# 13 Aneurysms of the Anterior Circulation

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**Checklist: Anterior Circulation Aneurysms (One of Two—Management of Intraoperative Rupture)**

| Equipment needed | Procedural steps |
|---|---|
| OR Technicians<br>• Temporary clips<br>• Permanent clips<br>• Microdissectors<br>• Microscope, with ICG angiography<br>• EVD catheters available<br>• Micro-Doppler flow probe<br>• Cotton<br>Nursing<br>• Mannitol<br>• Hypertonic saline<br>• Anticonvulsant<br>• Direct vasodilators<br>• Staff pager/cell phone numbers for endovascular neurosurgery and neurointerventionalist<br>Anesthesia/Neuromonitoring<br>• ICP monitoring<br>• Burst suppression<br>• Adenosine<br>• Cardiac defibrillator in place<br>Neurointerventionalist<br>• Groin prepped for intraoperative angiography<br>• Radiolucent Mayfield clamp<br>Neurosurgery<br>• EVD<br>• Bypass plan<br>• Staff pager/cell phone numbers for endovascular neurosurgery and angiography | Identify and dissect<br>• Proximal, distal, neck, then dome<br>Initiate and engage<br>• Alert *entire* team<br>• Suction to area with large suction tips to identify source<br>• Apply fixed retractor to free both hands<br>• Place temporary clips<br>• Reexamine rupture site<br>• Anesthesia: burst suppression<br>• Anesthesia: evaluate cardiovascular adjuncts (i.e., adenosine)<br>Repair and reconstruct<br>• Gently dissect free surrounding arachnoid if traction on structures is noted<br>• Clip reconstruct or place pilot clip at rupture site<br>• Release temporary clips<br>• Identify additional bleeding<br>• Rupture at neck of aneurysm may require clip-wrap or cotton-clipping<br>• If unsuccessful, consider trapping<br>• Assess patency of parent and daughter vessels<br>• Perform ICG<br>• Adjust clips as needed<br>• Assess acute vessel spasm<br>• Assess need for direct vasodilators (i.e., papaverine)<br>Perform, as needed<br>• Additional imaging<br>• EVD |

**Checklist: Anterior Circulation Aneurysm (Two of Two—Management of Cerebral Edema)**

| Equipment needed | Procedural steps |
|---|---|
| OR Technicians<br>• Temporary clips<br>• Permanent clips<br>• Microdissectors<br>• Microscope, with ICG angiography<br>• EVD catheters available<br>• Micro-Doppler flow probe<br>• Bypass instruments<br>• High speed drill<br>Nursing<br>• Mannitol<br>• Hypertonic saline<br>• Anticonvulsant<br>• Direct vasodilators<br>• Staff pager/cell phone numbers for endovascular neurosurgery and neurointerventionalist<br>Anesthesia/Neuromonitoring<br>• ICP monitoring<br>• Burst suppression<br>• Hyperventilation<br>• Mannitol<br>• Hypertonic saline<br>• Elevate head of bed<br>Neurointerventionalist<br>• Groin prepped for intraoperative angiography<br>• Radiolucent Mayfield clamp<br>Neurosurgery<br>• EVD<br>• Bypass plan<br>• Staff pager/cell phone numbers for endovascular neurosurgery and angiography | Identify and inspect<br>• Elevate head of bed or reverse Trendelenburg<br>• Modest hyperventilation (end-tidal CO2 of 25 mmHg)<br>• Avoid hypertension<br>• EVD drainage of CSF<br>• Cisternal drainage of CSF<br>• Evaluate for additional bone removal<br>Initiate and engage<br>• Alert *entire* team<br>• Place or remove temporary clips<br>• Anesthesia: burst suppression<br>• Anesthesia: evaluate hypertonic adjuncts<br>• Consider mild hypothermia<br>Repair<br>• Open lamina terminalis if possible<br>• Consider Paine's point ventricular puncture and drain<br>• Identify any bleeding<br>• Assess patency of parent and daughter vessels (as possible cause of edema)<br>• Adjust clips as needed<br>• Assess acute vessel spasm<br>Perform, as needed<br>• EVD<br>• Additional bone removal<br>• CSF diversion |

**Complication Avoidance Flowchart**

| Complication | Cause | Avoidance |
|---|---|---|
| Retraction injury | • Use of fixed brain retractors | • Plan appropriately sized craniotomy and obtain adequate skull base exposure (i.e., drilling of sphenoid wing)<br>• Perform wide splitting of the Sylvian fissure<br>• Release CSF from basal cisterns |
| Venous infarction | • Sacrifice of Sylvian veins | • Avoid coagulation/division of large Sylvian veins |
| Arterial infarction | • Perforator clipping<br>• Prolonged temporary clipping<br>• Clip-associated parent artery stenosis | • Perform circumferential dissection and inspection of aneurysm<br>• Avoid more than 3 min of proximal artery temporary clipping prior to reperfusion<br>• Confirm adequate parent vessel caliber and blood flow using intraoperative angiography |
| Intraoperative aneurysm rupture | • Disruption of thrombus on aneurysm rupture site<br>• Aneurysm neck tear | • Obtain proximal parent vessel control prior to dissecting the aneurysm<br>• Generously release adjacent arachnoid to avoid traction on the aneurysm rupture site or neck |

