





# Cerebral artery anatomy, approach, and technique explored aneurysm clipping

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Although existing literature states that aneurysms are congenital lesions, supporting evidence is limited. Aneurysms are most probably degenerative acquired lesions, the effect of hemodynamic stress. Connective tissue disorders with loss of tensile strength are aggravating rather than causal factors.

Studies estimate that 1% to 5% of the general population, or as many as 400,000 people, have a brain aneurysm. Unfortunately, 85% to 90% are not diagnosed until rupture. At highest risk are people between the ages of 50 and 69. Most diagnosed cases occur between the ages of 40 and 65. Diagnosis is typically done through CT scan, MRI, or cerebral angiography.

Surgical clipping with a nonferromagnetic clip is the most effective means of preventing rupture and subarachnoid hemorrhage (Figure 1), thus effectively shutting off flow to the thin-walled aneurysm while maintaining the blood flow and integrity of the surrounding vessels.

## anatomy of the scalp

The scalp is composed of five layers (Figure 2): the skin, the subcutaneous tissue, epicranial aponeurosis (galea), loose areolar tissue, and pericranium (periosteum).<sup>1</sup> The skin is thick and contains hair and sebaceous glands. The subcutaneous tissue is fibro-fatty, has a network of fibrous septa, and is richly vascular as branches of the external and internal carotid arteries anastomose in this layer. The epicranial aponeurosis is a strong, tendinous sheet with three attachments: anteriorly to the frontalis muscle, posteriorly to the occipital muscle, and laterally to the small temporoparietalis muscles.

The galeal closure is the key for ensuring scalp flap integrity in the postoperative neurosurgical patient. Loose areolar tissue connects the galea to the pericranium of the skull. The areolar layer contains the valveless emissary veins, which connect the scalp veins with the diploic veins of the skull and, ultimately, the intracranial venous sinuses.<sup>2</sup> At the skull suture lines, the periosteum becomes continuous with the endosteum on the inner surface.

## Brain topography

The average adult male brain weighs approximately 1400 g, of which 80% is water.<sup>3</sup> Grossly, the brain is divided into the cerebrum, cerebellum, and brain stem. The cerebral surface is marked by gyri (eminences) and sulci (fissures). The major lateral sulcus (Sylvian fissure) is present at the base of the brain and extends posteriorly and upward.

The Sylvian is the most important fissure in relation to accessing the base of the aneurysm. It provides a easy route to clip a variety of aneurysms. The major central sulcus, or rolandic fissure, extends from the hemispheric midline downward and forward until it nearly meets the Sylvian fissure. The central sulcus demarcates the key precentral gyrus, or motor cortex, and postcentral gyrus, or sensory cortex.

## The hemispheres of the brain

The cerebral hemisphere is divided schematically into four lobes: the frontal, parietal, occipital,

and temporal lobes. The frontal lobe occupies roughly one third of the hemisphere, beginning anteriorly and ending at the central sulcus, with lateral extension to the Sylvian fissure. On the convexity, it is divided into superior, middle, inferior, and precentral gyri. The parietal lobe begins at the central sulcus and extends posteriorly to the parietooccipital fissure. Its lateral boundaries are marked by a line tangent to the Sylvian fissure. It is divided into postcentral, supramarginal, and angular gyri. The occipital lobe is situated posterior to the parietooccipital fissure and extends inferiorly to the preoccipital notch. The temporal lobe lies inferiorly to the Sylvian fissure and extends posteriorly to the parietooccipital fissure. The lateral surface is divided into three gyri—superior, middle, and inferior—respectively.

## Cerebral arterial system

Although the brain comprises only 2% of total body weight, it consumes 20% of the total oxygen.<sup>4</sup> This requires a blood flow of 750 ml/min and makes the brain sensitive to even a few seconds of reduced vascular flow. Gray matter has a higher oxygen requirement due to the density of synapses rather than the number of neurons.

## Brain stem circulation

The vertebral arteries supply blood to the rostral spinal cord and the caudal medulla (Figure 3). The anterior spinal artery is a branch of the vertebral arteries, which serve the anterior portion of the spinal cord as well as the pyramids of the medulla. The posterior inferior cerebellar arteries (PICAs) are also branches of the vertebral arteries and serve the posterior spinal cord and much of the caudal portion of the medulla. Occlusion of the PICAs can interfere with function in the spinal trigeminal nucleus and tract, nucleus ambiguus, and vestibular nuclei. In addition, the PICAs also supply blood to the inferior cerebellum including the vestibulocerebellum.

