

Intraoperative endovascular surgery for cerebral aneurysms

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✓ The application of a number of procedures that can be considered intraoperative endovascular neurosurgery has enhanced our ability to treat cerebral aneurysms from the abluminal surface. This study identifies a role for these techniques in the management of difficult aneurysms. A review of the last 1202 aneurysms undergoing direct clipping by the authors disclosed that these methods were used in 62 cases. Of these aneurysms, 36 arose from the internal carotid artery, 12 from the middle cerebral artery, eight from the vertebrobasilar distribution, and six from the anterior cerebral artery.

The indications for applying these methods were large size (12–60 mm), intraluminal thrombus, broad neck, plaque at the neck, the potential compromise of branches at the base of the aneurysm, or a combination of these problems. The most frequently chosen intraoperative technique was suction decompression with direct removal of plaque and thrombus using suction, dissection, and/or ultrasonic aspiration. The application of temporary clips was required in all cases in which the aneurysm was opened before definitive clipping. No special pharmacological cerebral protective regimen was used. In one case in which a greater occlusion time was anticipated, cardiopulmonary bypass with profound hypothermia was performed.

A favorable outcome was achieved in 73% of these difficult cases. An increased neurological deficit after surgery was seen in 11%, and the mortality rate was 8%. These methods should be considered and can be anticipated before surgery for unusual aneurysms. Many cases now being considered for embolization may be more suitable for definitive surgical obliteration.

KEY WORDS • cerebral aneurysm • endaneurysmectomy • endovascular therapy • giant aneurysm • surgical technique • thrombectomy

PROXIMAL artery ligation to treat intracranial aneurysms has been shown to be less effective than the direct surgical clipping of these aneurysms.^{26,36,54} Direct obliteration results in excellent long-term outcomes and is now the preferred treatment.^{1,12,13,37,41,49,54,57} Interventional neuroradiological procedures have recently produced encouraging short-term results in treating some of these lesions.^{9,19–24,34,35,51} These neuroradiological endovascular techniques have been used most commonly in those aneurysms that are considered too difficult to approach surgically. An important adjunct in the treatment of difficult aneurysms is the use of intravascular and intraluminal surgical maneuvers to facilitate the definitive surgical clipping of these lesions. Our experience with a variety of intraoperative techniques is reviewed.

Clinical Material and Methods

All cases of cerebral aneurysms treated surgically by the senior author (E.S.F.) between 1973 and 1993 were evaluated. Those cases in which intraoperative endovascular techniques were used before or during clip placement are the subject of this review. These endovascular

techniques include: suction decompression, endaneurysmectomy, thrombectomy, and aneurysmorrhaphy. Aneurysm size alone was not a criterion for inclusion in the study group. A subset of these cases was examined in greater detail. This subset included patients who underwent surgery at the Hospital of the University of Pennsylvania during the 6-year period from 1988 through 1993. These patients represent cases treated in the setting of readily available magnetic resonance (MR) imaging, MR angiography (MRA), and modern interventional neuroradiological techniques.

All patients received perioperative phenytoin and methylprednisolone and intraoperative mannitol. No other pharmacological agent was used for cerebral protection. Mild-to-moderate intraoperative hypothermia (core body temperature to 32°C) was induced in some cases. Temporary clips were used in most cases. During periods of temporary occlusion the systolic blood pressure was maintained above 130 mm Hg. Many patients had neurophysiological monitoring during the procedure.

Outcome was graded on a five-point scale. An excellent outcome was defined as the patient returning to baseline neurological status. A good outcome implied the presence

TABLE 1

Location of 1202 aneurysms treated surgically during the period from 1973 to 1993*

| Treatment | ICA | MCA | ACA | VB | Total |
|---|----------|----------|---------|---------|----------|
| all aneurysms treated surgically | 525 | 243 | 256 | 178 | 1202 |
| aneurysms in which surgical endovascular techniques were used (%) | 36 (6.9) | 12 (4.9) | 6 (2.3) | 8 (4.5) | 62 (5.2) |

* Abbreviations: ACA = anterior cerebral artery; ICA = internal carotid artery; MCA = middle cerebral artery; VB = vertebrobasilar distribution.

of minimal deficit that did not significantly hinder the patient's lifestyle. Fair outcomes were defined as patients requiring some assistance with daily activities, whereas those with poor outcomes needed significant amounts of support. Death was the fifth outcome.