## Introduction

Cerebral aneurysms of the anterior circulation include those that arise from the internal carotid artery (ICA) or any of its terminal branches. Although the indications for an endovascular approach to aneurysm treatment continue to expand, microsurgical treatment remains the preferred option for many patients with select anterior circulation aneurysms. The established durability, versatility, and effectiveness of microsurgical clip ligation for treating anterior circulation aneurysms set the standard by which all newer technologies must be judged. In this chapter, we provide a comprehensive review of the considerations necessary to effectively treat anterior circulation aneurysms microsurgically while avoiding common pitfalls..In addition to reviewing the salient general preoperative and intraoperative matters of relevance to anterior circulation aneurysm surgery, we also discuss the specific considerations for aneurysms in each location.

## Historical Background

The surgical treatment of aneurysms has continued to evolve since Norman Dott performed the first direct treatment of a ruptured anterior circulation aneurysm in 1931 [1, 2]. Dott reportedly fashioned a left frontal osteoplastic bone flap, approached the ipsilateral ICA from a lateral subfrontal trajectory, dissected distally to the ICA bifurcation, and finally moved toward the proximal middle cerebral artery (MCA) where brisk arterial bleeding was encountered from the aneurysm's dome. At this point a muscle wrap was used to tamponade the rupture site. Dott's patient made a remarkable recovery and returned to full functionality prior to dying from heart disease 11 years later. Such a feat was certainly remarkable in itself but more so considering that Dott accomplished this without the benefit of preoperative imaging, a surgical microscope, fine microinstruments, or modern monitoring and anesthesia.

The next major advancement in aneurysm surgery came when Walter Dandy performed the first clip ligation of another anterior circulation aneurysm in 1937 [3]. Dandy's patient presented with a complete third cranial nerve palsy due to compression from a posterior communicating artery aneurysm. In his seminal case report on the matter, Dandy explains that "An ordinary flat silver clip was placed over the neck of the sac and tightly compressed, obliterating it completely. The clip was flush with the wall of the carotid artery." The patient did exceptionally well after suffering a 3-day bout of delirium tremens postoperatively. The preoperative oculomotor palsy fully resolved 7 months after surgery.

Although Dandy is often credited with ushering in the modern era of cerebral aneurysm surgery, Yasargil's moniker as the "father of microneurosurgery" is a testament to his manifold contributions not only to cerebrovascular surgery but to neurosurgery as a whole. Yasargil's advocacy for routine use of the operating microscope during aneurysm surgery, development of modern aneurysm clips, elaboration of subarachnoid basal cistern anatomy, popularization of cerebral bypass techniques, and refinement of the "workhorse" frontotemporal/pterional craniotomy are just a small sampling of his contributions to cerebrovascular surgery [4].

## Procedural Overview

### Equipment

In addition to the standard tools necessary to turn a craniotomy flap and provide adequate skull base exposure (adjustable electric operating table, high-speed drill, various rongeurs, etc.), there are a number of specific instruments recommended to facilitate efficient and safe microsurgical clip ligation of anterior circulation aneurysms.

### Skull Clamp and Retractors

A radiolucent three-point skull fixation clamp is utilized for positioning prior to cerebral aneurysm surgery. Rigid head stabilization is essential to ensure safety and accuracy during delicate microsurgical maneuvers including deep drilling, arachnoid and aneurysm dissection, microvessel suturing, and aneurysm clipping. The radiolucent property of the skull clamp enables intraoperative catheter cerebral angiography to be performed without obstruction from radiopaque metal (Fig. 13.1).

We routinely utilize fishhooks attached to a Leyla bar by rubber bands to provide scalp and temporalis muscle retraction during the surgery. Such retraction not only facilitates low-profile exclusion of tissue from the operative field of view but also assists with muscle and scalp hemostasis (Fig. 13.2). A retractor system such as

Greenberg or Budde Halo apparatus should be rigidly secured to the skull clamp in case brain retraction becomes necessary, especially in the setting of subarachnoid hemorrhage when diffuse cerebral edema is present and intraoperative aneurysm rupture is more prevalent (Table 13.1).