At the junction of the medulla and pons, the right and left vertebral arteries fuse to form the basilar artery, which runs along the basilar pons (Figure 4). Just after they fuse, they give rise to

the anterior inferior cerebellar arteries (AICA) to serve the dorsal medulla/pons area. Along the midpontine portion of the basilar artery are numerous small paramedian branches that perforate the basilar pons.

At the pontine-midbrain junction, the basilar artery gives rise to the superior cerebellar arteries which carry blood to the anterior cerebellum, the dorsal pons and midbrain. Within the interpeduncular fossa of the midbrain, the basilar artery splits into the two posterior cerebellar arteries. These arteries serve the tectum of the midbrain as well as the posterior-medial cerebral cortex.

### The circle of Willis

The two arteries that give rise to the Circle of Willis are the vertebral and the internal carotid arteries.

The arteries that comprise the Circle of Willis are the basilar, the posterior cerebral arteries, the posterior communicating arteries, the middle cerebral arteries, the anterior cerebral arteries, and the anterior communicating artery.

### Internal carotid artery

The internal carotid arteries branch as they enter the cavernous sinus, giving rise to two large arteries (the middle cerebral artery and the anterior cerebral artery) and two relatively small arteries (the posterior communicating artery and the anterior choroidal artery). The internal carotid artery is divided into five segments: the cervical, petrous, cavernous, clinoidal, and supraclinoidal segments. The supraclinoidal segment exits from the dura mater, which forms the roof of the clinoidal segment, and then enters the intradural space on the medial side of the anterior perforated substance. It bifurcates in the area below the anterior perforated substance at the

medial end of the sylvian fissure into the anterior and middle cerebral arteries.<sup>5</sup>

### Middle cerebral artery

The middle cerebral artery continues laterally and enters the lateral sulcus, separating the temporal lobes from the frontal and parietal lobes, and then travels along the lateral surface of these lobes, as well as the superior temporal gyrus and middle temporal gyrus. In fact, virtually all of the blood to the lateral portions of the cerebrum is supplied by the middle cerebral arteries.

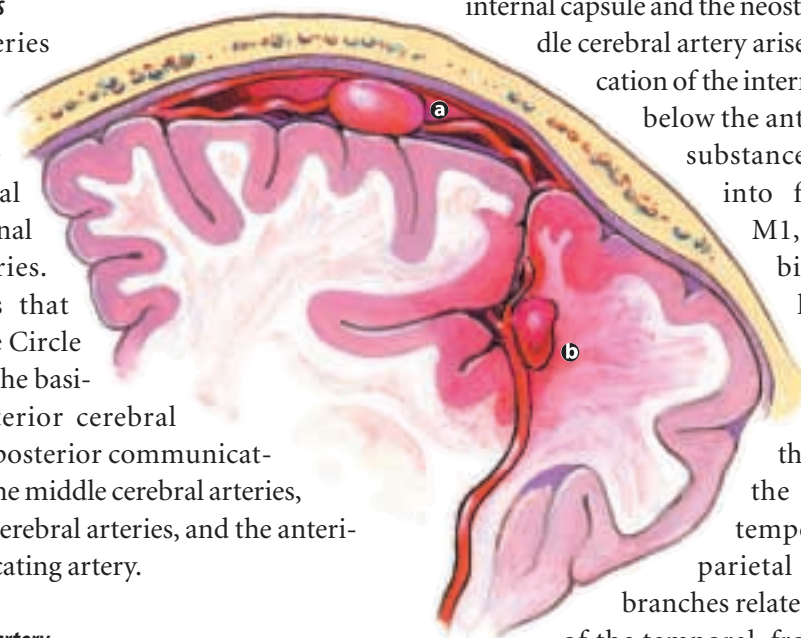
As the middle cerebral artery passes through the lateral sulcus, it gives off a series of branches (lenticulostriate arteries) that serve most of the internal capsule and the neostriatum. The middle cerebral artery arises from the bifurcation of the internal carotid artery, below the anterior perforated substance, and is divided into four segments:<sup>6</sup>

M1, from the carotid bifurcation to the limen insulae; M2, all branches related to the insula from the limen insulae to the opercula of the temporal, frontal, or parietal lobes; M3, all branches related to the opercula of the temporal, frontal, or parietal lobes; and M4, the cortical branches of the middle cerebral artery after exiting the Sylvian fissure.