Results

A total of 1202 cases of cerebral aneurysms were treated. One or more intraoperative endovascular technique was used in 62 (5.2%) of these cases. The aneurysm arose from the internal carotid artery (ICA) in 36 (58.1%), the middle cerebral artery (MCA) in 12 (19.4%), the vertebrobasilar distribution in eight (12.9%), and the anterior cerebral artery (ACA) in six (9.7%) (Table 1).

A favorable outcome (excellent or good) was achieved in 45 cases (72.6%). There were 12 (19.4%) fair or poor outcomes and 5 (8.1%) deaths (Table 2). Seven patients (11.3%) had increased neurological deficits after surgery. These seven cases plus the five deaths result in a combined morbidity and mortality of 19.4% (12 patients).

During the 6 years reviewed in greater detail, 391 aneurysms were treated surgically. Surgical endovascular techniques were used in 27 (6.9%) of these cases. The age of the patients ranged from 19 to 74 years with a mean of 54 years. The patients presented after hemorrhage (44%), with symptoms of local mass effect (26%), or the aneurysm was found incidentally (30%). The size of the aneurysms ranged from 12 to 60 mm with a mean size of 33 mm. The outcomes of these patients were similar to the entire population of patients (Table 2).

Also during this 6-year period, six patients underwent radiological endovascular treatment for cerebral aneurysms. These cases represent 1.5% of all aneurysms treat-

TABLE 2

Outcome in patients with aneurysms treated by intraoperative endovascular techniques

| Treatment | Good/Excellent (%) | Poor/Fair (%) | Dead (%) |
|--|--------------------|---------------|----------|
| all aneurysms treated surgically 1988 to 1993 | 78.8 | 17.1 | 4.1 |
| aneurysms in which surgical endovascular techniques were used 1973 to 1993 | 72.6 | 19.4 | 8.1 |
| 1988 to 1993 | 74.1 | 18.5 | 7.4 |

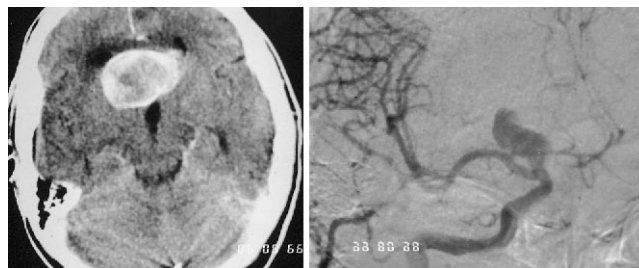


FIG. 1. Case 1. Contrast-enhanced computerized tomography scan (left) demonstrating the right internal carotid artery aneurysm extending upward and across the midline. Right anteroposterior angiogram (right) revealing that only a 2-cm portion of the aneurysm remains patent.

ed during this period but do not include aneurysms that were confined to the cavernous portion of the ICA. Two of these patients underwent surgical exploration, and it was discovered that the aneurysms could not be safely clipped. The other four patients were treated primarily with radiological endovascular techniques: two because their poor neurological status precluded surgical intervention and two whose aneurysms were not believed to be surgically approachable.

Indications cited for using surgical endovascular techniques included: 1) a broad aneurysmal neck, 2) the presence of intraluminal thrombus, 3) large aneurysm size, 4) a firm plaque in the aneurysm neck, 5) the potential compromise of branches at the aneurysm base, or 6) a combination of these problems. The aneurysm was isolated with temporary clips except in those cases in which the aneurysm arose from the proximal intracranial carotid artery. In these instances proximal control of the aneurysm was achieved by isolation of the cervical carotid artery. Temporary clip time ranged from 0.5 to 60 minutes. Circulatory arrest with extreme hypothermia was used in one case. The following are representative cases.

Case 1

Presentation. This 62-year-old man presented to another hospital with complaints of decreased appetite, difficulty standing, and severe headaches. These symptoms had become most prominent during the week prior to admission. Diagnostic evaluation included: a lumbar puncture that revealed xanthochromic cerebrospinal fluid, computerized tomography (CT) of the head demonstrating a right hemisphere mass that extended across the midline, and a cerebral angiogram that better defined the mass as an aneurysm (Fig. 1). The aneurysm was 5 cm in diameter and projected upward to the level of the foramen of Monro. It arose from the right ICA and was partially thrombosed, with the patent portion measuring 2 cm in diameter. Neurological examination showed intact visual fields, motor function, and speech. The patient was alert and oriented but did have some difficulty with simple calculations and was noted to have a blunted affect.