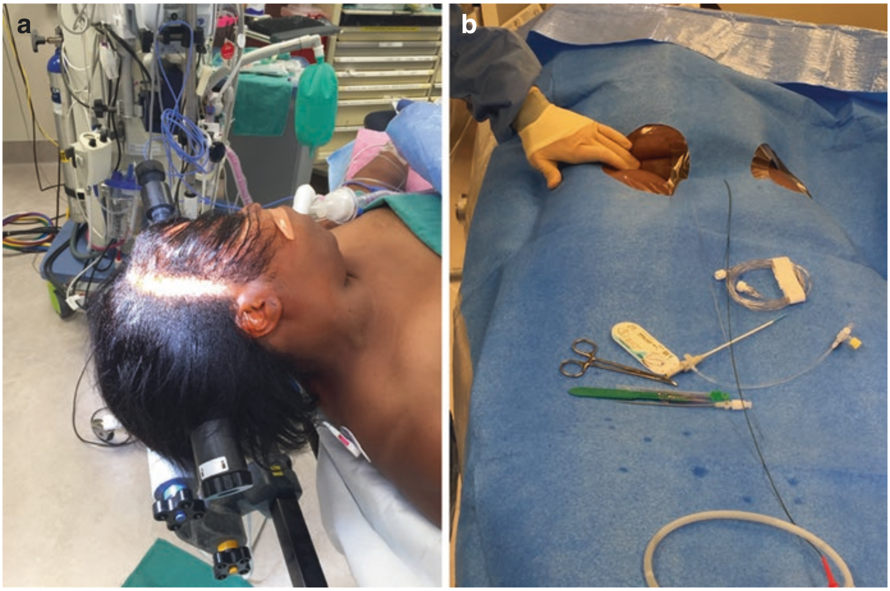

**Fig. 13.1** Cranial fixation and intraoperative angiography. The head is secured in a three-point radiolucent skull clamp and rotated about 30° contralateral to the operative side. The planned curvilinear incision from the widow's peak to the anterior tragus is outlined by the strip shave (**a**). The groin is prepped and draped allowing an introducer sheath to be placed either pre- or intraoperatively in preparation for catheter angiography (**b**)

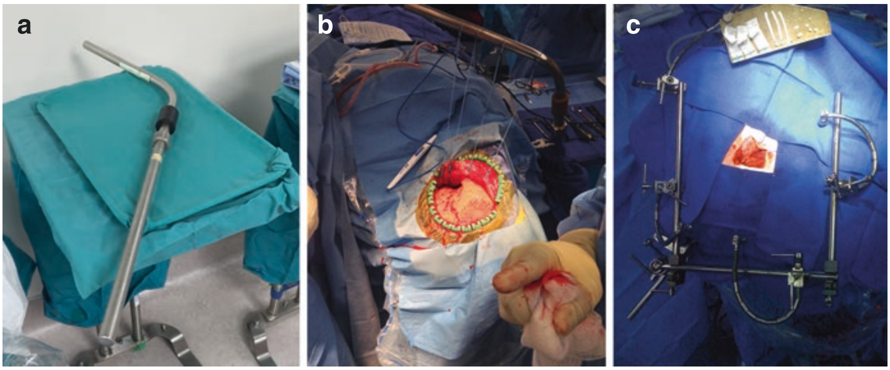

**Fig. 13.2** Retractor setup for a pterional approach. The Leyla bar is used routinely in the operative setup for anterior circulation aneurysm surgery (**a**). It facilitates low-profile scalp and temporalis muscle retraction giving access to the keyhole and entire frontotemporal region (**b**). A brain retractor system such as the Greenberg should be assembled in case its use becomes necessary (**c**)

**Table 13.1** Checklist for managing intraoperative aneurysm rupture

| |
|---|
| • Attempt to clear the operative field of blood using one or more suctions as needed |
| • Placement of a fixed brain retractor may be needed to free both hands for additional microsurgical manipulation |
| • Suction on wet cotton within the field to improve the surface area cleared |
| • Consider temporary cardiac pause with adenosine if blood is not easily cleared |
| • Initiate burst suppression and place a temporary clip on the proximal feeder artery if possible |
| • Determine the rupture site on the aneurysm and place a suction tip over this point to halt extravasation |
| • Free remaining arachnoid and perforators from the aneurysm neck and dome |
| • Clip the aneurysm neck if the rupture site is on the fundus; alternatively a temporary “pilot clip” that occludes the rupture site can be helpful prior to definitive direct neck clipping |
| • A tear at the neck of the aneurysm may require a clip-wrap or cotton-clipping strategy as outlined by Barrow and Spetzler (Neurosurgery. 2011 Jun; 68: 294–9) |
| • In the event that cotton clipping is ineffective, aneurysm trapping from the parent vessel may be necessary |
| • Consider a bypass strategy if trapping is performed |