Only the M1 segment is related to the mesial temporal lobe. Because of differences in topographical anatomy, the M1 segment can be divided into a proximal and a distal half. The proximal half of the M1 segment is related superiorly to the anterior perforated substance, posteriorly to the semilunar gyrus and temporal amygdala, and inferiorly to the entorhinal area of the uncus.

### Anterior cerebral artery

The anterior cerebral artery continues antero-medially and enters the superior longitudinal



**FIGURE 1**

A subarachnoid hemorrhage due to aneurysm rupture.

- Ⓐ Subarachnoid hemorrhage
- Ⓑ Intracerebral hemorrhage

fissure separating the right and left cerebral hemispheres. Soon after entering the superior longitudinal fissure, the two anterior cerebral arteries come together to form a very small anterior communicating artery. The anterior cerebral arteries continue anteriorly and follow the superior surface of the corpus callosum. The anterior cerebral artery provides, therefore, most of the blood supply for the medial surfaces of the frontal and parietal lobes.

## FIGURE 2

### Anatomy of the scalp

#### Posterior communicating artery

The posterior communicating artery arises from the posteromedial or posterolateral wall of the supraclinoid segment of the internal

#### Anterior choroidal artery

In most cases, the anterior choroidal artery arises distal to the posterior communicating artery from the posterolateral wall of the internal carotid artery.<sup>7</sup> Initially, it runs posteriorly, superiorly, and medially behind the internal carotid artery in the carotid cistern, medial to the anteromedial surface of the uncus to reach the optic tract superolateral to the posterior communicating artery. At this point, it diverges from the posterior communicating artery and runs posteriorly, superiorly, and laterally under the optic tract to enter the crural cistern between the superior part of the posteromedial surface of the uncus and the crus cerebri. After passing the posterior edge of the intralimbic gyrus, it enters the temporal horn of the lateral ventricle. The anterior choroidal artery supplies blood to the central portion of the internal capsule and the globus pallidus.

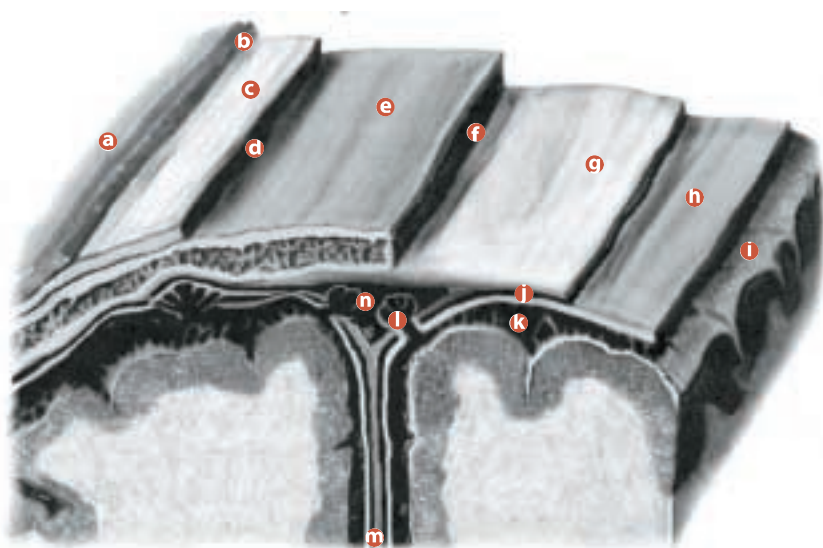
#### Posterior cerebral artery

The posterior cerebral arteries arise as the terminal branches of the basilar artery in the interpeduncular cistern and are divided into four segments.<sup>8</sup> P1 extends from the basilar bifurcation to the posterior communicating artery. P2A extends from the posterior communicating artery to the posterior edge of the crus cerebri. P2P extends from the posterior edge of the crus cerebri to the posterior margin of the midbrain. P3 begins at the posterior midbrain, runs within the quadrigeminal cistern, and ends at the anterior limit of the calcarine fissure. P4 is the cortical segment of the posterior cerebral artery. The posterior cerebral arteries serve the medial portions of the occipital lobe, some of the lateral occipital lobe, as well as the inferior portions of the temporal lobe, including the inferior temporal gyrus and parahippocampal gyrus.