Operation. After induction of general anesthesia, a lumbar subarachnoid catheter was placed and scalp electroencephalographic (EEG) electrodes were applied. The right cervical common carotid artery and ICA were then isolat-

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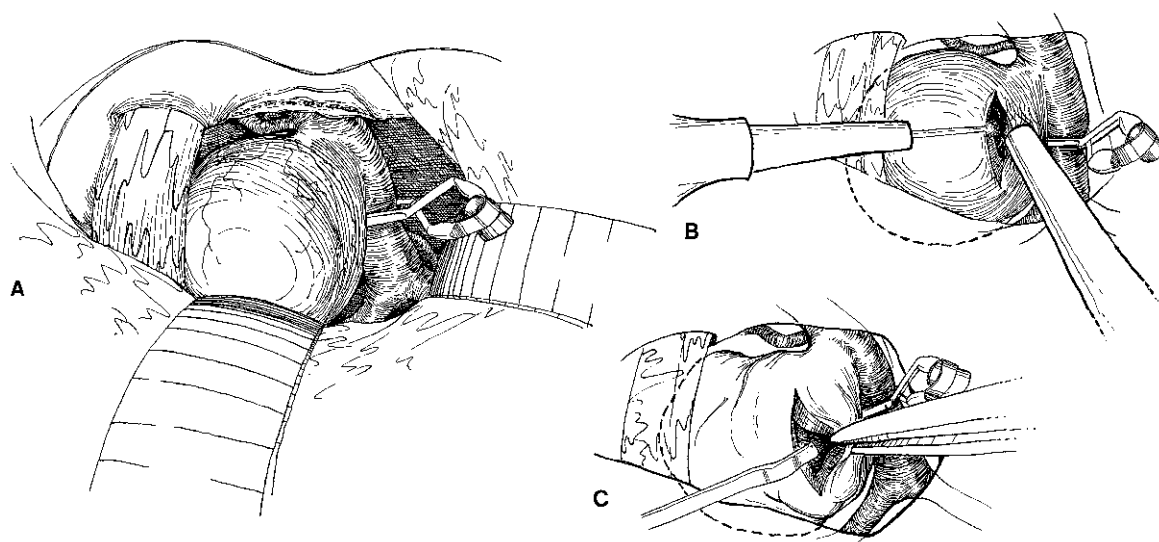


FIG. 2. Illustrations showing the operative management of Case 1. A: The anterior clinoid process has been removed, the cervical internal carotid artery is occluded (not shown), and a temporary clip is positioned on the carotid artery distal to the aneurysm. B: After incising the aneurysm, the high-speed drill is used to enter and decompress the patent portion of the aneurysm. C: The calcified thrombus is dissected away from the aneurysm neck to permit clip placement.

ed with vascular loops. A right-sided pterional craniotomy was performed. Retraction of the frontal and temporal lobes after widely opening the sylvian fissure allowed adequate visualization of the intracranial carotid artery, the third cranial nerve, and the aneurysm, which was markedly displacing the right optic nerve. The base of the aneurysm was noted to be densely calcified and could not be compressed. This calcification extended 1 cm up the neck of the aneurysm.

To permit better visualization of the proximal aspect of the aneurysm neck, the anterior clinoid process was then removed using a high-speed drill. The cervical ICA was occluded, and a temporary clip was placed on the intracranial ICA distal to the aneurysm. The aneurysm dome was opened and a small amount of backbleeding from the ophthalmic artery was encountered but was easily controlled with suction (Fig. 2). The calcification proved to be quite firm and required the use of rongeurs and the high-speed drill to fragment. Gradually the calcium was removed until a thin vascular wall remained. Two aneurysm clips were used to obliterate the aneurysm neck and preserve the ICA. The temporary occlusion of the carotid artery was removed (Fig. 3). The occlusion time was 20 minutes and there were no changes noted in the EEG. Because of its large size, the remaining aneurysm mass was removed. This was done without difficulty.

Postoperative Course. After surgery the patient was alert and had intact visual fields. He demonstrated a mild left-sided hemiparesis and worsening of his confusion. The weakness and mental status deficits improved over the next few months. At his 3-month follow-up examination he was neurologically intact.

