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MCA ANEURYSMS: CLIP FIRST POLICY SINGLE INSTITUTIONAL EXPERIENCE

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Abbreviations

ABBREVIATIONS

BOT : Balloon occlusion test

CT : Computed tomography

CTA : CT angiography

DSA : Digital subtraction angiography

EC-IC : Extracranial-intracranial

GOS : Glasgow outcome score

ICA : Internal carotid artery

M1As **:** M1 segment aneurysm

MCA : Middle cerebral artery

MRI : Magnetic resonance imaging

mRS : Modified Rankin scale

SAH : Subarachnoid hemorrhage

STA : Superficial temporal artery

WFNS : World federation of neurosurgeons

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General introduction

Subarachnoid hemorrhage (SAH) from ruptured intracranial aneurysm accounts for 5% of all strokes [1]. The worldwide SAH incidence is 7.9 per 100 000 person-years [2]. In our country, the incidence of aneurysm accounts for about 17 cases per year in Marrakech [3], whereas in Rabat the incidence is 63 +/- 16 cases per year of which 27% are middle cerebral artery aneurysms [4].

Anterior and posterior communicating arteries followed by middle cerebral artery are the locations intracranial aneurysms most frequently found (Figure 1.1) [5]. Among the risk factors reported for aneurysm development we can find genetic predisposal like familial aneurysms, ADPKD and Marfan's disease, female gender, smoking, hypertension and old age. On a histopathological point of view, Both vascular remodeling and inflammation contribute significantly to the formation of intracranial aneurysms [6]. The wall shear stress at the branching points of intracranial arteries is one of the potential hemodynamic factors that have a part in the pathogenesis process of intracranial aneurysms [7], [8]. Examples of predisposing factors for aneurysm rupture: demographic profile, hypertension, age >70 years, aneurysm size >7 mm, location of aneurysm (anterior circulation), and history of SAH [9].

Management strategies for intracranial aneurysms have changed dramatically over the past decades. Both with the publication of the International Subarachnoid Aneurysm Trial (ISAT) and the improvement of endovascular techniques, centers has been increasingly adopting endovascular treatment as the primary procedure [10], [11]. Unfortunately, ISAT did not focus on patients with middle cerebral artery aneurysms and optimal treatment modalities are still controversial. However, microsurgical treatment remains well established as the preferred strategy for definitive obliteration of MCA aneurysms.

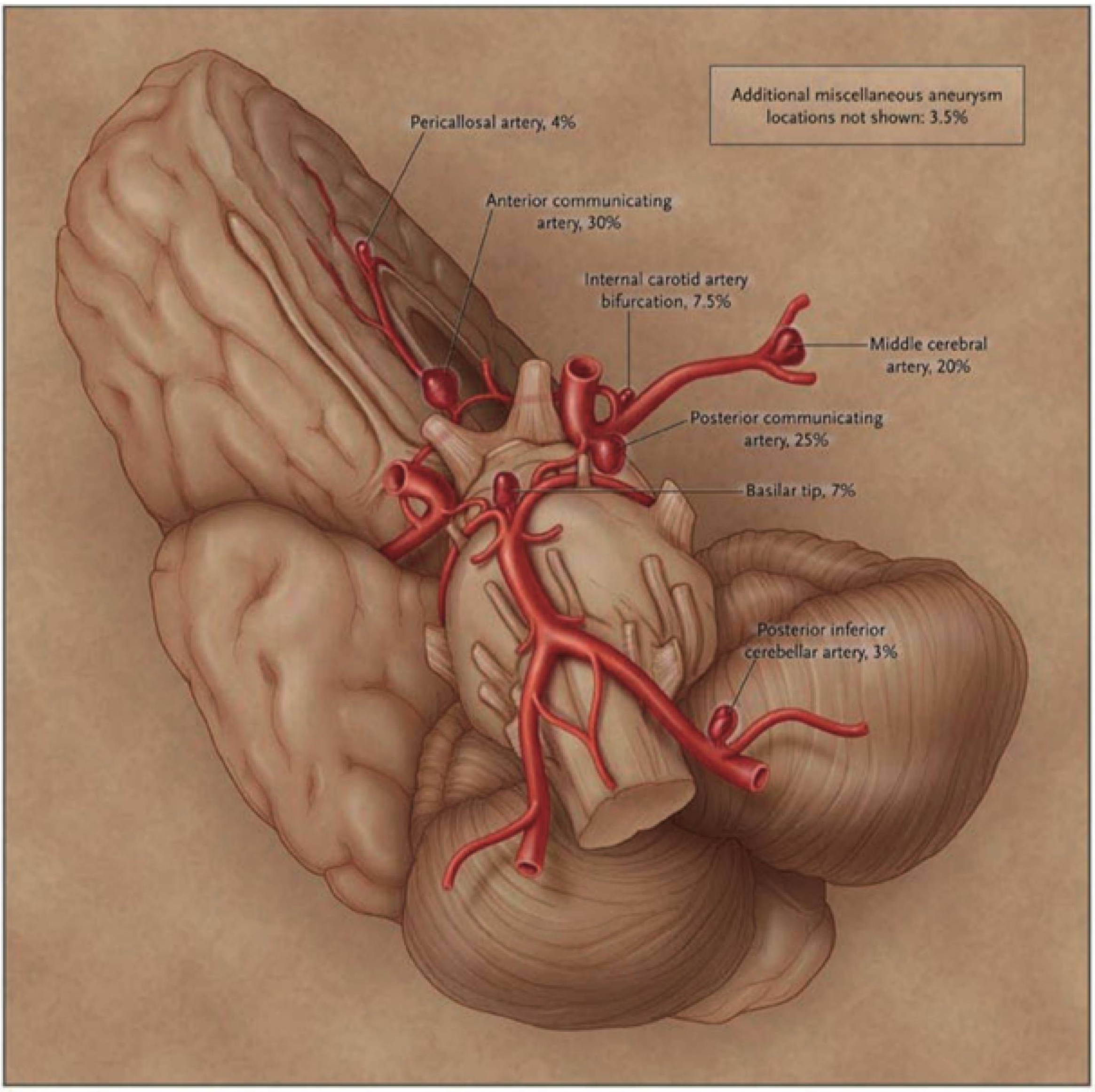

***Figure 1** The intracranial vasculature, showing the most frequent locations of intracranial aneurysms. Massachusetts Medical Society. Percentages indicate the incidence of intracranial aneurysms.*

Microanatomy

The middle cerebral artery (MCA) is the most voluminous and straightforward branch of the ICA. It lies laterally and slightly anteriorly beneath the anterior perforated substance and about one centimeter posterior to the sphenoid wing. It curves abruptly posterior and superior to the insula limen inside the sylvian fissure in order to gain access to the surface of the insula. At its outer edge, MCA branches run along the medial surface of the operculum of the frontal, temporal, and parietal lobes. It ends up running on the surface of the brain in the form of cortical branches.

In general, we can count 4 segments in the MCA:

- M1 = sphenoidal segment
- M2 = insular segment
- M3 = opercular segment
- M4 = cortical segment.

The M1 segment which is the sphenoidal segment starts at the bifurcation of the ICA and runs on the deeper part of the sylvian fissure ending at the genu around the limen insula. Gibo et al[12] and Yasargil [13], eported that in most anatomical dissections (86%), the bifurcation of the MCA takes place close to this genu. Ture et al [14], on the other hand, found that in 57.5% of the bifurcation is located at the genu, in 27,5% it is situated distal to the genu and in 15% it is located proximal to the genu. The M2 or insular segment starts at the level of the genu of the MCA bifurcation and ends at the level of the circular sulcus. The termination of the M1 segment and the beginning of the M2 segment are disputed. The end of the M1 segment and the beginnings of the M2 segment are a matter of controversy. In general, the origin of the M2 segment has been defined as the genu of the ACM at the level of the limen insula.

However, some authors believe that the origin of the M2 segment is the bifurcation point of the MCA. [12]–[15].

The MCA splits at the insula limen into two branches, a superior and inferior one, which pass over the insula as the M2 segment. Both upper and lower trunks may be identical in terms of diameter, or different.

Umansky et al [15], suggest the existence of 4 types of ramification scheme:

1) collateral branches arising from a single vessel ending in the angular artery (6%)

2) frontal (superior) and temporal (inferior) trunks (64%) ;

3) Three branches superior, middle and inferior (29%);

4) four trunks division (1%).