#### Pterional approach for aneurysm clipping

##### Scalp incision/flap

All aneurysms of the Circle of Willis and the upper basilar artery can be approached through a frontotemporal, sphenoidal approach, or the



- a Skin
- b Subcutaneous tissue
- c Galea
- d Areolar tissue
- e Periosteum
- f Bone
- g Dura mater
- h Arachnoid mater
- i Pia mater
- j Subdural space
- k Subarachnoid space
- l Arachnoid villi
- m Falx cerebri
- n Superior sagittal sinus

carotid artery<sup>5</sup> and runs posteromedially between the tuber cinereum and the sella turcica and the oculomotor nerve. It continues close to the overlying dura of the posterior clinoid process before piercing the Lilliequist membrane of the interpeduncular cistern where it joins the posterior cerebral artery. Along the short length of the posterior communicating arteries, small branches supply blood to the overlying hypothalamus.

The posterior communicating artery joins the anterior and posterior circulatory routes. The sizes of posterior communicating arteries vary, being quite large in some individuals and quite small in others.

pterional approach promoted by Yasargil.<sup>9</sup> Its advantages are: maximal surface exposure, expendable wide bone removal from the cranial base, wide arachnoid and basal cistern dissection, and minimal brain retraction. The patient lies supine, with the head elevated, turned 45° away, extended 15°, and secured to a 3- or 4-pin head rest.

The incision is made behind and parallel to the hairline, extending from midline to the zygoma just anterior to the tragus. A #20 blade is used to avoid the ascending frontotemporal branch of the facial nerve and the superficial temporal artery. Raney clips are applied to the scalp edges to provide hemostasis. Using electrocautery, the scalp flap is reflected forward with the periosteum, which is separated from the superior temporal line, and retracted with scalp hooks or a self-retaining retractor.

The temporal fascia is separated into an outer layer, attached to the lateral zygoma surface of the temporal bone, and a deeper layer, attached to the medial zygomatic border. The fascia is opened and split near the frontozygomatic process. The outer fascial layer is reflected forward toward the orbit and forms a sleeve to protect the nerve to the frontalis muscle. The inner fascial layer is reflected along with the bulk of the temporalis muscle inferior-posteriorly toward the ear and is retracted with scalp hooks. An alternative approach is to reflect the temporalis muscle forward. This exposes the bony surface of the lateral orbital ridge and temporal fossa.

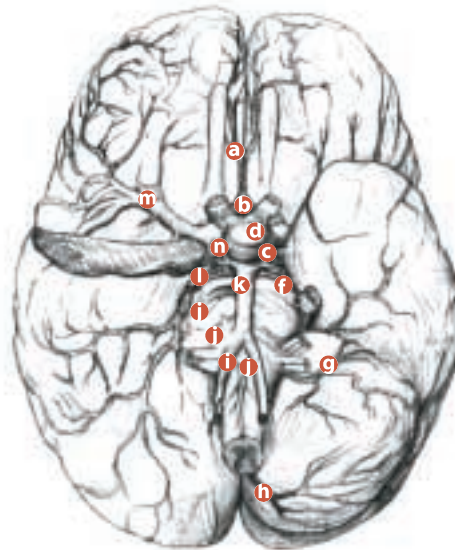
After the surgeon is satisfied with the margins of the flap, an X-ray detectable sponge is rolled lengthwise and placed under the flap that is secured with scalp hooks. This maneuver ensures that the vessels in the scalp flap are not occluded, reducing the chance for ischemic necrosis of the flap.

### **Bone flap creation**

The first and most important burr hole is drilled just behind the zygomatic process of the frontal bone so the cosmesis is protected by preserving the orbital and temporal bony ridges. Exposure of the dura along the floor of the anterior fossa

is accomplished utilizing a high-speed drill, a Craniotome, or a Hudson brace fitted with a McKenzie perforator. If the surgeon chooses to do so, three to four additional burr holes are drilled along the circumference of the exposure frontally and temporally. A free bone flap is raised using a high-speed drill fitted with a footplate on the end of the drill cutter to protect the underlying dura and brain surfaces.