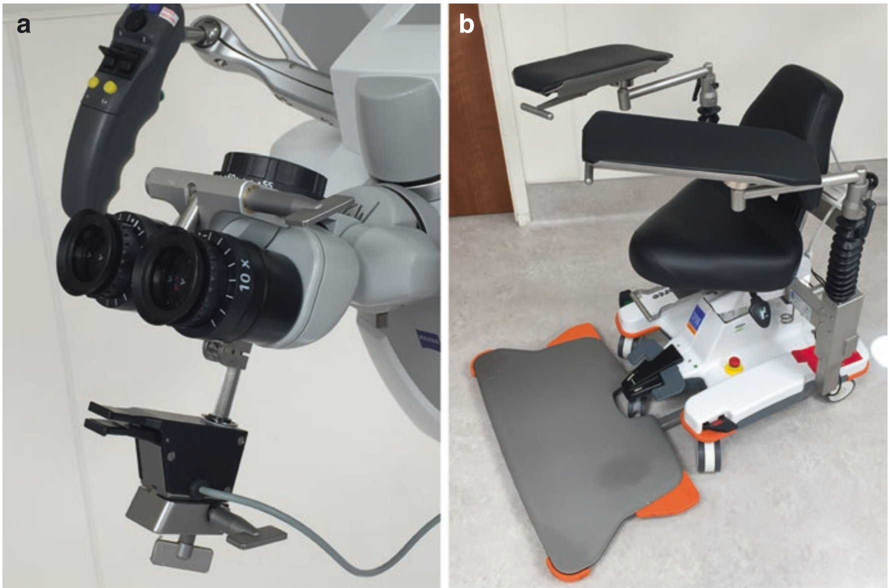

**Fig. 13.3** The operating microscope and chair. A microscope equipped with a mouthpiece is helpful for allowing uninterrupted bimanual work within the operative field (**a**). Alternatively, foot pedal control may be preferred. A comfortable chair with an armrest can also facilitate the performance of fine microsurgical maneuvers (**b**)

## Microscope

An operating microscope equipped with either foot pedal controls or a mouthpiece is essential for allowing fine adjustments to the focus, zoom, and field of view without removing either hand from the operative field (Fig. 13.3). It is also recommended that the microscope be equipped with an indocyanine green (ICG) fluorescence filter such that intraoperative videoangiography can be performed. Alternative or additional filters for fluorophores such as fluorescein have also been utilized in aneurysm surgery [5].

## Microinstruments

Fine tip bipolar cautery, arachnoid knives, microscissors, a variety of angled microdissectors, and variable strength suctions with teardrop finger controls (Fig. 13.4) are important tools that facilitate microsurgical exploration during aneurysm surgery. A microvessel anastomosis set including—at a minimum—fine jeweler forceps, tying forceps, and a microneedle driver is an essential component of the vascular neurosurgeon's toolbox. While vessel suturing is typically not needed during most anterior circulation aneurysm surgeries, one should always be prepared to perform a bypass or repair an injured vessel—typically with a 9-0 monofilament suture. In addition, we routinely utilize micro-Doppler ultrasound to confirm vessel patency after clip placement prior to obtaining an angiogram.

## Pharmacological Adjuncts

Several medications are routinely given to the patients in the operating room prior to the commencement of aneurysm surgery. Prophylactic antibiotics with skin flora coverage such as cefazolin should be given prior to making an incision. Seizure

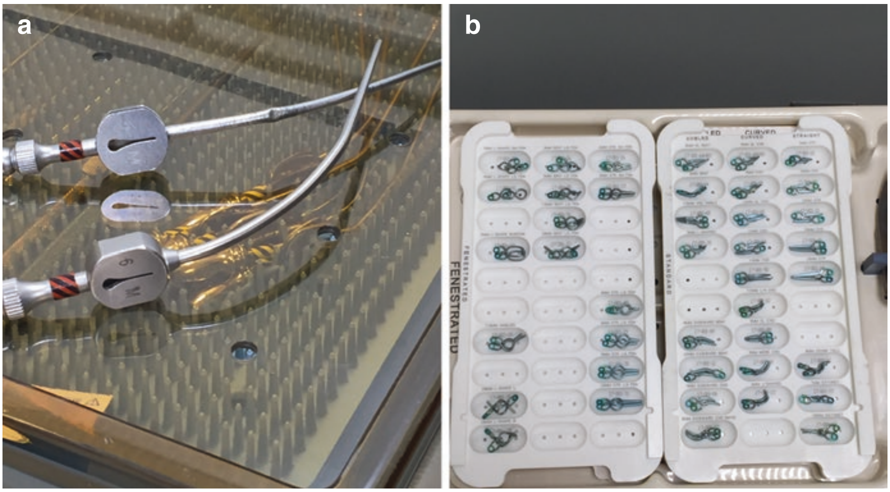


**Fig. 13.4** Microsurgical suctions and aneurysm clips. Suction injury to surrounding vessels and brain structures can be avoided with the use of teardrop finger-controlled suctions during microsurgery (**a**). An aneurysm clip set including a variety of straight, angled, curved, and fenestrated clips is an essential part of the cerebrovascular surgeon's toolbox (**b**)

prophylaxis with levetiracetam or phenytoin is also prudent. Mannitol at a dose of 0.5–1 g/kg reduces cerebral water content thus relaxing the brain and may have additional microcirculatory rheological effects thought to be neuroprotective. Similarly, dexamethasone at a dose of 10 mg may have beneficial effects in terms of reducing brain edema as well as reducing postoperative nausea and vomiting. Blood glucose should be kept in the normal range using an insulin infusion if necessary. Additional agents such as adenosine to effect temporary flow arrest and local vasodilators including nicardipine and papaverine should be available if needed. Intra-arterial cerebral vasodilator agents such as verapamil may also be of utility in the treatment of severe intraoperative vasospasm.

