall has become aneurysmal in giant lesions. On the other hand, giant superior hypophyseal aneurysms are rarely adherent to the optic nerve but are often adherent to the oculomotor nerve, tentorium, and skull base. They often have distal necks intimately associated with the posterior communicating artery and often require opening the cavernous sinus inferolateral to the ICA to expose the proximal aneurysm neck. The third type are giant posterior carotid wall aneurysms, which usually arise in association with the posterior communicating artery and typically require only a minimal amount of anterior clinoid resection.

In our experience, a standard but general pterional craniotomy combined with extensive drilling of the sphenoid wing and orbital roof provides more than adequate bone exposure to surgically treat giant proximal carotid aneurysms. The sacrifice of superficial sylvian veins and gentle retraction of the temporal tip provides quick, simple, and reliable exposure of the paracaloidal region and does not require lengthy or time-consuming subtotal extradural dissection. We have also found the CUSA to be an invaluable tool when dealing with giant aneurysms that may require thrombectomy before clip reconstruction.

All things considered, the authors provide an excellent discussion of some of the pitfalls and problems, both contemporary and historical, of the treatment of giant paraclinoid artery aneurysms. The question remains whether the additional removal of portions of the orbit and skull base significantly affects the difficulties encountered in identifying the microsurgical anatomy of the proximal aneurysm neck and the ensuing clip reconstruction of these formidable lesions.

Thomas A. Kopitnik, Jr., M.D.
Duke Samson, M.D.
Department of Neurological Surgery
UT Southwestern Medical Center
Dallas, Texas

This paper from Dr. Al-Mefty's group in Little Rock emphasizes the benefits of skilful exposure and the necessity of proximal control and collapse of a large sac to successfully clip these often difficult aneurysms.

Many years ago, Dr. Drake and I used the intracarotid balloon inserted transfemorally, but abandoned it after traumatic dissection and thromboembolism from the end of the catheter that caused the patient injury. We have come to rely on the "Dallas technique" as published by Batjer and Samson which, although a little bit more time-consuming and requiring a separate incision, has proved to be very satisfactory. As well, we have not been impressed with the efficacy of most of the reported methods for cerebral protection, but rather rely on raising the blood pressure and administering an extra gram per kilogram of 20% mannitol and restoring flow whenever the evoked potentials change. These aneurysms, particularly when giant size and calcified, will remain a surgical challenge.

S. J. Peerless, M.D., FRCSC
Mercy Neuroscience Institute
Miami, Florida

The authors combine a skull-base approach with endovascular balloon occlusion of the ICA and suction decompression for giant and large paraclinoid aneurysms. The results of the treatment are acceptable. The skull-base approach can provide a wide surgical field; balloon occlusion and suction decompression with intraoperative angiography are useful options.

The manuscript brings up an important issue for discussion. The authors used the cranio-orbital zygomatic approach for all large and giant paraclinoid aneurysms. Was the cranio-orbital zygomatic approach indeed required in all cases? In our experience, the pterional approach with drilling of the anterior clinoid process and optic roof can provide a wide enough surgical field for large and giant carotid aneurysms. Some difficult cases, including thrombosed aneurysms and those with an associated lesion, would seem to be the main indications for the cranio-orbital zygomatic approach. The decision-making process regarding the use of a skull-base approach to these aneurysms is one of the most important issues in minimally invasive neurosurgery.

Drilling of the anterior clinoid and optic canal were done in all patients. One would like to know which is more risky: extra- or intradural drilling...
of the anterior clinoid process. I prefer intradural drilling, especially for high risk aneurysms, because vibration and pressure on the aneurysm can be avoided under direct view.

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Shinshu University School of Medicine
Matsumoto, Japan

This is an excellent article. The authors combined transient endovascular occlusion of the ICA with a skull-base approach for giant and large paraclinoid aneurysms. The average occlusion time of the ICA was 11 minutes. Arnautovic et al favor endovascular occlusion of the cervical ICA versus temporary clipping. The advantages, according to the authors are 1) more working space for the neurosurgeon, 2) the ability to aspirate clots, and 3) the ability to perform intraoperative angiography.

However, this technique also has disadvantages compared to temporary clipping. I think that it increases the risks of distal emboli because the balloon remains deflated in the ICA for several hours. The patient cannot be anticoagulated. Several inflations of the balloon may be necessary, increasing the risk of emboli each time it is deflated. Iatrogenic complications such as dissection may occur (one case in this series), a potential catastrophe if the patient has insufficient collateral circulation. This is why my main concern is the necessity of performing a balloon occlusion test in this group of aneurysms before the surgical procedure.

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University of Illinois at Chicago
Chicago, Illinois

In this paper, Al-Mefty’s group summarize their experience with “a combined skull-base and endovascular approach” to large and giant paraclinoid aneurysms. Although the authors did not cite our paper, the technical aspects reported here are almost the same as our procedure [1]. I agree completely with the authors’ conclusion that this combined approach is a successful option for the treatment of complex ICA aneurysms. I do not think, however, that such extensive bone removal as an orbitozygomatic craniotomy is necessary.

The key point for successful clipping of large or giant paraclinoid aneurysms is to dissect these lesions completely, particularly the proximal side. For complete dissection of the proximal neck and dome of the aneurysm, resection of the anterior clinoid process and opening of the distal carotid ring is necessary. The authors emphasize the orbitozygomatic approach for complex paraclinoid aneurysms. From my experience (more than 20 cases of surgically treated giant paraclinoid aneurysms), it seems that removal of the orbital rim is not necessary because upward visualization is not required in these operations. The viewing trajectory in the management of these lesions is usually superior-to-inferior rather than inferior-to-superior. The standard pterional craniotomy with extensive resection of the sphenoid ridge and anterior clinoidectomy can provide an adequate operative field both for good visualization and for clip application.

It is no exaggeration to say that the retrograde suction decompression technique is now the principle surgical adjunct to facilitate dissection and clipping of giant paraclinoid aneurysms. When we use this suction technique, however, the duration of temporary occlusion of the ICA is an important issue. Even with the use of this technique, it is usually not possible to complete dissection and clipping of the aneurysm within a few minutes. The authors did not describe the temporary occlusion times in each case in their series. In our series, the occlusion time ranged from 15–60 minutes, with a mean of 30 min. Accordingly, a balloon Matas test should be performed routinely to select the best treatment. For patients at high risk from temporary arterial occlusion, the use of the retrograde suction decompression technique should be considered more carefully. Although the balloon occlusion test is not perfect in predicting the tolerable occlusion time in each case, this test can select patients who cannot withstand even a short period of temporary occlusion. Such patients usually develop motor disturbance, aphasia, or loss of consciousness within a minute after test occlusion. For patients who are intolerant of the test occlusion, we have used a combination of high-flow graft and proximal ICA occlusion, or direct clipping using the suction decompression technique after performing a high flow bypass graft in the same operative session.

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REFERENCES