15 Surgery of Middle Cerebral Artery (MCA) Aneurysm

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15.1 Sign and Symptoms

Middle cerebral artery (MCA) aneurysm is one of the most popular cerebral aneurysm. The incidence of ruptured MCA aneurysm is about 21% (which is the third incident). The first incident is anterior communicating artery (AcomA) aneurysm about 40%, and the second is internal carotid artery (ICA) aneurysm about 30% [1]. The most popular portion of MCA aneurysm is M1–M2 bifurcation, and the incidence is 80–85%. MCA aneurysms occasionally arise at the origin of the anterior temporal branch or at the origin of the lenticulostriate arteries. In the rare event that an MCA aneurysm occurs distally in the sylvian fissure, it may become a giant, heavily thrombosed aneurysm so-called giant serpentine aneurysm (Fig. 15.1) [2]. However, small aneurysm that arises far distally in the MCA is usually mycotic. MCA aneurysm can be bilateral and in patient with mirror aneurysms is sometimes difficult to determine which one has bled.

In the report according to the anatomical relationship of ruptured and unruptured MCA aneurysm, the factors of rupture by multivariate analysis were first perpendicular to the height/neck diameter, second flow angle, and third M1–M2 angle. MCA aneurysm is located relative superficial in sylvian fissure. It is relatively easy to find MCA aneurysm than other aneurysms. However, the neck dome ratio is larger than other aneurysms. Branches of the MCA may emerge from the sac or neck of MCA aneurysms, making their treatment quite complicated. Therefore, surgical clipping is preferable to coil embolization in treating MCA aneurysm even now. So, we neurosurgeons must learn harder about the feature, specificity, the method of simulation, intraoperative monitoring, and surgical technique of MCA aneurysm.

Overall patient outcomes are mostly determined by preoperative state, and the surgical-related morbidity is actually low. The preoperative poor Hunt-Hess grade is a strong indication endovascular coiling, except if they have a big temporal hematoma that needs to be evacuated. Also, some patient may benefit from hemicraniectomy. Open surgery may provide the chance to do reconstruction clipping of the majority MCA aneurysms; additional to that at the same time, surgeon may be able to do thrombectomy, bypass, or even entrapment of the aneurysm.

On the other hand, about unruptured MCA aneurysm, the number of registered unruptured MCA aneurysm has the most number in record, and the rate is 36%; however, rupture rate is half of AcomA and ICA aneurysm according to UCAS Japan [3]. In our experience, there is no permanent neurological deficit of 78 cases of unruptured MCA aneurysms [4].