## Brain Relaxation

The benefits of mannitol and steroids have already been mentioned for the purposes of effecting brain relaxation. It goes without saying that basic principles of proper patient positioning should be followed including having the head above the level of the heart and minimizing venous outflow obstruction with aggressive head turning. Additional strategies for achieving further brain relaxation include instituting moderate hyperventilation, placement of a preoperative external ventricular or spinal drain, placement of an intraoperative ventriculostomy, and performing in situ cisternal cerebrospinal fluid evacuation (Table 13.2).

## Hyperventilation

Moderate short-term hyperventilation with a goal end-tidal $CO_2$ of 25–30 mmHg causes cerebral vasoconstriction which results in reduction of both cerebral blood flow and blood volume. This cascade in turn reduces intracranial pressure which clinically manifests as a more relaxed brain. While effective, moderate hyperventilation should be instituted with caution to prevent ischemic sequelae especially in the setting of vasospasm. Thus, maintenance of normotension or even moderate hypertension is prudent when hyperventilation is instituted.

**Table 13.2** Checklist for managing intraoperative cerebral edema

| |
|---|
| • Elevate the head of bed or put the patient in reverse Trendelenburg position |
| • Initiate modest hyperventilation to an end-tidal $CO_2$ of 25 mmHg |
| • Avoid hypertension |
| • Ensure that mannitol has been given, may consider giving an additional bolus of hypertonic saline |
| • Evacuate CSF from the basal cisterns and/or open the lamina terminalis if possible |
| • Open the spinal drain if one was placed preoperatively |
| • Initiate burst suppression and ensure that the patient is modestly hypothermic |
| • Place a Paine’s point external ventricular drain if necessary |

## CSF Drainage

As a matter of protocol at our institution, all patients presenting with poor clinical grade subarachnoid hemorrhage or symptomatic hydrocephalus will have a preoperative external ventricular drain (EVD) in place. A temporary spinal drain placed in the operating room after anesthesia induction is most commonly utilized for good clinical grade subarachnoid hemorrhage patients who do not have symptomatic hydrocephalus. This is also a consideration when an interhemispheric approach is utilized since access to the subarachnoid cisterns is limited. Should immediate intraoperative CSF drainage become necessary in a patient without an EVD or spinal drain, a Paine's point ventriculostomy can be easily placed after the dura is opened. Brain relaxation can be further facilitated by wide opening of the Sylvian fissure and the basal cisterns including the chiasmatic, lamina terminalis, and carotid cisterns.

## Sylvian Fissure Dissection

Sylvian fissure dissection is generally the first microsurgical step for gaining access to most anterior circulation aneurysms. A wide, generous splitting allows the frontal and temporal lobes to become untethered and provides unimpeded access to the basal cisterns (Fig. 13.5). When the Sylvian fissure is split in this fashion, minimal or no fixed brain retraction is necessary. The depth, length, and direction of Sylvian fissure dissection are partially dictated by the location of the aneurysm and partially the result of surgeon preference. In general, middle cerebral artery aneurysms require relatively deep and lateral dissection into the Sylvian fissure. In contrast, proximal ICA and anterior communicating artery aneurysms require less deep and more medial Sylvian fissure dissection.

Developmentally, middle cerebral artery branches exclusively irrigate either the frontal lobe or the temporal lobe and do not cross the Sylvian fissure, whereas veins

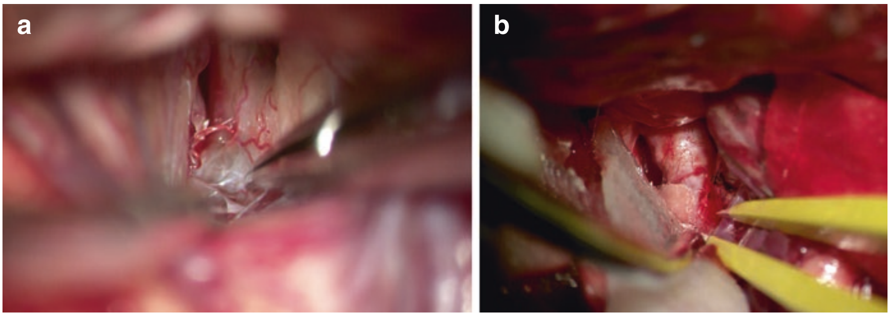


**Fig. 13.5** Opening the basal cisterns. After Sylvian fissure dissection, arachnoid may be generously freed posteriorly toward the optic chiasm and lamina terminalis (**a**). The optico-carotid cistern is opened, freeing the internal carotid artery to provide proximal blood flow control (**b**)

do not strictly follow this rule. Thus, arteries should never have to be divided during Sylvian fissure dissection, while this is sometimes necessary for crossing veins. Nonetheless, large draining veins to the sphenoparietal sinus should be spared when feasible to avoid complications resulting from venous congestion. Veins tend to run more closely in association with the temporal lobe, so it is often more favorable to begin the Sylvian fissure arachnoid dissection biased toward the frontal side. Use of meticulous microsurgical technique with strict avoidance of subpial dissection is emphasized to ensure the best possible result.