There are 8 to 12 vessels originating mainly from the superior trunk of the M2 segment which becomes the M3 segment. The frontal M2 branch gives rise to the prefrontal, precentral and central arteries. The anterior and posterior parietal arteries originate in the superior branch of the M2 segment in 22.5% of cases according to Ture et al [14]. They irrigate the lower and opercular frontal cortex, as well as the cortex of the parietal and central sulcus. The inferior branch of the M2 segment provides posterior and middle temporal arteries, supplying mostly the middle and posterior temporal cortex, the temporo-occipital, angular and posterior parietal cortex.

The M3 (insular operculum) segment begins in the periinsular sulcus and ends on the lateral surface of the brain. They mainly supply the inner insular cap surface and to a lesser extent (25%) the upper or lower insular perimeter groove.

The M4 (cortical) segment is the distal branch above the cortical surface. In a recent article [14] it was proposed to add the M5 segment, the M4 segment as the lateral segment, and the M5 segment as the terminal segment. The M4 and M5 segments give rise to the orbitofrontal, prefrontal, precentral, central, preparietal, posterior parietal, angular, temporo-occipital, posterior, middle, anterior, and temporal polar arteries.

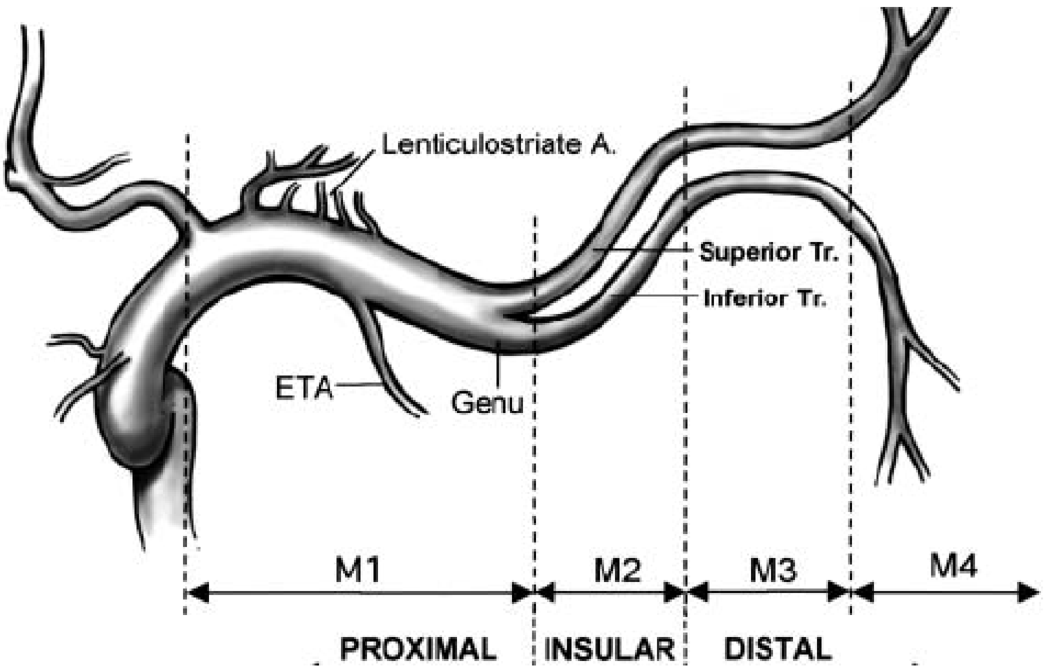

Figure 2 *Divisions of MCA-schematic diagram*

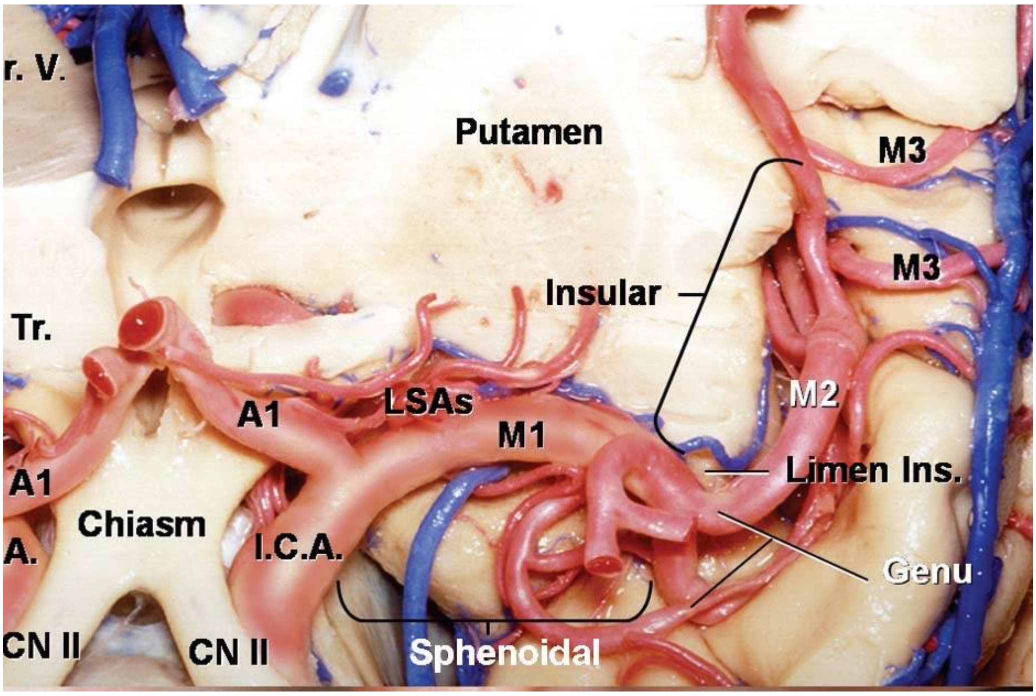

Figure 3 *MCA branches*

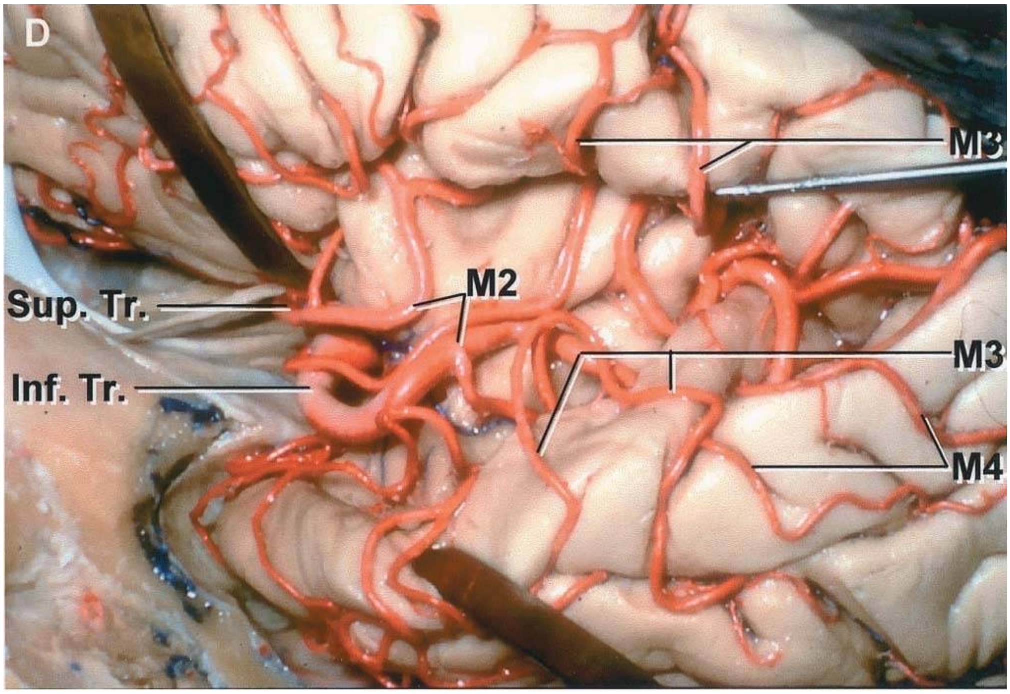

Figure 4 *Distal MCA branches*

The perforators of the MCA enter the anterior perforating substance, called the lenticulostriate artery. There is an average of 10 (range 1-21) lenticulostriate arteries per hemisphere [12]-[14]. In each case, the lenticules were derived from the anterior bifurcation of the M1 segment and the posterior bifurcation of the M1 segment of the hemisphere. About 80% of all the lentils originate from the fork of M1. Most of the rest are from the posterior bifurcation part of M1, but a few are from the proximal part of the M2 genera.