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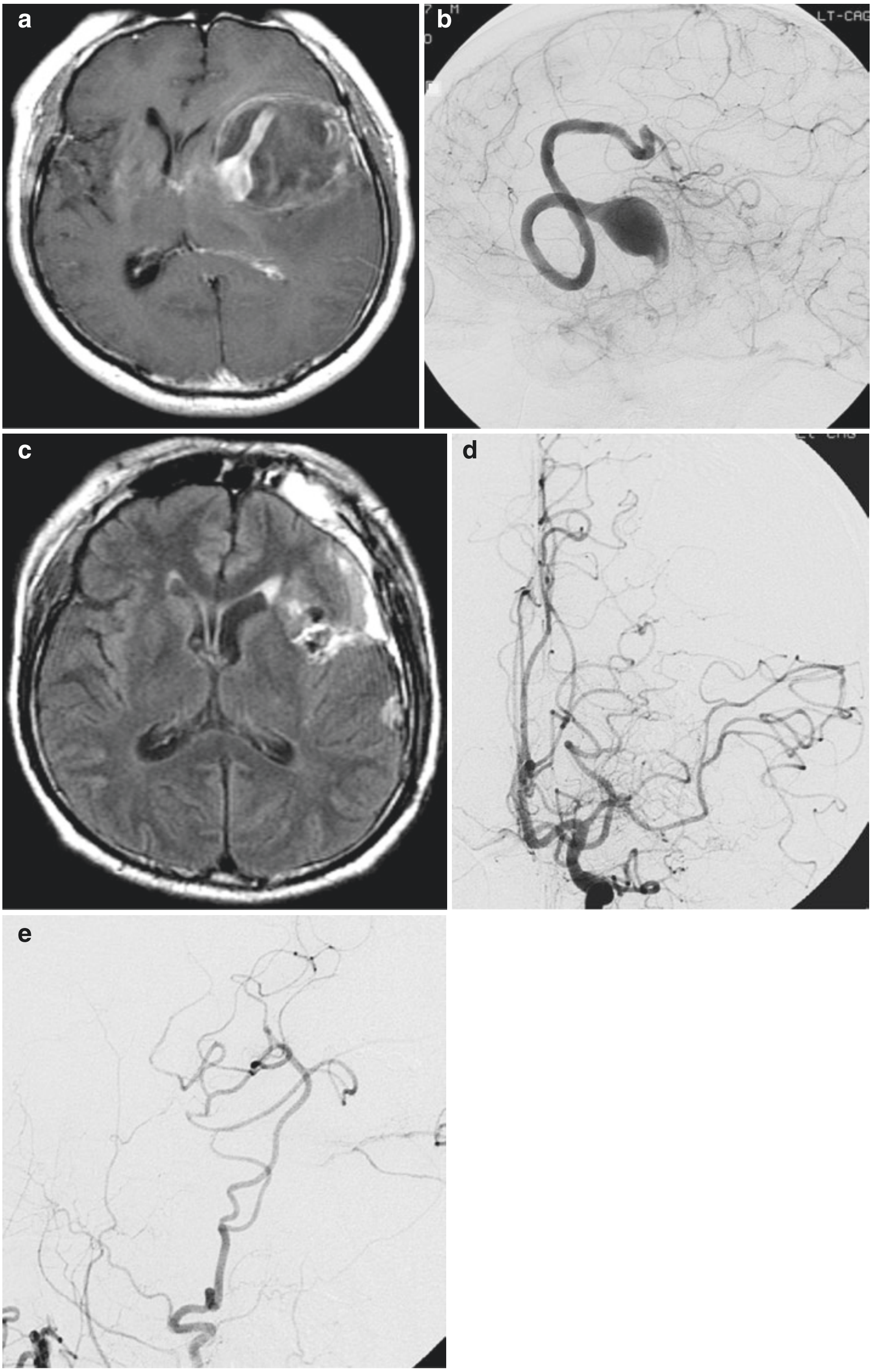

Fig. 15.1 Giant serpentine aneurysm. (**a**) Gd-enhanced MRI T1-wighted image revealed partial thrombosed giant aneurysm in left hemisphere. (**b**) Digital subtraction angiography(DSA) showed giant serpentine aneurysm in capillary phase. (**c**) Postoperative FLAIR image demonstrated disappearance of mass effect. (**d**) AP view of left internal carotid angiography showed no aneurysm. (**e**) Lateral view of left external carotid angiography showed middle cerebral artery from superficial temporal artery

15.2 Investigation and Imaging

Recently, the quality of computed tomography angiography (CTA) was improving. The first diagnostic imaging modality after subarachnoid hemorrhage (SAH) is CT scan, second diagnostic imaging modality about information of ruptured aneurysm is not digital subtraction angiography (DSA) but CTA now in almost institutes in Japan. Actually, we can operate surgical clipping only information by CTA without DSA. CTA have the information not only of the artery but also of the vein and bone. If CTA cannot reveal the ruptured aneurysm, DSA is considered for further investigation. Magnetic resonance image (MRI) can show the additional information about aneurysm of intra-aneurysmal thrombosis or perianeurysmal edema.

15.3 Preoperative Preparation and Simulation

Important preoperative informations by imaging are the following [5]: first the length of M1 segment, second the curvature of M1 segment, third the direction of aneurysm, fourth the location of rupture point, fifth the length between aneurysm and sylvian vein and/or skull base, sixth the relationship between aneurysm and sphenoidal ridge, and seventh the shape and the number of superficial sylvian vein. The preoperative simulation by 3D CTA is more useful because of the information not only of the artery but also of the vein and skull bone. We can decide the dissection point of sylvian fissure and the length between aneurysm and sylvian vein or skull base preoperatively.

In few straightforward cases, no need to routinely expose the entire M1 prior to aneurysm dissection. To translate the imaging information to the surgical planning is very important. The surgeon needs to address few thinking such as: how does he want to start the sylvian fissure dissection? How he should avoid premature rupture either by his retractor placement of his surgical maneuver? And where approximately the aneurysm located and where he will prepare for the proximal control?