Case 2

Presentation. This 46-year-old woman underwent a CT scan of the head because of a 1-month history of

headaches. Her neurological examination was normal. Subsequent MR imaging and angiography revealed a 3-cm aneurysm at the bifurcation of the right ICA (Fig. 4). She underwent surgical exploration at another hospital; however, involvement of the anterior choroidal artery (AChA) with the aneurysm precluded its clipping. The patient was transferred to the Hospital of the University of Pennsylvania where it was decided that a second attempt would be made at surgical obliteration of the aneurysm.

Operation. Scalp EEG electrodes were placed after induction of general anesthesia. The patient's existing craniotomy incision and bone flap were then reopened. Retraction of the frontal lobe demonstrated that the aneurysm arose from the posterior wall of the ICA. Multiple branches of the AChA and perforating branches from the

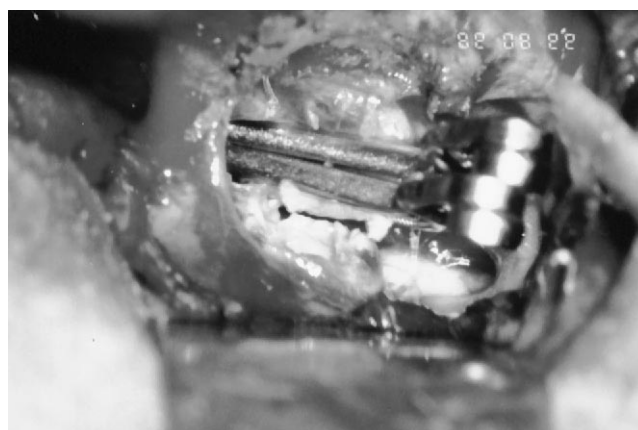


FIG. 3. Case 1. Intraoperative photograph showing final clip placement. The neck of the aneurysm is obliterated with two straight clips on the remaining vascular wall.

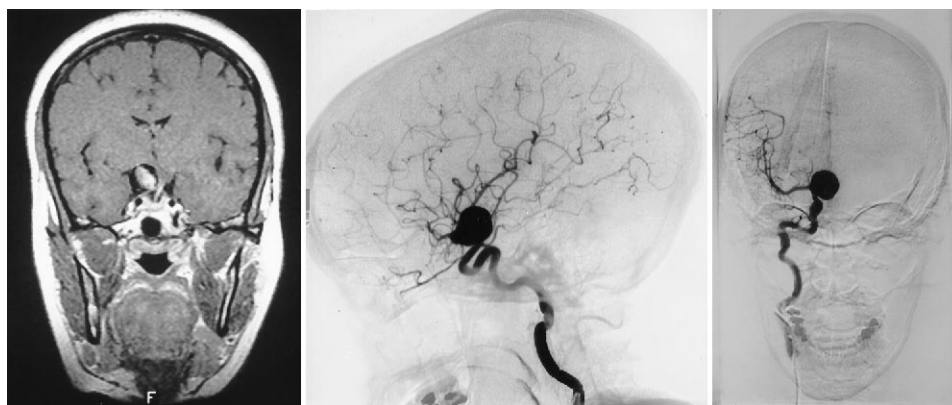


FIG. 4. Case 2. Coronal T₁-weighted magnetic resonance image (*left*) showing a right internal carotid bifurcation aneurysm that is fully patent. Lateral (*center*) and anteroposterior (*right*) angiograms better define the origin of the aneurysm.

top of the carotid artery bifurcation and the posterior communicating artery (PCoA) were seen draped over the dome of the aneurysm. These branches were dissected from the aneurysm dome to permit passage of clip blades. At this point the patient's temperature had been cooled to 32°C and her systolic blood pressure was raised to 130 mm Hg. Temporary clips were applied to the proximal ICA, the ACA, and the MCA. Despite the temporary clips, the aneurysm remained tense; therefore, a fourth temporary clip was placed on the large PCoA (Fig. 5 *left*). Three fenestrated clips were used to obliterate the aneurysm neck while preserving flow in the ICA and its branches. To facilitate final clip adjustments, suction decompression was performed using a 23-gauge butterfly needle. After each clip adjustment the patency of the aneurysm was tested by releasing only the temporary clip on the PCoA. All temporary clips were then removed after an occlusion time of 15 minutes (Fig. 5 *right*). There were no EEG changes seen during the period of temporary occlusion. A microvascular Doppler probe was used to

confirm flow in the major branches arising from the carotid artery.