## Cerebral Protection

Cerebral protection strategies during aneurysm surgery aim to reduce ischemic neuronal injury that may result from reduced local or global oxygen delivery. Such a state may occur secondary to either intentional or unintentional reductions in cerebral blood flow. Intentional local blood flow reduction occurs most commonly during temporary clipping. Intentional global blood flow reduction may be due to induced hypotension or temporary cardiac pause after adenosine injection. Unintentional local blood flow reduction may be secondary to fixed brain retraction or vasospasm. Similarly, unintended global blood flow reduction can also result from diffuse cerebral vasospasm or hypotension. Specific strategies including institution of mild hypothermia, induction of burst suppression, and maintenance of mild hypertension may be helpful in mitigating the downstream effects of reduced neuronal oxygen delivery.

### Hypothermia

While deep hypothermia is incontrovertibly known to be neuroprotective, the benefits of mild hypothermia are less definitive. The systemic complications associated with induction of deep hypothermia have rendered this technique of historical interest for aneurysm surgery [6]. In contrast, mild hypothermia is readily tolerated by most patients and seems to at least not be harmful. Given the theoretical benefits of even mild reductions in the cerebral metabolic rate from temperature reduction, we routinely aim for a core temperature of approximately 34–35 °C until the aneurysm has been secured.

### Burst Suppression

Similar to the effect of hypothermia on cellular energy consumption, neuronal burst suppression can significantly reduce the cerebral metabolic rate of oxygen consumption. While barbiturates are no longer routinely utilized for this purpose, propofol-induced burst suppression is advocated by some practitioners during temporary clipping [7]. This is frequently done in combination with mild induced hypertension to facilitate perfusion via collateral pathways.

## Neuromonitoring

Electrophysiological monitoring with electroencephalography and, more recently, bispectral index monitoring is necessary if true burst suppression is desired intraoperatively. Additional monitoring of motor and somatosensory evoked potentials has utility in terms of predicting postoperative ischemic injury. Nonetheless, these modalities are not absolutely sensitive or specific and thus may give a false sense of security. This is especially the case during long periods of temporary clipping. Alternatively, we favor limiting the duration of temporary clipping to cycles of 3 min occlusion followed by 5 min of reperfusion without the routine use of eletrophysiological monitoring.

## Craniotomy

The vast majority of anterior circulation aneurysms can be approached from either a frontotemporal/pterional craniotomy or from a frontal parasagittal craniotomy. In rare circumstances, an alternative craniotomy may be used in cases such as a distal middle cerebral artery aneurysm (usually a mycotic M4 aneurysm) or if a decompressive craniectomy must also be performed. Specific modifications to the pterional craniotomy including orbital extension or an orbitozygomatic approach are rarely necessary. Additional variations such as the "mini-pterional" or a lateral supraorbital craniotomy can also be utilized, particularly in the unruptured setting. Similarly, the parasagittal craniotomy as utilized for interhemispheric approaches to distal anterior cerebral artery aneurysms (DACA) may be altered to accommodate the anatomy of each unique case.

### Pterional Craniotomy

The basics of this "workhorse" cranial approach are familiar to most neurosurgeons; however, some points are worth reviewing [8]. First, there are several options for how to dissect the temporalis muscle for exposure to the region. This includes (1) anterior reflection as part of a curvilinear myocutaneous flap extending from the widows peak to the anterior tragus, (2) posterior reflection after making a muscle incision just posterior to the fat pad, (3) interfascial or subfascial dissection allowing posterior reflection from the lateral orbital rim, or (4) posterior inferior reflection over the zygoma after both dissections from the lateral orbital rim and making a posterior muscle belly incision extending from the superior temporal line to the root of the zygoma. While all the aforementioned treatments of the temporalis muscle inevitably result in some atrophy, we favor the anteriorly reflected myocutaneous flap for its simplicity as well as the favorable cosmetic results.

Another important point regarding the pterional craniotomy for anterior circulation aneurysm surgery is that the lesser sphenoid wing and lateral orbital roof should be generously drilled flat to the depth of the superior orbital fissure. Indeed routine unroofing of the posterior orbit as advocated by Yasargil is ideal but not necessary for most cases. Similarly, extensive anterior temporal and high anterior frontal bone removal is frequently not necessary. Deepening the bone removal along the lesser sphenoid wing leads to the anterior clinoid process and optic canal roof. The indications for anterior clinoidectomy are further discussed in the section on specific aneurysms. Although either extradural or intradural anterior clinoid removal is generally acceptable, we favor the intradural approach for aneurysm surgery. The anterior clinoid process has three attachments to the skull base including the optic canal roof, the lesser wing of the sphenoid bone, and the body of the sphenoid bone via the optic strut. A 2 mm diamond burr or ultrasonic aspirator with bone attachment may be used to remove these connections allowing the clinoid to be freed.