On the anteroposterior (AP) view of the CTA, DSA, and MRA, it is important to evaluate the curvatures and length of the M1 to establish proximal control. Namely, when the M1 is straight and long, it is easy to expose the proximal M1 to the aneurysm by distal transsylvian approach. Regardless of the length of M1, if the M1 can curve downward toward the skull base, it is easier to just expose the M1 segment to the aneurysm by distal transsylvian approach. If the segment of M1 is long, we can capture more easily proximal M1 to the aneurysm by distal transsylvian approach, because direct dissection of sylvian fissure reaches the proximal M1 segment. However, aneurysms may be located superficially and within the temporal lobe. It is more dangerous to dissect the superficial sylvian fissure near the skull base, and distal and deep sylvian fissure are safer portion to dissect. When the M1 can be short and curve upward toward the anterior perforated substance and limen insula, it is difficult to expose the M1 segment only by distal transsylvian approach because M1 segment may be hidden by the anterior perforated substance and limen insula.

15.4 Steps of the Surgery

15.4.1 Position (Fig. 15.2)

The patient is placed in a supine position with the head maintained at 20–40° rotation opposite side of the craniotomy. The backboard was tilted up about 20°. With extension of the head and neck, the frontal lobe falls away from the floor of the frontal cranial fossa slightly.

15.4.2 Skin Incision (Fig. 15.3)

The hair is shaved partially even in the case of SAH, and cork screw electrodes for transcranial motor-evoked potential (MEP) are placed in both

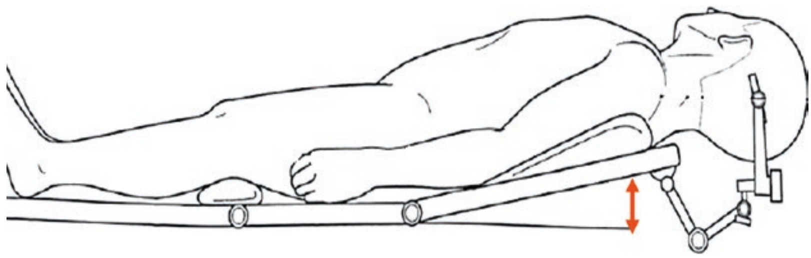

Fig. 15.2 Positioning. The patient is placed in a supine position with the head maintained at 20–40° rotation opposite side of the craniotomy. The back plate was tilted up about 20° (*arrow*). With extension of the head and neck, the frontal lobe falls away from the floor of the frontal cranial fossa slightly

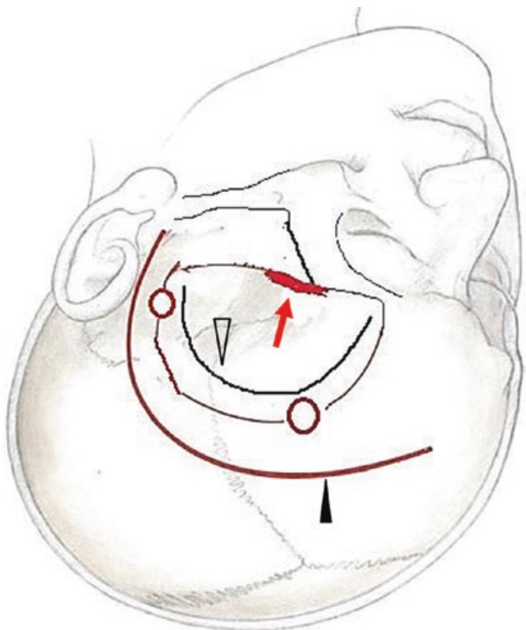

Fig. 15.3 Skin incision, craniotomy incision, and dural incision. Skin incision (*arrow head*) is from the front of ear to midline of forehead. With two burr hole, cosmetic osteotomy is performed by electric craniotomy. The pterion is cut by chisel and hammer with minimum bone defect (*arrow*). Superficial temporal artery (STA) should be preserved during skin incision. Semicircular dural incision (*open arrow*)

sides of the head (Fig. 15.4). Skin incision is from the front of ear to midline of forehead. Superficial temporal artery (STA) should be preserved during skin incision, because STA will be necessary in case of large or giant MCA aneurysm or troublesome cases.