The lenticulostriate arteries are divided into medial, intermediate, and lateral groups, each with unique origin, composition, morphology, and characteristic distribution in the anterior perforating substance. The middle group is the smallest constant of the three groups and exists only in the hemisphere. Branches before entering the anterior perforating material were less common than in the medial or lateral groups. The middle lenticulostriate artery forms a complex series of branches before entering the anterior perforated material between the medial and lateral lenticulostriate arteries. They are present in more than 90% of hemispheres [12]. They are mainly from the main or pre-fork part or early branch of M1. Arteria lenticulostriatalateralis is present in almost all hemispheres. They appear mainly on the lateral part of M1, extending in an S shape and into the posterolateral part of the anterior perforated material. They can also arise from earlier branches of M1 or M2.

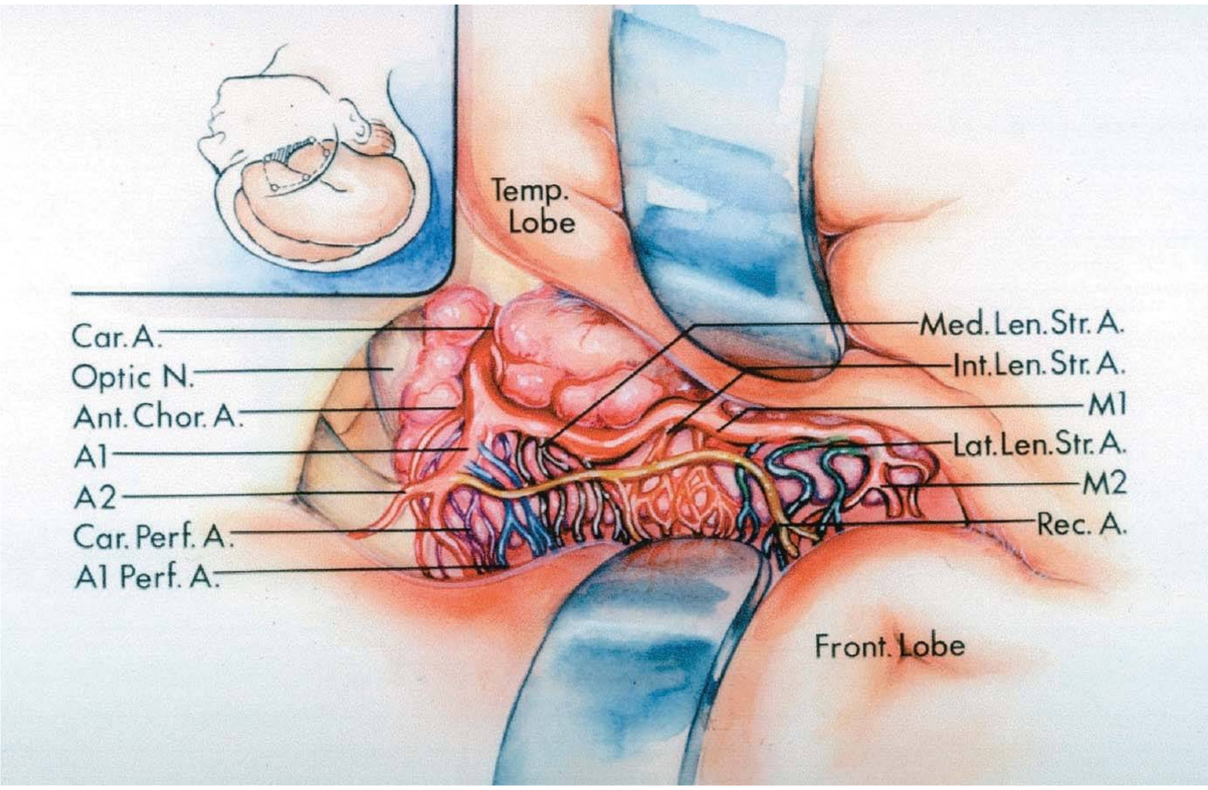

Figure 5 *Perforators of MCA*

Clinical features

MCA aneurysms have certain peculiarities that are not found in other aneurysms. Giant MCA aneurysms are more common than giant aneurysms at other sites, with the possible exception of the paraclinoid region of the ICA [16]. This observation may be related to the fact that MCA aneurysms can reach enormous proportions without causing symptoms by destroying vital structures. If large enough, unruptured MCA aneurysms can produce clinical symptoms of a mass [17]. Headache with signs of elevated intracranial pressure, including papilledema, rarely occurs in larger aneurysms. Temporal lobe epilepsy is another symptom that rarely occurs with MCA aneurysms, but only with aneurysms elsewhere. Ischemic symptoms such as transient ischemic attack and mini-stroke, although rarely caused by aneurysms, are more common in MCA aneurysms than in aneurysms elsewhere. These symptoms are suspected to be the result of thrombosis and subsequent embolization within the aneurysm [18].

Rupture of an aneurysm usually results in a syndrome indistinguishable from that associated with subarachnoid hemorrhage (SAH) from rupture of an aneurysm in any other location. Certain clinical characteristics, however, favor the diagnosis of a ruptured MCA aneurysm. These characteristics were first described by Hook and Norlen [17]. Approximately 60% of patients with an MCA aneurysm lose consciousness at the onset of rupture (a higher proportion than with aneurysms at other locations).

Approximately one third of patients with a ruptured MCA aneurysm have primarily unilateral headache, which is much less commonly seen after rupture of aneurysms elsewhere. When such unilateral headache is present, it is almost always on the side of the aneurysm. Approximately 80% of the patients in the series of Hook and Norlen [17] had focal neurologic deficits when first seen. Similar deficits generally corresponded of hemiparesis, aphasia, visual field deficits, and central facial weakness, out of which half had severe deficits.

Only 34 of cases with ruptured aneurysms in other locales had similar findings when first seen, and only 7 had severe deficits. When a case with a ruptured aneurysm is first seen awake but with severe hemiparesis, the most likely position of the aneurysm by far is the MCA. These aneurysms are also slightly more likely to affect in seizures after rupture than aneurysms in other locales. The propensity of MCA aneurysms to beget focal symptoms and signs is attributable to their tendency to bleed at least incompletely into the brain parenchyma as well as into the subarachnoid space. The prevalence of intracerebral hematoma in cases with ruptured MCA aneurysms is between 30 and 50 [19], which is vastly advanced than with aneurysms in other positions. These intracerebral hematomas are much of great distinguishing value when detected by computed tomography (CT). A hematoma extending into the anterior opercula and the temporal opercula, bridging the sphenoid ridge, is practically pathognomic of a ruptured MCA aneurysm.

Imaging

In every case admitted with incertitude of a SAH, anon-contrast computed tomography (NCCT) checkup is made to dig up the hemorrhage. This NCCT-checkup can also be used to determine the hemorrhage volume, the midline shift and the presence of hydrocephalus. When the SAH is verified, a CT-angiography (CTA) (or a Magnetic resonance angiography (MRA) is made to find the cause of the SAH. A SAH can be aneurysmal or non-aneurysmal. Possible causes ofnon-aneurysmal SAH are AVMs, trauma, reversible cerebral vasoconstriction pattern (RVCS). In case of an aSAH, the CTA can show the position and anatomical configuration of the causative aneurysm. When no cause of the SAH is find with CTA, a digital deduction angiography with 3-dimensional rotational angiography (3DRA) can be made also (20). This DSA with 3DRA can also be used to determine whether the aneurysm is suitable for treatment with endovascular coiling or not. In case multiple aneurysms are plant, the blood distribution pattern on NCCT combined with the aneurysm position and anatomical configuration can be useful in trying to discover the causative aneurysm. When the NCCT shows no subarachnoid hemorrhage, an LP is performed a minimum of 12 hours after the SAH ictus to count bilirubin in the CSF (21). The subarachnoid hemorrhage can be graded on a NCCT using the modified Fisher score or the Hijdra scale (22). This has shown to have value in the cast of the event of vasospasm (in that time allowed to be cause of delayed cerebral ischemia (DCI)) after aSAH. The Fisher scale is a four-point scale (score 1 = no blood, 4 = intraventricular clot with or without verbose SAH). The modified 4- point Fisher scale is more accurate in auguring vasospasm, taking thin (< 1 mm) and thick (> 1 mm) cisternal hematoma and ventricular hematoma into account, but this still leaves the interpretation to the health provider that reads the CT scan findings. The Hydra scale is a four- point scale (No blood = 0 points, fully filled with blood = 3 points, maximum 30 points), and grades the quantum of blood in the rudimentary tuns, crevices and the fourth ventricle. These scales are rough (Modified Fisher), laborious (Hijdra) and driver-dependent (both).

Studies using these scales have reported on the clinical significance of subarachnoid hemorrhage grading, by showing that further blood after aSAH has a advanced association with the circumstance of vasospasm. The up-coming step would be to develop, and validate, an easy to use, accurate, driver-independent automatic quantification system to study the association of real hematoma volume (whole and on different locales) after aSAH with DCI [23][24].