### Parasagittal Craniotomy

The parasagittal craniotomy can be modified in terms of size and rostro-caudal placement. This is based both on the specific anatomy of the aneurysm to be treated as well as on the location of bridging veins to the superior sagittal sinus. While certainly not necessary, frameless stereotaxy has some utility in aneurysm surgery for the precise placement of this particular bone flap. Proximal A2 aneurysms require a more rostral bone flap placement than is needed for distally located anterior cerebral artery aneurysms. In general, a non-dominant interhemispheric approach is favored. The bone flap is planned such that it spans the superior sagittal sinus and is eccentric to the right side. The degree of patient neck flexion warranted is determined by the aneurysm's location. A supine or lateral patient position may be utilized. Although we favor the supine position, it is recognized that in the lateral position with the approach side facing down, gravity assists with opening up the interhemispheric corridor.

## Considerations for Specific Aneurysms

### Cavernous and Clinoidal Segment Aneurysms

Cavernous and clinoidal ICA segment aneurysms are generally not treated microsurgically. Indeed most such aneurysms do not require any treatment at all, even when they become quite large. This is due to the fact that they rupture at an exceedingly low rate and furthermore are extradural in location [9]. Large symptomatic cavernous aneurysms can be effectively treated with flow diversion in most instances. Some large clinoidal segment aneurysms may extend intradurally past the distal dural ring which would elevate the level of concern for its capacity to result in subarachnoid hemorrhage. When such an aneurysm is unruptured, it is often favorable for some form of endovascular treatment including simple or balloon-assisted coiling, stent-assisted coiling, or flow diversion. In the rare setting of subarachnoid hemorrhage from a clinoidal segment aneurysm not amenable to either simple or balloon-assisted coiling, clip ligation is prudent. Microsurgical clip ligation is also favored if there is optic nerve compression resulting in visual disturbance since direct aneurysm dome decompression can be simultaneously accomplished.

An anterior clinoidectomy with complete opening of the distal dural ring to expose the distal and proximal aneurysm neck is mandatory to treat clinoidal segment aneurysms. Ipsilateral cervical ICA dissection to gain proximal control is recommended to safely approach these aneurysms.

## Ophthalmic Segment Aneurysms

Ophthalmic segment aneurysms include three separate anatomic types including ophthalmic artery aneurysms, superior hypophyseal artery aneurysms, and dorsal carotid aneurysms. The specific considerations for each aneurysm type are unique and reviewed separately.

Ophthalmic artery aneurysms arise at or just distal to the takeoff of the ophthalmic artery. The aneurysm projection is typically superiorly, approximately perpendicular to the parent ICA. Intradural inspection is necessary to determine whether an anterior clinoidectomy is necessary to expose the proximal neck of this aneurysm. In many cases, a clinoidectomy is unnecessary, and adequate neck exposure is either already present or necessitates only release of the falciform ligament around the optic nerve. Much like for clinoidal segment aneurysms, ophthalmic artery aneurysms generally present with little proximal intradural ICA available to allow for temporary clipping. Proximal control is best gained by exposing the cervical ICA in this situation. Alternatively, temporary flow arrest with adenosine can be utilized to facilitate aneurysm softening and neck clipping.

Superior hypophyseal artery aneurysms project from the medial surface of the ICA distal to the dural ring. Like clinoidal segment aneurysms, superior hypophyseal aneurysms tend to have a low rupture risk and are often followed conservatively. If microsurgical clipping is elected, the anatomy generally requires use of a right-angled fenestrated clip with the ICA within the fenestration. Interestingly, exposure of superior hypophyseal aneurysms from a contralateral approach may actually give the most direct view and facilitate more straightforward clipping.

Dorsal carotid wall aneurysms arise without relation to a specific arterial branch. The saccular variety can often be directly clipped in a very straightforward fashion. Frequently, however, dorsal carotid aneurysms are of the blood blister type and do not have a discreet neck. These aneurysms are most favorable for clip-wrapping with Gore-Tex. A mild degree of non-flow limiting ICA stenosis is generally acceptable at the site of wrapping, indicating that the clip has adequately cinched the Gore-Tex around the bleed site.

## Communicating Segment Aneurysms

Communicating segment aneurysms include those of the posterior communicating and the anterior choroidal arteries. Notable points regarding the clipping of aneurysms in this segment include ensuring that anterior thalamoperforating arteries are excluded from the clip blades, preoperative recognition of fetal posterior cerebral arteries with attention to intraoperative preservation during clipping, and, finally, uncompromising regard for maintaining the patency of the anterior choroidal artery.

A subfrontal approach with minimal or no Sylvian fissure splitting is one way to access simple aneurysms in this region especially when there is no subarachnoid hemorrhage (Fig. 13.6). Alternatively, it is more generally recommended to open the medial aspect of the fissure to provide wider access and limit the need for fixed brain retraction. Intradural proximal ICA control is usually easily accessible without the need for anterior clinoidectomy.

While communicating segment aneurysms have historically been considered among the simplest aneurysms to clip, this also tends to be true regarding the feasibility for coiling them. Thus, in the current “endovascular era,” communicating segment aneurysms that are best treated microsurgically are generally of higher complexity than was seen in prior generations.