15.4.3 Craniotomy (Fig. 15.3)

With two burr holes, cosmetic osteotomy is performed by electric craniotomy. The pterion is cut by chisel and hammer with minimum bone defect as much as possible. After removing the bone flap, the outer sphenoid wing is removed down to the meningo-orbital band. The outer sphenoid wing is removed with a rongeur. However, if a patient has a large or giant aneurysm or has a tight brain following SAH, the surgeon may also perform wide osteotomy, which entirely removes the pterion from the surgical field and thus increases the workspace. In the case of severe brain swelling due to SAH and sylvian hematoma, external decompression is performed.

15.4.4 Dural Incision (Fig. 15.3)

The dura mater is tacked to the bone margins. After the semicircular dural incision, dura is opened and reflected over the sphenoid wing and temporal muscle to prevent blood from running into the operative field.

15.4.5 Dissection of Sylvian Fissure

To expose an MCA aneurysm, the surgeon must open the sylvian fissure widely. First, we start by splitting the sylvian fissure from distal side, beginning approximately 4–5 cm posterior to the

Fig. 15.4 Transcranial motor-evoked potential. Hair is shaved partially even in the case of SAH, and cork screw electrodes for transcranial motor-evoked potential (MEP) are placed in both sides of the head

pterion. We cut the arachnoid membrane with proper tension using fine tip forceps and microscissors. Usually the arachnoid is opened between the large sylvian veins. We can avoid cutting the vein and bleeding by only cutting the arachnoid membrane above the veins. We can preserve any small veins by only cutting the arachnoid membrane even in the case of SAH. The surgeon can begin gradually by separating the frontal and temporal lobes with microforceps and microscissors, achieving gentle retraction with the suction tip and, occasionally, a self-retaining retractor. The proximal aspect of the fissure is opened from the inside out and the outside in to avoid damage to the interdigitated frontal and temporal operculae. This technique is useful principle for neurosurgeon because it is difficult for the surgeon to open the adhesive opercula. Therefore, it is important for us to reach the deep sylvian fissure of insula with perivascular cistern and less adherent area.

From dissecting the distal sylvian fissure, M3 segment is easily caught and confirmed and following M3 segment reached M2 segment. This visible M2 segment in front of you is expected to be superior or inferior trunk by simulating preoperatively; however, especially in SAH case, its confirmation is sometimes difficult because of subarachnoid clot. It is important to irrigate the subarachnoid clot enough, and we can confirm this visible M2 segment is superior or inferior trunk by careful observation. For patients who undergo acute surgery for large temporal hematoma, we usually make a small incision in the middle temporal gyrus, decompressing the hematoma partially. The surgeon can facilitate brain relaxation by further aspirating cerebrospinal fluid from the ventricle drainage. The surgeon separates the frontal and temporal lobes, usually, the arachnoid membrane is opened superomedial to the superficial middle cerebral vein, and the opening is extended to the pterion.

15.4.6 Selection of Proximal and Distal Approach

A principle of aneurysm surgery is capturing the proximal artery to the aneurysm. Whichever approach you select, you must catch the proximal artery to the aneurysm. In some MCA aneurysms, the widely careless dissection of sylvian fissure to reach the internal carotid artery is dangerous, because the aneurysm is located near beneath the sylvian vein which is very superficially than we expected. Thus, from distal M2 to proximal, M1 approach is safer to capture the proximal M1 segment to the aneurysm. We should decide which approach is better preoperatively, proximal or distal approach, for safer clipping of the aneurysms. Therefore, we should simulate preoperatively using CTA, MRA, and/or DSA.

15.4.7 Proximal Approach (From ICA to M1 Approach)

To expose aneurysms located very proximally to so-called M1 aneurysm (i.e., those found at the origin of the anterior temporal artery or lenticulostriate vessels), the fissure must be opened from a proximal IC to M1 direction. The surgeon first opens the lateral sylvian fissure to M1–M2 junction, after that point, stops dissecting from distal side and moves proximal ICA, opens the carotid cistern, and follows the carotid artery toward the bifurcation and further laterally, following the M1 segment. If we select distal approach especially in upward direction M1 aneurysm, we cannot capture proximal M1 safely prior to aneurysm. Even if the aneurysm ruptures during distal approach, proximal control is impossible. Therefore, we should dissect the carotid cistern right after confirming the MCA bifurcation. We should dissect from IC bifurcation to proximal M1 segment to apply temporary clip to proximal M1. While dissecting the MCA and its branches, the surgeon should stay along the anterior and anterolateral surface of the vessel because the lenticulostriate perforators arise from the posterior and medial surfaces.