Management options

With the exception of fusiform, serpentine, and dissecting aneurysms, almost all MCA aneurysms have a neck and therefore are suitable for clipping and reconstruction. Endovascular treatment presents a feasible substitute option to open microsurgery in named cases. To make this selection duly, an accurate assessment of the vascular structure of the aneurysm, particularly the size of the neck in relation to the height of the fundus, is necessary. The discussion axes on whether to treat a particular case with a particular aneurysm by open microsurgery or by an endovascular approach. undoubtedly, cases who present symptoms due to mass effect of a temporal hematoma should be treated with open surgery to clear out the hematoma and, at the same time, occlude the aneurysm. Let's review the available operation options.

I. ENDOVASCULAR TREATMENT:

Endovascular coil embolization of intracranial aneurysms was introduced in the early 1990s. During its original use, the approach was primarily used to treat aneurysms in the posterior circulation, where surgical access is particularly technically demanding. Presently, the strategy is extensively accepted as a valid choice to surgical one in the treatment of anterior circulation aneurysms.

In 1991 Guglielmi et al [24] (Table 1) reported on the experimental results and the clinical application of electrolytically detachable platinum coils. These coils were very soft, retrievable, controllable and detachable at will. They did solve most of the problems encountered by previous investigators except for coils progressive compaction in terminal aneurysms and in aneurysms with a wide neck. As an attempt to improve the results in wide necked aneurysms, J. Moret et al [25] proposed to deliver the coils while a temporary balloon was inflated across the neck of the aneurysm. This so-called "romedelling technique" [25] became part of the armamentarium in the mid-1990s.

It is the author's opinion that this technique might entail more thromboembolic complications. Furthermore, loops of coils may herniate out of the aneurysm on deflation of the balloon.

In the early 2000s, widespread use of self-expandable stents was accompanied by the emergence of problems linked to the thrombogenicity of these new prostheses which highlighted the primordial importance of parameters such as the medicated preparation as well as the capacity of the stents to open correctly and to adapt to the anatomy of the arteries easily [26].

Based on findings from the International Subarachnoid Aneurysm Trial (ISAT) [27], coiling of ruptured cerebral aneurysms is associated with the lowest immediate morbidity and mortality rates compared to other treatment options after one year follow up. Follow-up study published in 2005 [28] found that the benefit continues for at least seven years after the procedure. It also found that, while the risk of repeated bleeding is low with both techniques, it is slightly higher with coiling at 10 years follow up.

For the time being when we do consider endovascular treatment for MCA aneurysm, especially for giant one, Flow Diverter Devices (FDD) represent a groundbreaking intervention since their inception in 2007 [29] as parent vessel reconstruction is becoming the most preferred endovascular strategy. However, despite numerous reports on successful treatment of aneurysms with flow diverter, various unpredictable complications have also been reported that one should be aware of when managing MCA aneurysms.

Even if the ISAT trial [30] showed a benefit for endovascular treatment of ruptured aneurysms on all sites, MCA aneurysms were underrepresented, leaving space for deliberation on what's the best treatment for MCA aneurysms

[30]. One published review on the treatment of MCA aneurysms showed that endovascular treatment is doable and effective, but that the periprocedural morbidity and mortality was concrete [31].

Still, this study didn't include studies describing MCA aneurysm treatment outgrowth in all the groups of the study population, and didn't compare surgical treatment with endovascular one.

Table 1 *Evolution of endovascular devices*

Endosaccular balloon embolization	**Guglielmi Detachable Coil**	**Balloon assisted coiling (Remodelling technique)**	**Matrix detachable coil (GDC coated)**	**Stent assisted coiling (Self-expandable intracerebral stent)**	**Pipeline Embolization Device**
1974 F. Serbinenko [32] (NS) (Russia)	1991 G. Guglielmi [24] (NS) (USA)	1994 J. Moret [25] (NR) (France)	1998 Vinuela & Y. Murayama [33] (NR) (USA)	2001 Boston Scientific [34] (USA)	2007 EV3/ Covidien [29] (USA)

Some authors endorse strict endovascular treatment of all MCA aneurysms, with or without fresh bias (balloons and stents) implacable of the advanced pitfall of complications using stents [35]. Others endorse strict surgical treatment also to maintain surgical experience in an epoch that further and further aneurysm are treated endovascularly [36]. The presence of a coexisting intracerebral hematoma (ICH) after aSAH from an MCA aneurysm can also play a part in the determination of the favored treatment strategy, meaning the surgical one. A systematic, extensive review comparing conventional coiling and clipping of MCA aneurysms might help to end this lingering discussion.

II. SURGICAL TREATMENT

Three surgical approaches are commonly practiced depending on the location of the aneurysm, its configuration and local angioarchitecture. These approaches include: sylvian fissure approach, medial transsylvian approach and distal transsylvian approach. They were reviewed in detail by Ogivly et al [18] and Baskaya et al [37]. By using the preoperative radiological studies to define the characteristics of an MCA aneurysm, the choice of surgical option can be made to maximize safety of aneurysmal treatment.

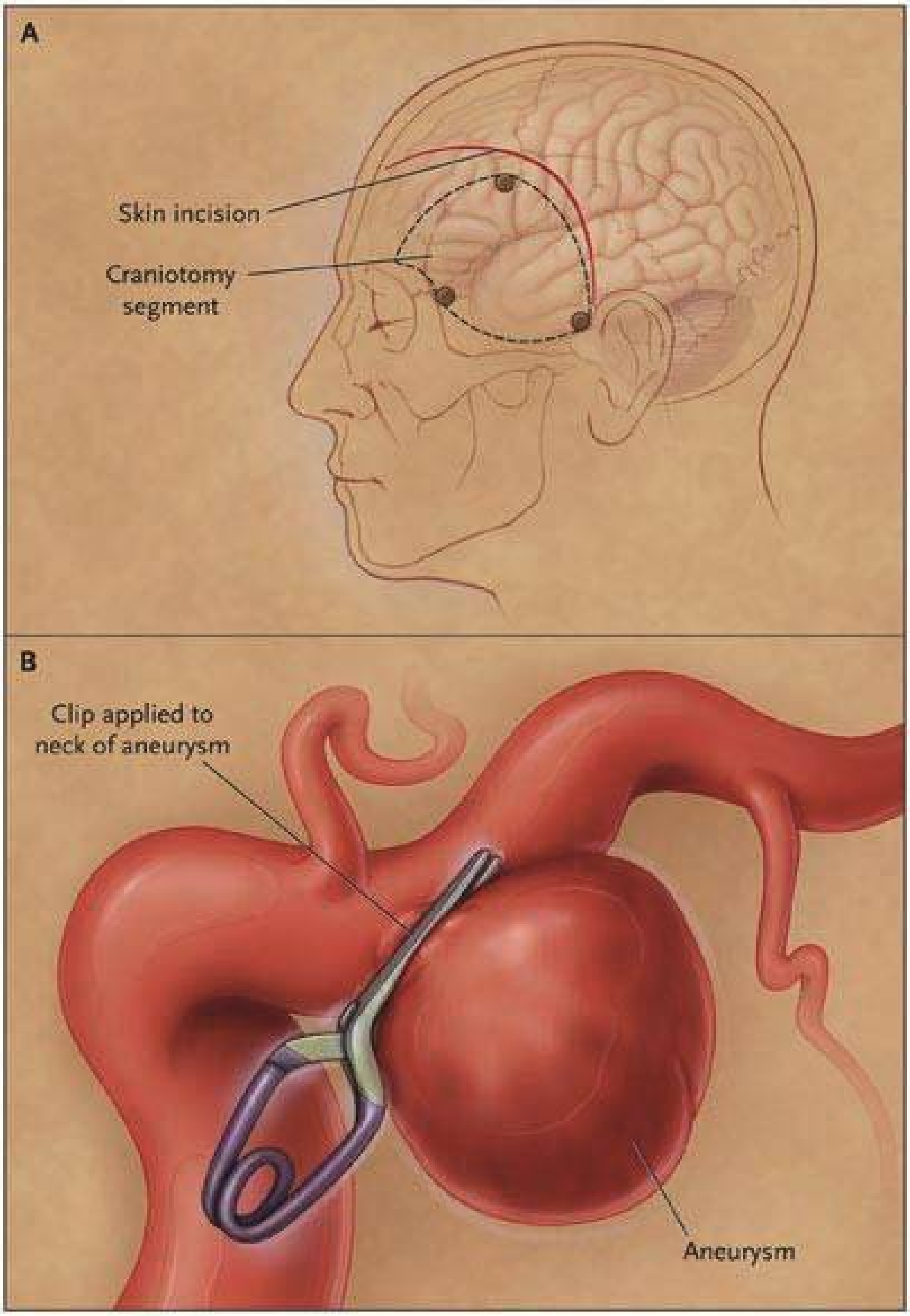

Figure 6 *Microsurgical clipping with (A) outline of skin incision and craniotomy segment and (B) application of the clip blade to the neck of the aneurysm. Reproduced with permission from (Brisman et al. NEJM 2006), Copyright Massachusetts Medical Society.*