Postoperative Course. The patient was neurologically normal after surgery except for a palsy of the third cranial nerve. At her 2-month follow-up examination her third nerve dysfunction had completely resolved and she remained neurologically intact.

Case 3

Presentation. This 54-year-old man presented to another hospital after experiencing an extremely severe headache. Neurological examination revealed a short-term memory deficit and mild confusion. There were no focal signs on the examination. He had also been receiving psychiatric treatment for a 2-year history of altered personality.

A CT scan revealed a 6-cm left hemisphere mass with calcifications and fresh subarachnoid blood. An MR image demonstrated a large flow void within the partially

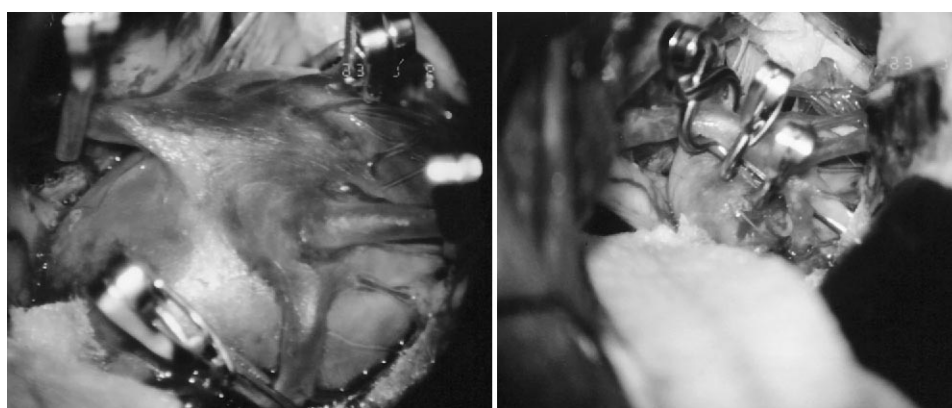


FIG. 5. Case 2. Intraoperative photographs. *Left:* Placement of temporary clips to completely isolate the aneurysm prior to final dissection and clip placement. Temporary clips are placed on (clockwise from the upper right) the posterior communicating artery, middle cerebral artery, anterior cerebral artery, and proximal internal carotid artery (ICA). *Right:* After final clip placement, three fenestrated aneurysm clips have reconstructed the ICA without compromising patency of the branches.

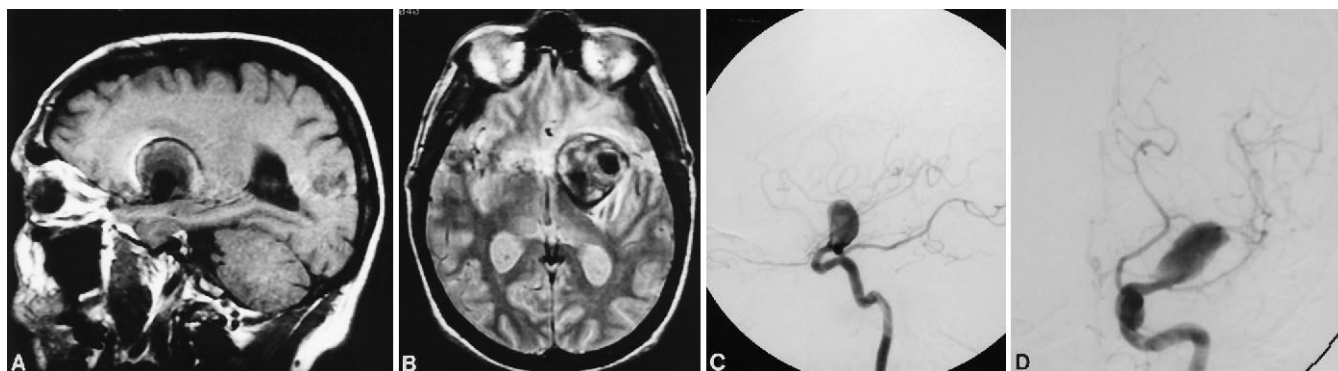


FIG. 6. Case 3. Sagittal T₁-weighted magnetic resonance (MR) image (A) showing the patent portion of the aneurysm arising from the left internal carotid bifurcation, surrounded by a large amount of thrombosed aneurysm. Axial T₂-weighted MR image (B) also demonstrating the patent portion of the aneurysm as well as the surrounding edema from this large lesion. A lateral (C) and anteroposterior (D) angiogram better highlight the origin of the aneurysm from the carotid bifurcation.

thrombosed aneurysm (Fig. 6A and B). Angiography confirmed the aneurysm arising from the bifurcation of the left ICA (Fig. 6C and D). Approximately one-third of the aneurysm was patent.