In case 1 (Fig. 15.5), we operated by proximal approach for M1 aneurysm.

15.4.8 Distal Approach (From M2 to M1 Approach)

To obtain proximal control of the M1 segment, open the sylvian fissure proximally before actually exposing the aneurysm. In most patients with small or large MCA aneurysms, the sylvian fissure

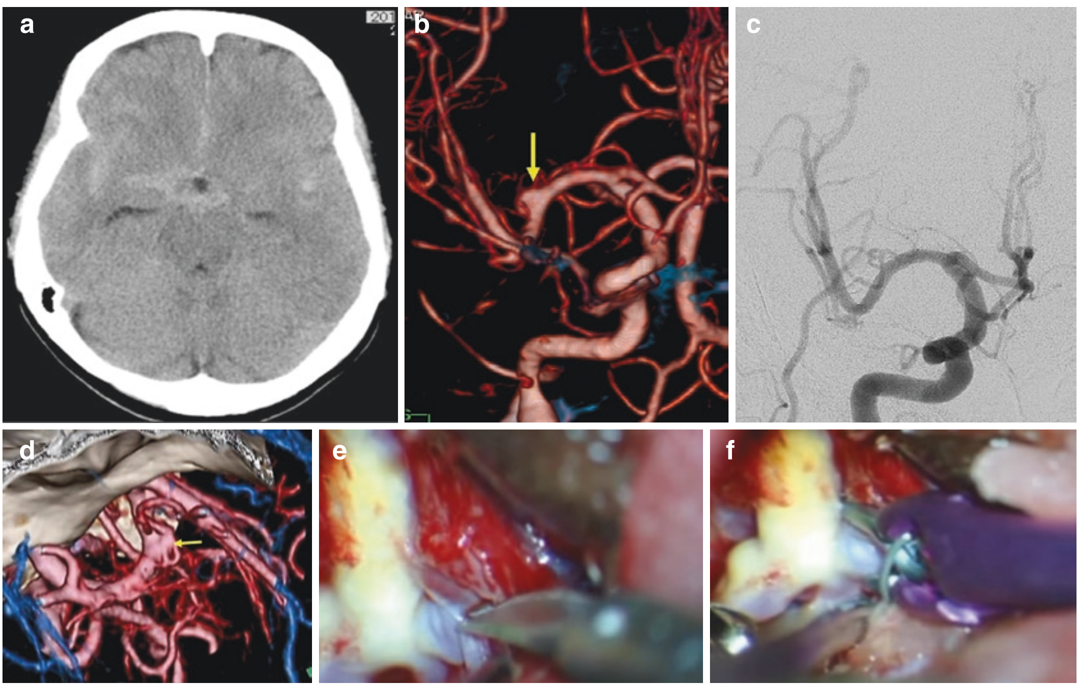

Fig. 15.5 Case1. M1 aneurysm 67-year-old female with subarachnoid hemorrhage. (**a**) CT scan revealed SAH with Fisher group 3. (**b**) CTA on admission showed ruptured M1 aneurysm (*arrow*), which is located at the origin of the lenticulostriate artery. (**c**) Postoperative DSA showed disappearance of aneurysm. (**d**) Simulation image by preoperative CTA showed anatomical relationship between the artery and skull base. You can understand the relationship of aneurysm and lenticulostriate artery. (**e**) Dissection between aneurysm and lenticulostriate artery by microscissors because of severe adhesion. (**f**) After appliance the temporary clip to proximal M1, neck clipping by mini clip is applied

can be adequately opened from a lateral to medial direction starting in its middle portion, even though proximal control is not achieved. In such cases, if the aneurysm will be exposed partially during opening of the sylvian fissure, the surgeon should move further proximally to obtain control of the proximal M1 segment. In the standard trans-sylvian approach, it is important to remember that the aneurysm usually is located more superficially. Regardless of the length of M1, if the M1 can curve downward toward the skull base, it is easier to just expose the M1 segment to the aneurysm by distal transsylvian approach. In these cases, if we select the conventional transsylvian approach, we may seize the aneurysm before internal carotid artery. So we need not see the internal carotid artery. In the case of long M1 segment, the aneurysm is usually within the temporal lobe. We can catch the proximal M1 by dissection of frontal side of a sylvian fissure.