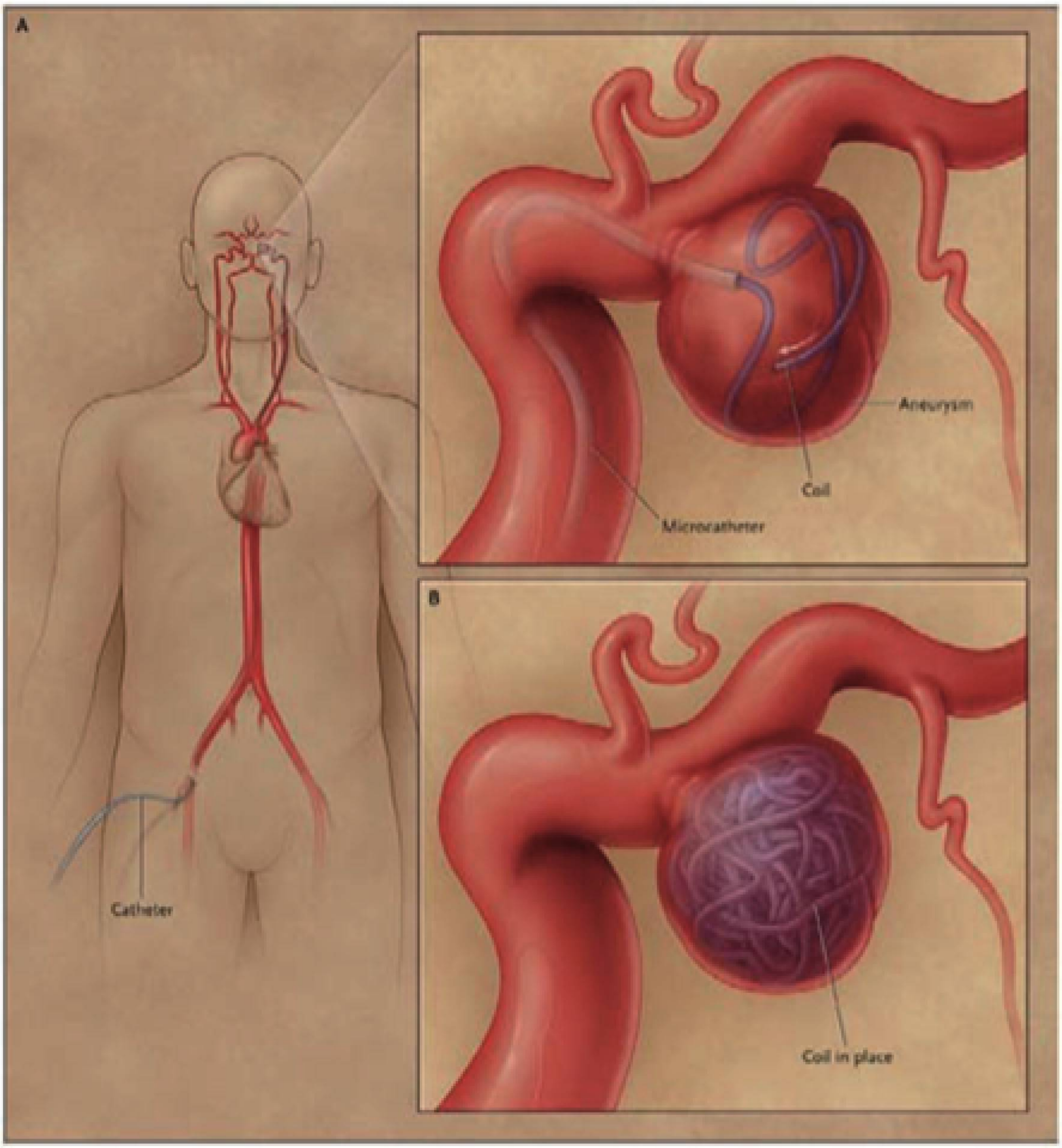

Figure 7 *Endovascular coiling with (A) route from groin to brain and microcatheter in the aneurysm and (B) aneurysm occluded with coils. Reproduced with permission from (Brisman et al. NEJM 2006), Copyright Massachusetts Medical Society.*

Strong consideration should be given to the presence or absence of intracerebral hematoma, the direction of the aneurysm and his size. Analysis of preoperative angiograms should include details about the length of the MCA trunk and its relationship with the aneurysm.

In 2018, a systematic review assessed clinical and imaging outcome rates of coiling and clipping of unruptured and ruptured MCA aneurysms during a follow-up period up to 2 years [38]. Studies included within this review Studies included within this review described at least than 10 cases with either coiled or clipped MCA aneurysms; and the study reported at least one of the following particulars for the group of MCA cases — death, clinical status during follow-up, or postdate-up imaging (DSA, MR angiography, or CT angiography) with aneurysm occlusion rate and/ or retreatment rates. Studies in which different aneurysm types were described and anatomized, similar as complex, fusiform, mammoth, or mycotic aneurysms were included only when these aneurysms were subject to regular coil or clip treatment.

There seems to be an advantage for surgical option of unruptured aneurysms with respect to death rate. Favorable outgrowth rates after surgical and endovascular options of unruptured aneurysms were similar to the95.6 percent and 95.9 percent rates reported in the International Study of Unruptured Intracranial Aneurysms (ISUIA) study [39], whereas death rates for coiling and clipping were lower than the reported death rate for all aneurysm sites in the ISUIA study (3.4 percent for coiling and 2.7 percent for clipping, independently). The post-treatment hemorrhage rate after coiling of unruptured aneurysms was similar with the one reported in the Unruptured Cerebral Aneurysm Study (UCAS) study, varying between0.23 percent and 1.56 percent in unruptured MCA aneurysms of 3 – 9 mm, but superior than the rupture rate per year equivalent of 0.1 percent in all untreated unruptured aneurysms< 7 mm in the ISUIA study.

It's certainly unclear whether treatment of unruptured aneurysms has an advantage over a delay and see policy. A prospective randomized trial to determine the smart strategy in unruptured aneurysms comparing surgical and endovascular option with conservative care seems justified, although recent trials have proved to be vain [40].

In this review it wasn't possible to separate periprocedural thromboembolic events from clinically apparent ischemia or ischemic changes reported on imaging studies. Although ischemia is reported more constantly after endovascular treatment than after surgical one of unruptured aneurysms, this didn't affect the favorable outgrowth rate, perhaps because not all reported thromboembolic events led to clinical sequelae. The superior prevalence of thromboembolic complications might be explained by an increased probability to dig up thromboembolic events during the endovascular procedure. Likewise, follow-up MR imaging, including T2 weighted and three-dimensional time of flight MR angiography images, are more routinely performed after endovascular treatment to assess the occlusion rate of the occluded aneurysm, so ischemic changes are more readily detected. In ruptured aneurysms, there seems to be an high ground of endovascular treatment with respect to clinical outgrowth rate andpost-treatment hemorrhage rate. Still, the lower death rate after coiling than after clipping is presumably related to the fact that neurological status on admission was worse in the surgical group. The reason could be that cases with large intracranial hematomas carrying a worse prognostic are presumably more frequently operated on for the purpose of relaxation and/ or hematoma evacuation, but we couldn't confirm this in our review as utmost studies didn't report on this subject. Another factor related to poor outgrowth could be that morphologically complex aneurysms are frequently infelicitous for endovascular treatement, and thus more prone to be microsurgicaly managed, during frequently technically grueling procedures.

After curling and trimming of ruptured aneurysms, the favorable outgrowth rates were alike with the overall favorable outgrowth rates in the ISAT study (76.3 and 69.4 percent, independently), suggesting that the threat profile and treatment of MCA aneurysms, which are subject to regular coil or clip treatment, doesn't differ from aneurysms in other spots.

Thepost-treatment hemorrhage rate in cases with surgically managed ruptured MCA aneurysms in this review appeared to. be lower than the overallpost-treatment hemorrhage rate within 1 year for ruptured aneurysms in the ISAT trial (2.6) and the Cerebral Aneurysm Rerupture After Treatment (CARAT) study (3.4) but this might be caused by the further variable time to follow-up [41].