Operation. After induction of general anesthesia, a left pterional craniotomy was performed. Care was taken to preserve the superficial temporal artery. Fresh subarachnoid clot was visualized. The supraclinoid ICA was exposed, the PCoA identified, and the AChA was seen and dissected from the body of the aneurysm. The ACA and MCA were then isolated distal to the aneurysm. After cooling the patient to 32°C, temporary clips were applied to the supraclinoid ICA (distal to the PCoA) and the MCA and ACA. The aneurysm ceased pulsating but remained tense. Suction decompression was performed with a 19-gauge needle. Despite decompression, the aneurysm could not be clipped because of the clot within the aneurysm neck. The aneurysm was then incised and the thrombus in the region of the neck was removed with a combination of gentle dissection and ultrasonic aspiration. This permitted placement of the aneurysm clip parallel to the parent vessel, which preserved flow into the vessel's branches (Fig. 7). Temporary clips were removed after a 20-minute occlusion time.

Because of the significant mass effect of the aneurysm on the left hemisphere, the ultrasonic aspirator was then used to remove a large amount of thrombosed material from the aneurysm dome. No attempt was made to remove the dome of the aneurysm or to separate it from the brain.

Postoperative Course. The patient had no new deficits after surgery. His confusion resolved within 1 week and the short-term memory deficit improved over the next 6 months. He was then able to return to work.

Discussion

Treatment Options for Difficult Cerebral Aneurysms

Operative obliteration of aneurysms by placing a clip at the neck was first introduced by Dandy¹¹ in 1937. Advances in neurosurgery since then have made this surgical

intervention much safer than it was in Dandy's time. The concept, however, of curing the defect in the vessel wall by reapposing two portions of the normal endothelial surface has been very successful. Large series of aneurysms repaired in this way have shown very low recurrence rates. Yaşargil⁵⁷ reported the results of operations in 355 patients between 1979 and 1983, with a rerupture rate of 0.6%. Other groups have shown a rerupture rate from 0.14% to 1.0%.^{13,29,41} Many of these cases of recurrent hemorrhage have been shown to occur in aneurysms that had residual angiographic filling after clipping.^{12,13,29,41} In fact, many consider that a completely clipped aneurysm has no significant chance of recurring.^{37,54,56}

Extraordinary aneurysms exist that challenge our ability to apply this standard approach. Recent advances in neuroangiography have led to the capability of approaching these aneurysms from a different direction, the in-

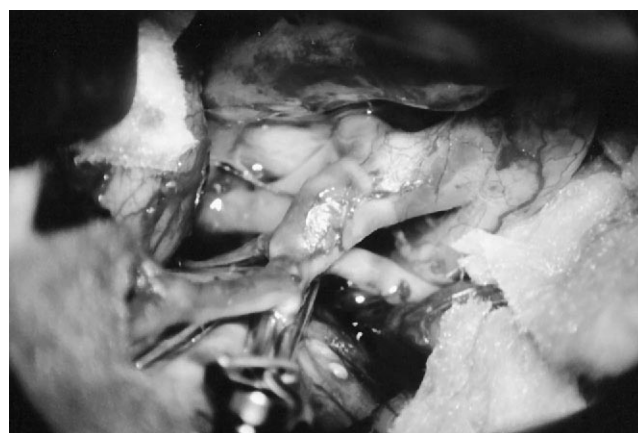


FIG. 7. Case 3. Intraoperative photograph demonstrating final clip placement. The remaining aneurysm wall can be seen on both sides of the aneurysm clip and the hole in the aneurysm is blocked by the hub of the clip. Prior to decompression of the aneurysm, the rigid wall continued to force the clip blades downward and thereby obstructed flow in the middle cerebral artery.

travascular space. The placement of coils into the aneurysm itself can halt any angiographic filling.²⁵ Some institutions have documented significant experience with these techniques,^{9,19-22,34,51} however, long-term data do not yet exist which demonstrate that the outcome in these patients is as good as in those who have had the aneurysm completely obliterated surgically. These techniques clearly remain experimental.^{19,24,35}

This review includes aneurysms that were treated surgically, yet required specialized techniques in addition to adequate dissection and clip application. We believe that being prepared to perform a number of intraoperative endovascular treatments increases the chances of successfully obliterating these aneurysms without compromising normal blood flow. Many of these techniques require preoperative preparations and therefore their use must be anticipated during surgical planning rather than during aneurysm dissection.