Distal MCA aneurysms can be approached through an opening of the lateral sylvian fissure. The surgeon usually begins such opening in the middle portion of the fissure and proceeds distally. It is easy to mistake one of the deeper sulci for the sylvian fissure distally. To confirm that the sylvian fissure is actually being entered, the surgeon should trace one of the branches of the MCA proximally. The opening of the distal sylvian fissure must be done meticulously to avoid damaging adjacent areas of the brain, which have great functional importance. If severe intratemporal hemorrhage or brain swelling makes the opening of the fissure impossible, the surgeon can make an incision through the middle temporal gyrus and perfonn brain resection with a suction until the sylvian fissure is exposed.

In case 2 (Fig. 15.6), we operated by distal approach for usual MCA aneurysm.

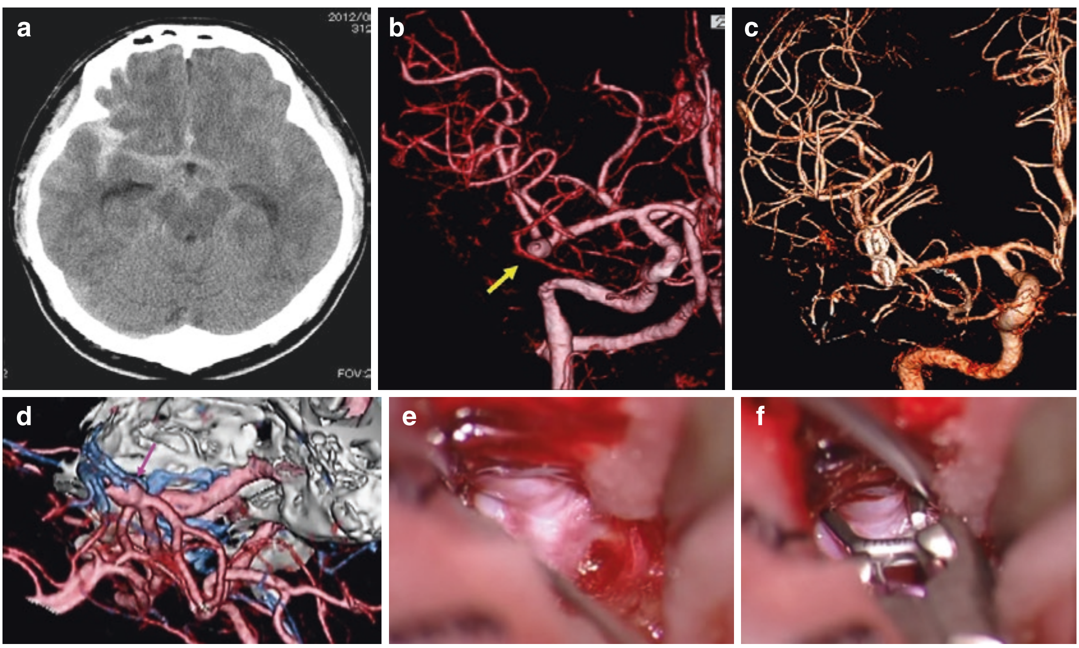

Fig. 15.6 Case 2. Ruptured MCA aneurysm with long and curved downward toward skull base M1, 36-year-old male. (**a**) CT scan revealed SAH with Fisher group 3. (**b**) CTA on admission showed ruptured MCA aneurysm (arrow). M1 segment curve downward toward the skull base. (**c**) Postoperative DSA showed disappearance of aneurysm. (**d**) Simulation image by preoperative CTA showed anatomical relationship of M1, M2, aneurysm, sylvian vein, and skull bone. You can understand the relationship of aneurysm and M1–M2 junction in operative field. (**e**) Dissection of aneurysmal neck by microdissector. (**f**) After appliance of the temporary clip to proximal M1, neck clipping by mini clip is applied

15.4.9 Dissection of the Aneurysm and Neck Clipping

After the proximal and distal vessels have been exposed, dissection of the aneurysm can begin. During this stage of the operation, we usually employ temporary clipping of the proximal vessel, with keeping normotension over 100 mmHg of systolic blood pressure, normothermia under 36.5 °C, and brain protective drugs. The aneurysm must be dissected in its neck, with no perforating vessels remaining adherent to the posterior surface of the aneurysm. It is sometimes useful to place a tentative clip across the dome of the aneurysm and then to dissect it from around the structure further before placing the final clip. MCA aneurysms often have a wide-based neck that involves 180° or more of the circumference of the bifurcation point. Optimal occlusion of such aneurysms requires the use of the application of multiple clips (Fig. 15.7). In some of these cases, it may also be necessary to use wrapping with some material to reinforce any unclipped areas of the neck. Perforators arising from the MCA must be handled with care. Most lenticulostriate vessels arise from the posteromedial surface of the M1 segment and enter the anterior perforated substance to supply the internal capsule and the basal ganglia.