The after-treatment hemorrhage rate in cases with clipped ruptured MCA aneurysms was superior than the overall rate for surgically treated ruptured aneurysms in the ISAT trial (1.0) and the CARAT study (1.3). The limitation in the “coil” and “clip” results is that not all studies reflected on hemorrhage post procedure. Assuming that the lack of complete reporting on this implies that there weren’t any after-treatment hemorrhages, the probabilities may be equal. Again, the lack of standardization in reporting on aneurysm form hinders solid conclusions.

Intraprocedural aneurysm ruptures were exclusively set out in coil studies and were of lower frequence in unruptured than in ruptured aneurysms. None of the studies on surgically managed aneurysms reported on intraoperative ruptures. During surgery, an intraoperative hemorrhage can generally be controlled effectively by temporary occlusion of the main artery, in combination with disposal of the extravasated blood. After stabilization, the aneurysm can be definitively clotted. Possible negative side complications of these hemorrhages are unpredicted to determine and are thus presumably not registered as a complication.

Follow-up imaging after coiling missed a strict time interval, which makes calculations on short tomid-term follow-up (< 1 year) delicate, if not insolvable. Still, the acceptable occlusion rate was high originally and sounded stable during follow-up. This review also showed that follow-up imaging wasn't routinely performed after trimming. Indeed in a lately published review including single center, single surgeon data, follow-up imaging was performed in only 22 of cases [42].

This study is limited by the fact that most papers were retrospective and no study reported on the neurological status prior to admission. Such extra detail may be critical when assessing the final neurological status at follow-up.

Mostly, there was a poor level of standardization in reports without a clear description of patient selection, clinical status at admission, anatomical aspects and aneurysm size, follow-up period, clinical result, and a clear indication of complications.

To improve the improve the up-coming aneurysm treatment studies, standardized data according to the recently published guidelines should be performed.

It should give a better idea about the appropriate treatment option [43], [44]. In the absence of such enhancements, firm statements cannot be made in a forthcoming systematic review regarding the treatment of MCA aneurysms.

The role of presumed bias in the choice of treatment is a major one. Regional accessibility, surgeon expertise, and specialist skills are key determinants of the choice of treatment for each case. Financial considerations may play a role in the choice of treatment as well. For example, there are those who argue that the clipping strategy for MCA aneurysms is fairly inflexible due to the relatively mild morbidity and mortality and allows neurosurgeons to keep up their clipping expertise [36]. In contrast, some treat MCA aneurysms exclusively by endovascular approach, including stent-graft-assisted coiling, with much higher complication rates [35].

It is likely the optimal policy that every case should be addressed at a leading neurovascular center, with a high level of expertise in both fields to deliver the best option possible based on the patient's clinical status and the angioarchitecture of the aneurysm.

❖ Difficult aneurysms:

1) Presence of large hematoma:

The presence of tiny perforating arteries in the subarachnoid space and fibrous adherence of the clot make evacuation of an intrasylvian hematoma challenging. In this case, the superior temporal gyrus method [37][18] is favored. The sylvian arteries can be recognized and traced proximally by working on the medial side of the clot space in the subpial plane. After the aneurysm is totally cut, the majority of the hematoma can be left intact until an aggressive hematoma resection is performed. The borders of the sylvian fissure can be difficult to determine in cases of recent hemorrhage, however the depth of the fissure can be explored and additional dissection performed by removing a small piece of anterior superior temporal gyrus.

2) Rupture before clipping:

Aneurysms can burst when the sylvian fissure is opened or the aneurysm base is dissected. The rupture occurs at the dome rather than at the base. Suction and/or compressing the bleeding spot with cottonoids should be attempted initially. In the event of uncontrolled bleeding, sudden and brief hypotension caused by cardiac arrest induced by intravenous adenosine can be employed to allow fast dissection and clipping [45]. If the ruptured secondary pouch is evident, a pilot clip can be introduced [46]. Otherwise, a temporary clip is put proximally or clips on both sides for further base dissection and final clipping.

During dissection, a tiny, thin-walled aneurysm may rupture at its neck. Reconstruction of the base by including a portion of the M1 trunk in the clip should be tried during temporary artery clipping. Because of the aneurysm's deep positioning, one alternative is to suture the burst site with 8/0 or 9/0 running sutures, then clip [47].

By integrating 3D CTA and 2D CT images and determining the relationship of the maximal thickness of hematoma around the aneurysm fundus, Wada et al [48] presented a method of detecting the probable site of rupture preoperatively. This allows the surgeon to make an educated prediction about the possible rupture site during surgery and take appropriate safeguards.

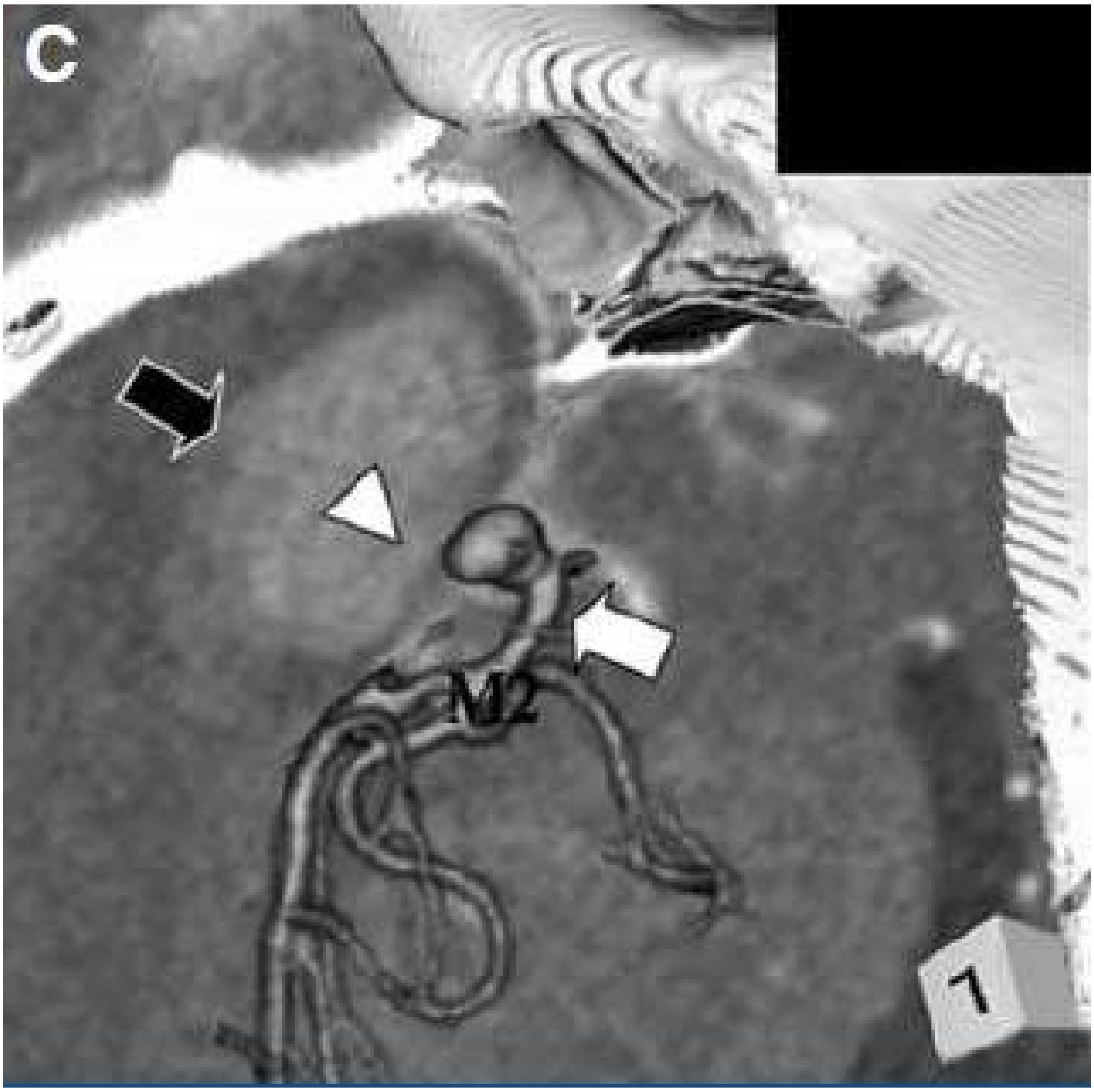

Figure 8 *Combined 3D CTA and 2D CT images (Black arrow-maximal hematoma, white arrow head-probable site of rupture)*

3) Very small aneurysms:

Clipping is difficult in very small (23 mm) aneurysms since the wall is fragile. M1 clipping temporarily reduces intraluminal pressure and softens the dome [18]. A thin portion of the healthy M1 wall is taken inside the clip for safe neck closure with minimal reduction of the M1 lumen [47]. Double clipping may be used if the first clip slides, exposing some of the neck. Another option is coagulation and wrapping under temporary M1 clipping.