Specific Intraoperative Endovascular Techniques

Cerebral Protection. Many of these cases require intraoperative regional or local circulatory arrest, which places portions of the brain at risk for ischemia. Some authors advocate the use of barbiturate coma during periods of ischemia.^{45,49} Others use etomidate for cerebral protection, citing fewer cardiovascular side effects.^{4,5} Laboratory data and recent data from both neural trauma and ischemia experience have suggested a beneficial effect of mild hypothermia on cerebral ischemia and outcome.^{8,10,18,27,31,38,55} A decrease of 1°C can result in a reduction of cerebral metabolism by 7%.⁴⁰ Currently we induce hypothermia to 32°C in all cases that may require temporary vessel occlusion. The potentially adverse cardiac or coagulation effects reported with more severe hypothermia are avoided by not lowering the temperature further.^{28,46} During periods of temporary vessel occlusion the systolic blood pressure is also maintained above 130 mm Hg to maximize collateral flow to regions of potential ischemia. Patients receive mannitol and phenytoin perioperatively for their effects on brain relaxation and seizures, respectively.

Circulatory Control. Circulatory control can be achieved by many methods: locally with temporary clips, regionally with occlusion of the cervical carotid artery, or systemically using cardiopulmonary bypass. All of these techniques achieve the same goal of reducing or halting blood flow through the aneurysm. This permits additional dissection around the slack aneurysm, reduces the risk of hemorrhage during this dissection, and allows for opening of the aneurysm to evacuate plaque or clot that may prevent accurate clip placement. Whereas many aneurysms can be isolated with temporary clips alone, those located on the proximal intracranial carotid artery require an alternative approach. We prefer to achieve temporary occlusion and proximal control during early dissection of the aneurysm by exposure of the cervical carotid artery. Having the ability to perform cardiopulmonary bypass for systemic circulatory arrest during aneurysm surgery is important.^{2,47,49} In this series, however, only one case that required endovascular access necessitated the use of a bypass.

Various attempts have been made to quantify the period of time that vessels can be safely occluded.^{5,50,54} Different

intraoperative protocols make this data difficult to summarize, especially given the wide variability seen even within specific series.^{50,54} Samson, *et al.*,⁴³ have shown that temporary arterial occlusion in the distribution of the perforating arteries of the distal basilar artery and the horizontal segment of the MCA may be the most hazardous. It is not yet clear whether intermittent reperfusion is helpful or detrimental during periods of temporary arterial occlusion.^{17,42,43,48,53}

Intraoperative Instrumentation. Specific instrumentation that is useful intraoperatively includes: 1) electrophysiological monitoring; 2) a suction decompression device; 3) the ultrasonic aspirator; and 4) the microvascular Doppler monitor. The interpretation of electrophysiological data (EEG, somatosensory evoked potentials, or brainstem auditory evoked responses) can be difficult intraoperatively, but with the aid of an experienced electrophysiologist, this information can be helpful.³⁹ Other groups have demonstrated the ability of evoked potential monitoring to signal the onset of clinically significant, yet reversible, ischemia.^{16,32,33,39,44} In cases that may require prolonged intraoperative temporary vessel occlusion, preoperative temporary balloon occlusion with the patient awake can be helpful.

Many different devices have been described for performing a suction decompression.^{6,14,52} Any apparatus that does not significantly interfere with the surgeon's view and working area can be used. We continue to use a butterfly needle that has had the wings removed and is then attached to a suction device, which has variable strength and can be controlled by the surgeon.¹⁴ Although we are comfortable with this direct technique of suction decompression, the cervical carotid artery suction decompression for proximal ICA aneurysms appears to be an excellent alternative.^{6,52} In those cases that require removal of thrombus from the inside of the aneurysm, the ultrasonic aspirator is helpful.^{15,37} This device permits rapid yet gentle removal of even organized thrombus.