Often, pan of the neck or dome is adherent to the vein and small artery. A fine micro dissector and microscissors are useful in the dissection from their vessels (Figs. 15.8 and 15.9). After the neck has been identified, selection and appliance of optimal clip help protect these vessels. Usually, multiple clips are needed for proper clipping of the MCA aneurysm.

15.4.10 Dural Closure

Primary tight dural closure by nylon suture with fibrin glue can prevent liquorrhea postoperatively.

15.5 Surgeon Plan to Handle the Complication

Many MCA aneurysms have a wide-based neck. Accordingly, placement of the clip may compromise the origin of one of these vessels, especially if the base of the aneurysm is partially calcified or atherosclerosis. A lenticulostriate artery originates from the deep side of the MCA distally along the M1 segment close to the bifurcation. This vessel may be occluded inadvertently by the tips of the aneurysm clip.

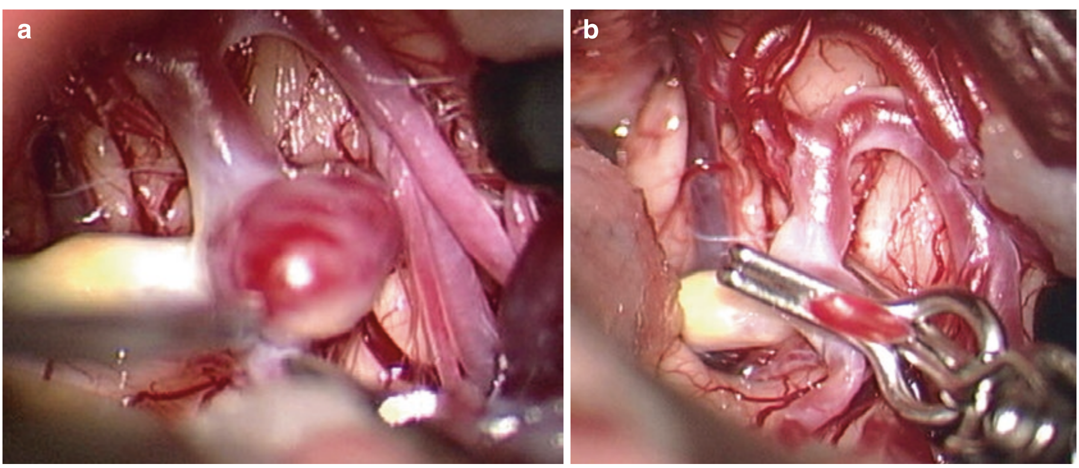

Fig. 15.7 Multiple clipping method for broad neck MCA aneurysm. (**a**) Broad neck MCA aneurysm. (**b**) Multiple clipping methods for MCA aneurysm using ring clip

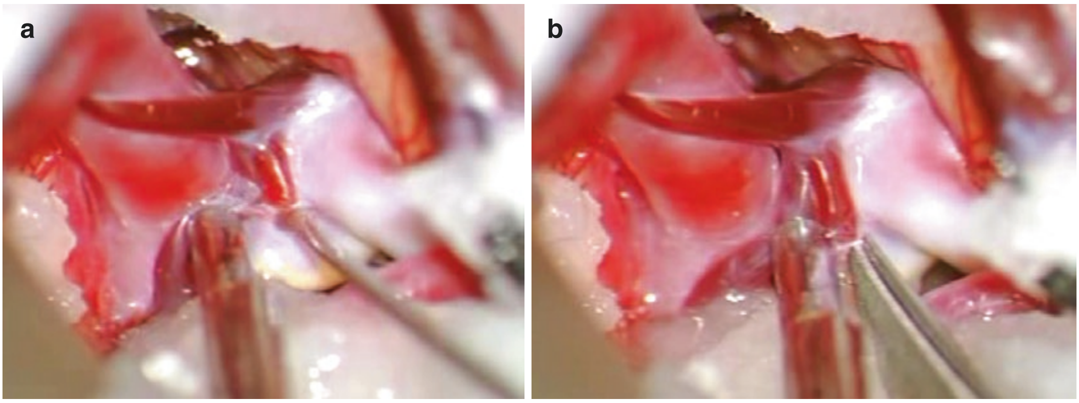

Fig. 15.8 Dissection between vein and aneurysm. (**a**) Dissection between vein and aneurysm by micro dissector. (**b**) Dissection between vein and aneurysm by microscissors