4) Fusiform aneurysms:

Vascular dissections are the most common cause of fusiform aneurysms. Distal MCA is prone to mycotic fusiform aneurysms. Fusiform M1As were uncommon in the Dashti et al [46], [47] accounting for only 0.6 percent of all MCA aneurysms. Wrapping, proximal occlusion, excision, trapping, and reconstruction are all techniques to keep in mind for when dealing fusiform MCA aneurysms [49], [50]. M1 lumen can be reconstructed by arranging a row of fenestrated clips, either rightangled or straight. Large fusiform aneurysms may also be treated with arteriotomy, followed by suturing alone or with clips and running sutures to reconstruct the M1 lumen. Parent artery occlusion with preoperative bypass should also be considered in giant fusiform aneurysms [51].

5) Intraluminal thrombus:

Temporary clips are put proximally in the event of intraluminal thrombus, and the aneurysm dome is sliced with a knife for internal decompression, generally by suction or, in the case of significant thrombus, by ultrasonic aspirator [52]. The intraluminal thrombus is meticulously removed allowing futher aneurysm decompression. The vascular clamp softens the neck of the aneurysm also minimizing intraluminal thrombus from sliding within M1. Saline is used to irrigate the lumen. The dome is then generally decreased enabling final dissection and proper clipping of the aneurysm.

6) Giant /multilobulated aneurysms:

Giant aneurysms require particular attention. When deciding on a technique, the surgeon must ensure that enough vision of the aneurysm neck anatomy is accessible. If a direct clipping of the aneurysm is planned, the same decisionmaking procedure as for a basic aneurysm should be followed. If the aneurysm is located laterally in the temporal lobe, a multimodal approach that includes the sylvian fissure exposure to identify the Ml vasculature and the superior temporal gyrus approach to split out the M2 branches can be employed.

Yasargil's [53] initial 184 cases had 83 (45 percent) multilobed aneurysms. MCA aneurysms are commonly oriented with the long axis parallel to the axis of the parent artery. This might make it difficult to establish a clear line of sight for optimal viewing. The proximal M1 segment is usually deeply located. Therefore, visibility for proximal control could be challenging. MCA aneurysm necks are knowen to be wide and round, making endovascular coiling procedures less successful.

Numerous technical approaches can be employed to treat complicated MCA aneurysms, including temporary artery occlusion, fundus coagulation, multiple clips construction (Figure 5), suction decompression (Figure 4), partial clipping followed by coil embolization, and wrapping. Dr. Charles Drake [54] initially developed and employed the fenestrated clip in 1969 as a therapy for complicated basilar aneurysms. Sugita et al. [55] described the treatment of 18 aneurysms (8 internal carotid and ten vertebral) with fenestrated aneurysm clamps. They demonstrated the use of interlocking fenestrated clips to treat complicated internal carotid artery aneurysms. They did not employ fenestration to allow clips to be placed at orthogonal or nearly orthogonal angles. Tanaka et al. [56] reported a wider series of patients that included some of these cases. They highlighted the use of a "multiple clipping approach" using combinations of fenestrated and non-fenestrated clips in this larger series. Six aneurysms needed clipping in perpendicular fashion. Clatterbuck et al [57] treated 15 patients with complicated MCA aneurysms with an interlocking tandem clipping approach (Figure 9). With a GOS of 5, all patients recovered entirely.

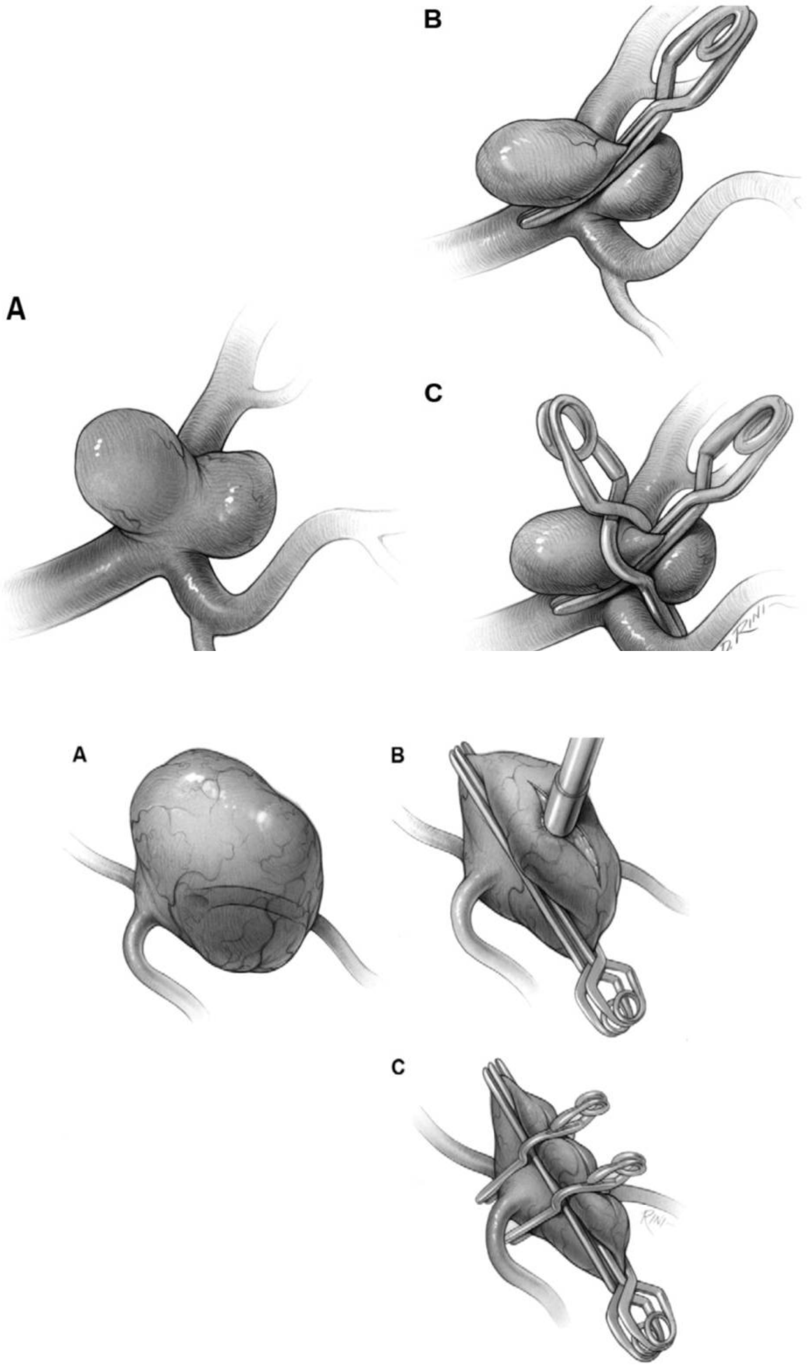

Figure 9 I*nterlocking tandem clipping technique [57]*

7) Complex MCA aneurysms

For cases with challenging MCA aneurysms, specific surgical management is necessary due to the variety of aneurysm shape, difficult vascular architecture, and hemodynamic features.

Wei Zhu et colleagues [58] created a new taxonomy based on aneurysm angioarchitecture. From March 2004 to July 2012, 59 complicated middle cerebral artery (MCA) aneurysms in 58 individuals were treated microsurgically and followed up on. Surgical planning is mostly dependent on the aneurysm's genesis and form. They classified complicated MCA middle cerebral artery aneurysms into three kinds in their study.

The aneurysm in type A started in the M1 segment. Type B aneurysm started from the M2 segment or the MCA bifurcation, whereas the type C aneurysm came from the M3 or distal segments.

Surgical strategies and modalities for treating complex MCA aneurysms are summarized in figure 10:

- When the M1 aneurysm is morphologically clippable, one must look for the lenticulostriate perforators, meaning if clipping can ensure their permeability, direct or reconstructive clipping shall be the right way to manage them. When the aneurysm isn’t suitable for clipping, one should consider aneurysm trapping. If trapping can ensure lenticulostriate perforators permeability, extra cranial-intracranial bypass is the right way to go. Otherwise, a staged ICA occlusion in addition to EC-IC bypass should be performed.
- When the M2 aneurysm is morphologically clippable, it is advised to perform direct or reconstructive clipping. If not, consider aneurysm trapping or resection coupled with IC-IC bypass.