## Carotid Terminus Aneurysms

The important principles to keep in mind when approaching aneurysms at the ICA bifurcation are similar to those in other locations: establish early proximal control, completely dissect the aneurysm dome from surrounding arachnoid adhesions, and avoid perforator injury or occlusion. Thus, with regard to obtaining early proximal control, it is sometimes feasible to commence dissection by

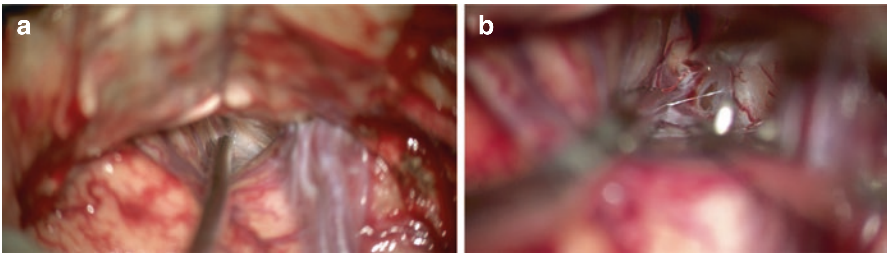


**Fig. 13.6** Lateral supraorbital corridor. The ipsilateral optic nerve is readily visible on initial subfrontal dissection with no Sylvian fissure opening (**a**). Such an approach to the anterior communicating region is facilitated by opening the lamina terminalis to release CSF from the ventricular system (**b**)

opening the carotid cisterns and progressing distally toward the horizontal aspect of the Sylvian fissure until the aneurysm is encountered. Alternatively, lateral to medial opening of the Sylvian fissure can be elected much in the way that middle cerebral artery bifurcation aneurysms are exposed. Important perforators to be aware of include the recurrent artery of Heubner and the anterior choroidal artery which course medial to the aneurysm on the operator's blind side. M1 lenticulostriate vessels that are adherent to the aneurysm should be dissected free prior to clipping.

## Anterior Communicating Artery Aneurysms

Anterior communicating artery aneurysms are often more complex than is initially appreciated. During the microsurgical treatment of these aneurysms, it is important to strive for identification of all incoming and outgoing arteries affiliated with the anterior communicating complex. These vessels include bilateral A1, bilateral A2, bilateral recurrent artery of Heubner, perforators from the posterior-superior aspect of the communicating artery, and the anterior communicating artery itself. The surgeon should have preoperative awareness of all anatomic variations in the region such as non-coronal orientation of the communicator, the presence of fenestrated or accessory communicators, or the persistence of a median artery of the corpus callosum resulting in three A2 vessels.

## Distal Anterior Cerebral Artery Aneurysms

Distal anterior cerebral artery aneurysms (DACA) include those occurring distal to the anterior communicating artery. Often referred to as pericallosal aneurysms, the prototypical type occurs in relation to the origin of the callosomarginal artery. Anatomically, these aneurysms commonly occur at or just distal to the genu of the corpus callosum. These aneurysms are best approached from a frontal interhemispheric corridor. On occasion, a more proximal A2 aneurysm can be accessed from a lateral subfrontal corridor in a similar manner to the approach for anterior communicating artery aneurysms. Again, it is wise to be aware of any anatomic variations to the arteries in the region such as the presence of an azygous or accessory A2s.

## Middle Cerebral Artery Aneurysms

Middle cerebral artery aneurysms (MCA) may include those occurring on the M1, those arising at the MCA bifurcation, or less commonly aneurysms that are found on branches more distally along the arterial tree. M1 aneurysms are commonly found either in association with lenticulostriate perforators or at the origin of an anterior temporal branch artery. Lenticulostriate aneurysms often project perpendicular to the parent M1 vessel with the dome buried in brain parenchyma making them difficult to locate. MCA bifurcation aneurysms are the most commonly observed type of MCA aneurysm. They are often wide-necked, large, and have a complex anatomy, making them less favorable for endovascular treatments. Classically, wide and deep splitting of the Sylvian fissure is advocated to approach these aneurysms although more minimalistic strategies have been reported [10]. Distal MCA aneurysms are infrequently seen but are more commonly mycotic in nature as compared to aneurysm found in other anterior circulation locations. An initial trial of antibiotic therapy is reasonable for many such mycotic aneurysms. If this conservative management fails to result in aneurysm regression, consideration should be given for direct clipping or resection.

**Conclusion**

Cerebral aneurysms of the anterior circulation have been safely and effectively treated surgically for nearly a century. Anterior circulation aneurysms are varied and a unique surgical solution must be devised for each case. It is important however to adhere to general principles including ensuring adequate skull base exposure, performing wide Sylvian fissure splitting, progressively opening the subarachnoid cisterns, securing proximal parent artery control, and completely dissecting the aneurysm from surrounding structures prior to clipping. Microsurgical refinements along with their utilization by dedicated practitioners continue to advance the field cerebrovascular surgery allowing more complex aneurysms to be durably and definitively treated.

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