The flap should be big enough to expose the anterior and middle fossae separated by the greater wing of the sphenoid bone as it merges laterally with the great wing of the pterion. The bone flap is dissected from the dura mater using an Adson periosteal elevator, taking care not to



**FIGURE 3**

### Cerebral arterial system

- Ⓐ Anterior cerebral artery
- Ⓑ Anterior communicating cerebral artery
- Ⓒ Circle of Willis
- Ⓓ Pituitary gland
- Ⓔ Superior cerebellar arteries
- Ⓕ Anterior inferior cerebellar arteries (AICAs)
- Ⓖ Posterior inferior cerebellar arteries (PICAs)
- Ⓗ Vertebral artery
- Ⓘ Pontine branches
- Ⓝ Basilar artery
- Ⓚ Posterior cerebral artery
- Ⓛ Middle cerebral artery
- Ⓜ Posterior communicating artery

tear the dura from the underside of the flap. Stop any bone bleeding by applying bone wax to the cut edges. The lesser wing of the sphenoid bone is removed with a high-speed drill and rongeurs after careful epidural dissection, exposing the dural reflection of the superior orbital fissure. The middle meningeal artery is coagulated with bipolar cautery and transected.

Bony removal of the lateral sphenoid wing and orbital plate gives access to the Sylvian fissure and basal cisterns with minimal retraction of the frontal lobe and temporal lobe. The dura from the frontal to temporal base is opened in a semilunar fashion using a #11 blade and Metzenbaum scissors, exposing the Sylvian

region. The dura is then sutured to the exposed temporalis muscle using 4-0 Neurolon suture. Once the opening of the dura is complete, the microscope, which is enclosed in a sterile drape, is brought into the field.

#### Dissection of the cisterns

Retraction is accomplished with a self-retaining cable system attached to the head holder. Retractor blades are bent and the cables are adjusted to lay flat to project a low unencumbered surface profile. Nonadherent gauze is placed on the brain's surface underneath the retractor blades to disperse their force onto the gauze and reduce the potential for brain injury.

section of the arachnoidal attachments. Lifting the arachnoid with a micro-hook and cutting it with a #11 blade works well.

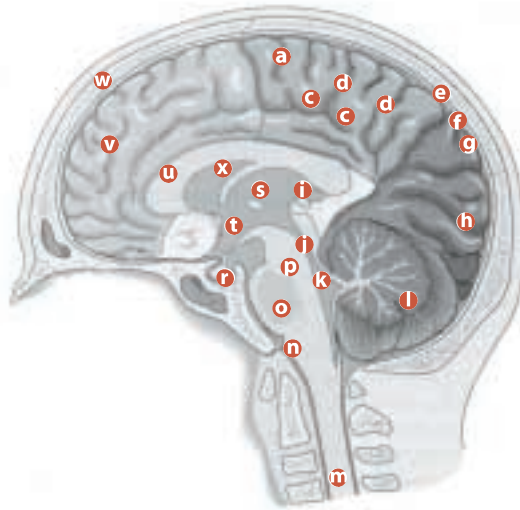
The internal carotid artery (ICA) is isolated at the dural base just lateral to the optic nerve. The ICA can be controlled with a temporary clip, if necessary. Control of the ICA should be the first strategic maneuver. This may require dissecting the dura of the anterior clinoid process and gradually drilling the clinoid away to expose the rostral fibrous ring of the carotid. Sometimes the fissure must be opened to gain access to the anterior superior compartment of the cavernous sinus (CVS). The membrane of Lilliequist (arachnoid sheath from the mammillary bodies to the posterior clinoids) is opened sharply to release CSF and gain access to the interpeduncular and prepontine cisterns en route to the basilar artery.