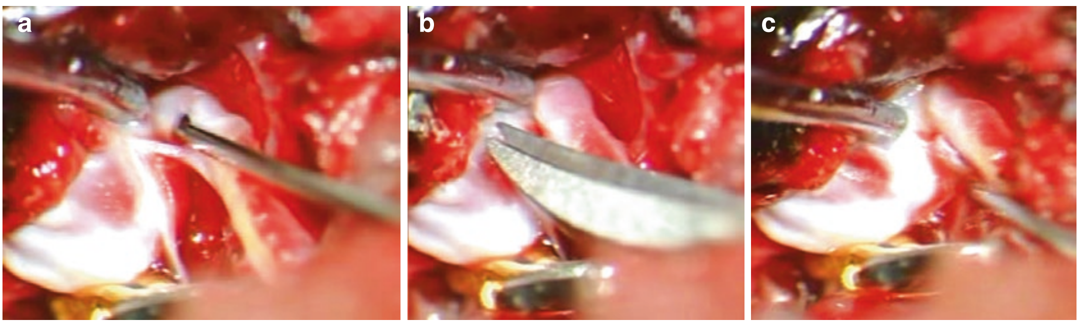

Fig. 15.9 Dissection between small artery and aneurysm. (**a**, **c**) Dissection between small artery and aneurysm by micro dissector. (**b**) Dissection between vein and aneurysm by microscissors

Thus, after the aneurysm clip is placed, it is important to visually inspect the tips of the aneurysm clip and to auscultate the M1 branches with a micro-Doppler probe. To inspect the all arteries around aneurysm, we must check them by using indocyanine green (ICG) video angiography. There are rare cases of postoperative small infarction of perforating area in spite of checking these modalities completely. So, MEP is the most useful intraoperative monitoring especially in M1 aneurysm in relation with lenticulostriate artery. If the wave of MEP reduced in its amplitude under 50% after neck clipping, we should release the clip and investigate all around aneurysm and find the obstructed lenticulostriate artery. MEP is very sensitive regarding with the damage of corticospinal tract, so we can trust MEP monitoring. If the patient has postoperative small infarction by MRI, he (she) is asymptomatic as long as MEP is normal.

It is important to reduce the pressure of parent artery and aneurysm using temporary arterial occlusion during the neck clipping of broad-based MCA aneurysm. In all cases, the brain must be protected during temporary arterial occlusion by brain protected drug, avoiding not only hyperthermia but also hypotension. The temporary occlusion time is usually less than 5 min per once. At the conclusion of the clipping process, papaverine is applied over the vessels to relax the mechanical spasm.

Preoperative three-dimensional CTA can enhance the surgeon’s ability to picture the anatomy of the aneurysm before surgery to plan the optimal clipping.

15.6 Expert Opinion/Suggestion to Avoid Complication

In patients with giant MCA aneurysms, the surgeon must often completely trap the MCA and its branches and empty the aneurysm before final clipping. However, even with this technique, it is impossible to achieve optimal clipping of some heavily thrombosed or calcified aneurysms. Such cases often require a bypass procedure. Options include the STA to MCA bypass, the saphenous vein graft, and radial artery graft bypass to the major branches of MCA, transposition of some MCA branches.

Large sylvian veins should be left intact and displaced laterally with the temporal lobe or medially with frontal lobe. We can preserve almost all sylvian vein by careful finding the anastomosis between sylvian veins. Extremely small bridging veins across the sylvian fissure call can be safely cauterized and divided; however, we should understand that careful dissection of small veins can lead us expert microsurgeon.

15.7 Things to Be Observed and Postoperative Care/Follow-Up

In case of SAH, the prevention and treatment of delayed cerebral ischemia (DCI) are essential. We use intraoperative irrigation by artificial cerebrospinal fluid (CSF) (Artcereb) and postoperatively statin, cilostazol for prevention of DCI. Especially in severe cases of MCA aneurysm with sylvian hematoma, external decompressive craniotomy is performed for better circulation of CSF to prevent the DCI.

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