The microvascular Doppler monitor has been useful in many cases. We use this tool routinely to confirm the absence of flow in the aneurysm dome after clipping and prior to puncturing the aneurysm.³⁰ In this series the Doppler was most useful after reestablishing local blood flow by confirming flow through the parent vessel and even smaller vessels whose origin may have been near the aneurysm neck. This technique is rapid, noninvasive, and easily interpreted. Intraoperative angiography is used by others to evaluate clip placement on difficult aneurysms.^{3,5} With the use of the Doppler monitor we have not found angiography to be a necessity; however, there are undoubtedly a small number of cases in which an intraoperative angiogram may be helpful.

Aneurysm Obliteration. Once confronted with an aneurysm that cannot be directly clipped, despite circulatory isolation and maximum dissection, various endovascular options must be considered. In those cases in which circulatory isolation cannot be completely achieved (Case 2), the aneurysm may not slacken significantly after the application of temporary clips. The use of suction decompression can help to further decompress the aneurysm.^{6,14,52} Decompressing the aneurysm prior to clip application helps achieve an accurate placement of the blades to

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reconstitute the parent vessel. The puncture of the dome should be done in a portion of the aneurysm that will not result in the suction device interfering with eventual clip placement or further dissection.

If thrombus is present in the aneurysm, it may also interfere with dissection and clip placement. An MR image will reveal this preoperatively and can be useful in surgical planning. Thrombus that is encountered after opening an aneurysm can often be removed with gentle dissection or the ultrasonic aspirator.^{15,37} Of course, the goal of initial thrombus removal is only to allow enough dissection to permit clip placement and then reestablish flow through the parent artery. After this has been achieved, additional clot may be removed, especially in those aneurysms that have presented because of symptoms associated with the aneurysm's mass. However, care must be taken to avoid injury to perforating vessels that are still adherent to the remaining aneurysm wall.

A firm plaque present in the aneurysm neck can usually be seen as yellow, atherosclerotic changes in the aneurysm wall. The presence of calcium can often be visualized preoperatively on a CT scan. Fortunately, atherosclerotic changes do not always indicate that the neck cannot be directly clipped. In those cases in which the plaque is clearly preventing placement of an aneurysm clip, an endarterectomy of the aneurysm neck can be performed.^{25,37,49}

An injury near the aneurysm's base may result in a neck that cannot hold an aneurysm clip and requires an aneurysmorrhaphy (the use of a portion of the aneurysm wall to reconstruct the parent vessel using either fenestrated aneurysm clips or direct suturing techniques).^{7,37,56} This is a difficult and time-consuming maneuver but may provide the only chance to reestablish flow through the parent vessel.

All of these techniques require a certain amount of working room, which is not always available. Use of traditional techniques such as aneurysm trapping (with or without a vascular bypass procedure) should be considered in cases in which there exists limited exposure for aneurysm dissection and manipulation.^{1,37,56} However, using these intraoperative endovascular techniques we rarely resort to aneurysm trapping and vascular bypass.

Surgical Outcome

Most large series of aneurysms have divided the aneurysms based on their size. This report includes aneurysms grouped by the degree of difficulty in their surgical obliteration. Therefore, larger aneurysms that could be directly clipped are excluded, whereas smaller aneurysms that resisted a direct approach are included. Given these parameters, we believe that a favorable outcome of 72.6% is acceptable. Ausman, *et al.*,¹ reviewed 10 series of giant aneurysms presented between 1977 and 1990. With 690 total cases, an excellent to good outcome occurred in 75.2%. The relative safety of these techniques is also evident in that only 11.3% of our patients had increased deficits postoperatively. The mortality rate of 8.1% also compares well with that seen in the 690 patients reviewed by Ausman, *et al.*,¹ who reported a 14.1% mortality rate.

Conclusions

Radiological endovascular techniques were a useful adjunct to treatment in six of our cases. However, during the period that these radiographic techniques were available, 98.5% of the aneurysms were treated with either traditional surgical methods or with those endovascular surgical techniques that we have described. A surgical cure for cerebral aneurysms remains the standard by which newer treatment modalities must be tested. The use of these intraoperative endovascular techniques broadens the range of aneurysms that are operable and therefore can be obliterated surgically with an acceptable morbidity. These techniques should be considered when planning an approach to treat difficult aneurysms.

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