When dissecting the carotid cistern, the small arterioles supplying the optic nerve and chiasm should be preserved. The posterior communicating artery (PCA) is seen coursing posterolaterally from the lateral carotid wall close to the tentorial edge. The oculomotor cranial nerve (CN III) is seen lateral to the PCA as it enters the superior lateral wall of the CVS. Multiple arterial perforating branches course rostrally from the PCA. It is not necessary to disturb these structures unless approaching the basilar artery. Aneurysms arising at the ICA-PCA junction are most common (60%).<sup>10</sup> They may locally compromise the third cranial nerve. These aneurysms usually project posterolaterally.

The neck is dissected circumferentially and must be separated from the PCA and the anterior choroidal artery. When a micro dissecting instrument can be passed between the aneurysmal neck and the adjacent branches, the neck can be clipped without disturbing the fundus or dome. The anterior choroidal artery (AchA) arises from the ICA just rostral to the PCA. It is protected as dissection of the ICA is continued rostrally. Retractor blades are readjusted to distract the open cisterns and expose the rostral ICA at its bifurcation. The arachnoidal shelf at the medial Sylvian fissure is opened sharply,

**FIGURE 4**

#### Structures of the brain



- a Parietal lobe
- b Gyri
- c Sulci
- d Dura mater
- e Arachnoid
- f Pia mater
- g Occipital lobe
- h Third ventricle
- i Cerebral aqueduct
- j Fourth ventricle
- k Cerebellum
- l Spinal cord
- m Medulla oblongata
- n Pons
- o Midbrain
- p Pituitary gland
- q Thalamus
- r Hypothalamus
- s Corpus callosum
- t Frontal lobe
- u Skull
- v Lateral ventricle
- w

The frontal lobe is gently lifted from the orbital plate until the optic nerve is visualized. The ipsilateral optic nerve identifies the chiasmatic cistern medially and the carotid cistern laterally. The arachnoid, which surrounds the cisterns, is opened by sharp dissection using a #11 blade and microscissors to release cerebrospinal fluid (CSF) and ease retraction. Malleable, fine-tip adjustable suction is used to evacuate CSF and gently disperse fine vessels and arachnoidal trabeculae. The cistern furthest from the aneurysm is dissected first to gain exposure and avoid disturbing the aneurysm prematurely. Sharp dissection with a knife or scissors is safer and less traumatic than blunt dis-

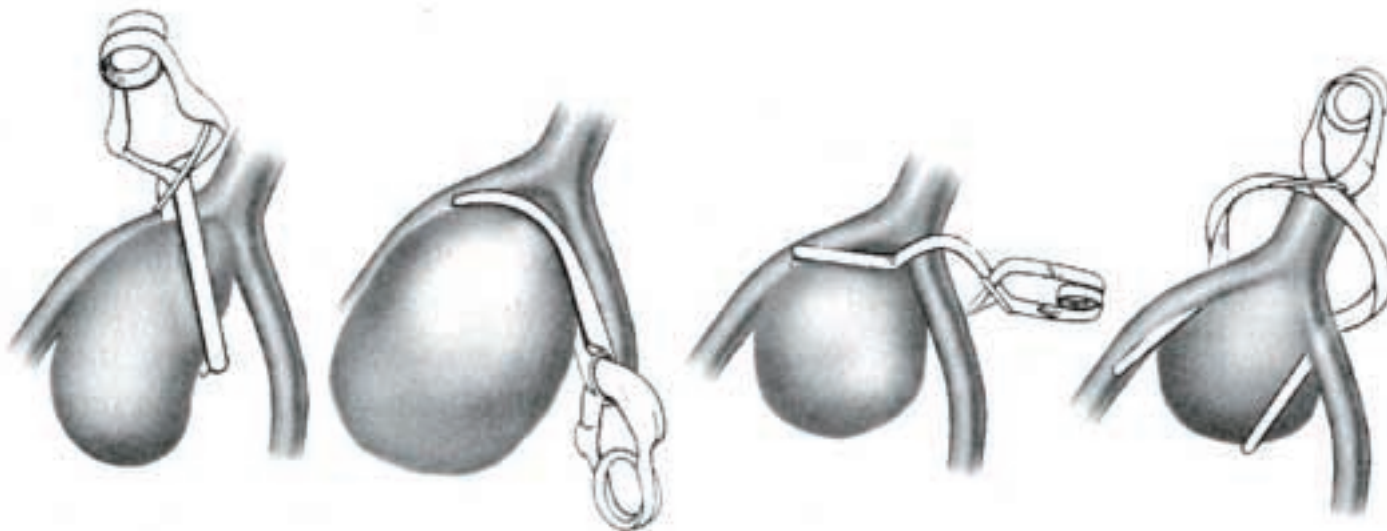
facilitating a view of the proximal anterior cerebral (A1) and the proximal middle cerebral arteries (M1).

#### **Lesion exposure**

Sharp, wide dissection in the natural anatomical planes of the sulci, fissures, and cisterns allows retraction of overlying brain to expose the aneurysm. Anatomical landmarks, such as dural reflections, major arachnoidal planes, cranial nerves, and arterial trunks, provide appropriate orientation. Limited resection of brain tissue may produce less injury to normal overlying brain tissue than retraction for treatment of aneurysms in selected locations.

A wiggle motion while applying the jaws of the clip, like a dissector upon application, helps prevent tears of the neck. After closing the clip, the tips are inspected to ensure that complete closure and inadvertent clipping of perforating vessels. If the surgeon is not satisfied, the clip may be removed and adjusted, guaranteeing optimal placement. In the event of migration or slippage, a booster clip or double clip may be applied. If a temporary clip was applied, it is removed at this time.

To confirm occlusion of the aneurysm, a 30-gauge needle mounted on a tuberculin syringe is inserted into the dome. If any gross blood is appreciated, the clip may have to be repositi-



#### **Aneurysm clip application**

After complete circumferential dissection of the aneurysm neck with a spatula-type microdissector, a clip is chosen, mounted on an applier, and inserted for trial on the neck to ensure the best fit. Once the surgeon is completely satisfied that the clip will occlude the neck, the field is prepared for permanent clip application. The brain is irrigated to prevent instruments from sticking to the tissues. If the surgeon chooses, a temporary clip is placed on the parent artery. This stops the blood flow inside the aneurysm, allowing manipulation of the neck while decreasing the risk of rupture. The permanent clip is then inserted onto the neck of the aneurysm (Figure 5).

tioned. Gelfoam cut into 3 x 3 inch pieces, soaked in Papaverine, is placed around the clip and parent vessels to help decrease the chance of vasospasm. After the surgeon is completely satisfied with the placement of the clip, the wound is irrigated with saline containing Bacitracin antibiotic, the retractors are removed, and the microscope is taken out of the field.

#### **Closure**

The dural edges are approximated using a running locking suture of 4-0 Neurolon on a TF needle. Braided suture is preferred because it swells and plugs the holes caused by the needle in the dura, reducing the potential for a CSF leak.

**FIGURE 5**

Examples of cerebral aneurysms with various types of clips.



A piece of Gelfoam is cut into the shape of the bone flap and placed on top of the dura. The bone flap is replaced and secured using titanium mini-plates and screws. Any large bony defects may be filled with a hydroxyapatite cement to ensure a good cosmetic result.

The Raney clips are removed, and the temporalis muscle is approximated using 0 Vicryl on a CT-2 needle in an interrupted fashion. Interrupted sutures of 3-0 Vicryl on a X-1 needle is used to approximate the galea and subcutaneous tissue. The skin is closed by a running stitch of 5-0 plain gut suture, eliminating the need to remove a nonabsorbable suture or staples post-operatively. Skin adhesive, adhesive strips, and 1x3-inch bandages are applied as a final dressing. The pins are removed from the head, and the patient is transferred to the gurney. The head is wrapped turban style with gauze and secured with tape.

### Conclusion

A cerebral aneurysm is a common cerebrovascular disorder caused by a weakness in the wall of a cerebral artery. The disorder may exist as a result of congenital defects or from preexisting conditions such as hypertensive vascular disease and atherosclerosis, or from head trauma. Microsurgical clipping remains the cornerstone of therapy for intracranial aneurysms. The aim of modern aneurysm surgery is the total elimination of the aneurysm sac with complete preservation of the surrounding normal arteries. The aneurysm neck is clipped with a titanium or other non-ferromagnetic clip. By using a combination of patient positioning, medications administered by the anesthesia team, and release of the patient's own cerebrospinal fluid, the neurosurgical team is able to safely manipulate and dissect the structures surrounding the cerebral aneurysm and clip it successfully.

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### About the author

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