- When it comes to aneurysm of M3 segment, and when it is morphologically clippable one must always think of direct or reconstructive clipping, and when it’s not possible, we shall do temporary occlusion of parent artery and monitor Motor evoked potential (MEP) to rule out any potential postoperative deficit. Obviously If MEP is negative meaning, if we don’t observe any deficit, aneurysm trapping or resection can be safely performed.

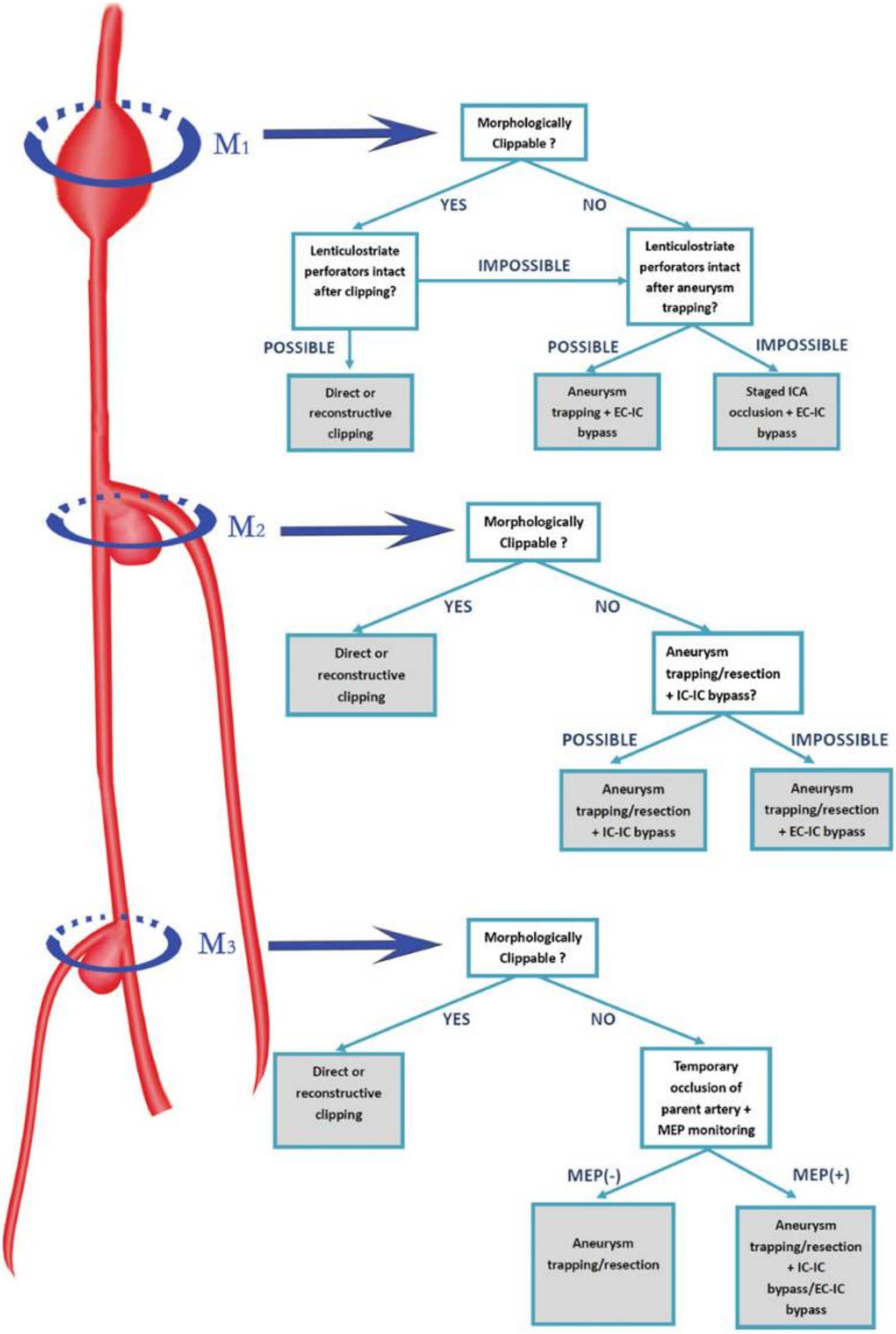

Figure 10 *The algorithm of our surgical strategies for treating complex middle cerebral artery aneurysms*

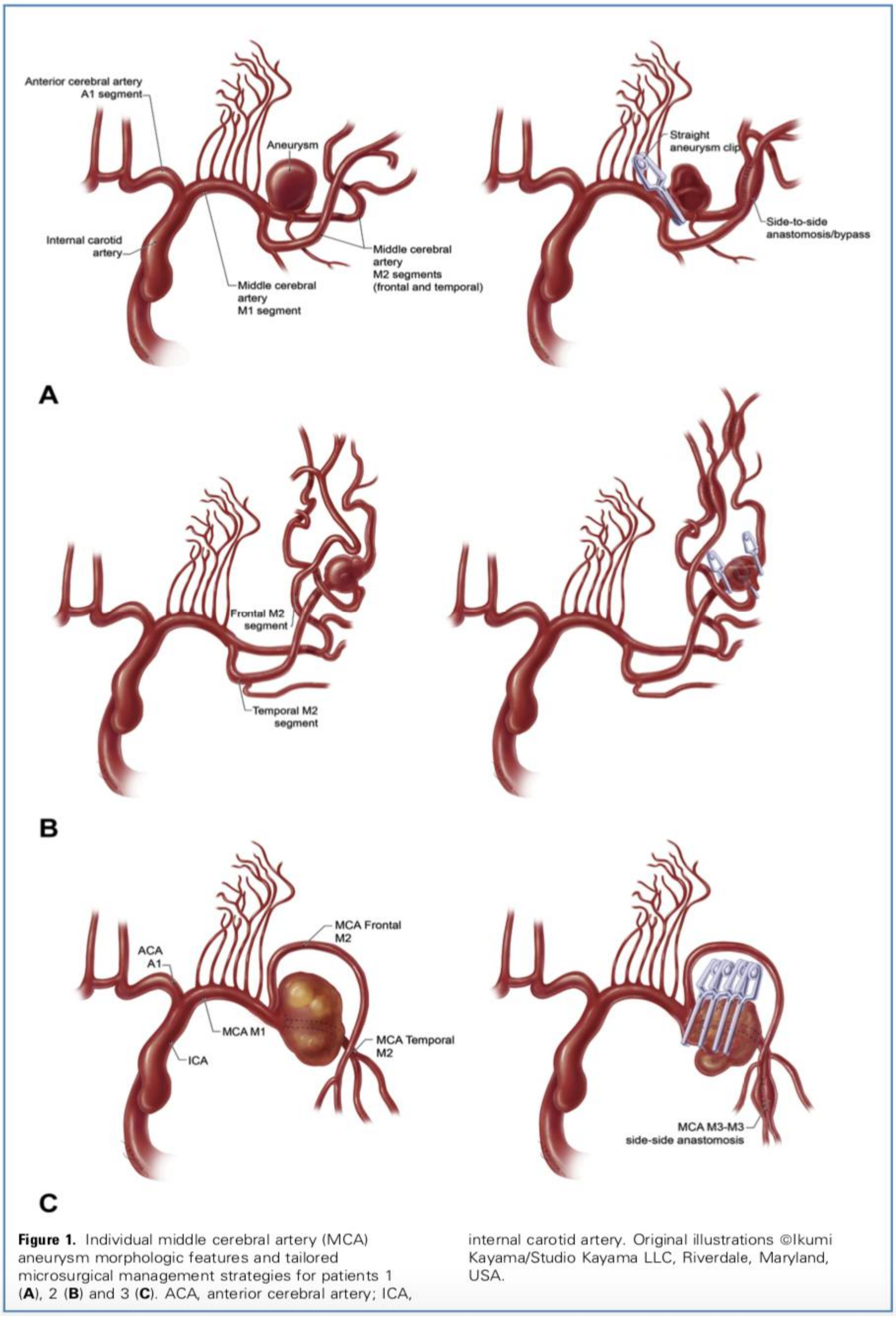

Figure 1. Individual middle cerebral artery (MCA) aneurysm morphologic features and tailored microsurgical management strategies for patients 1 (**A**), 2 (**B**) and 3 (**C**). ACA, anterior cerebral artery; ICA, internal carotid artery. Original illustrations ©Ikumi Kayama/Studio Kayama LLC, Riverdale, Maryland, USA.

***Figure 11** Individual middle cerebral artery aneurysm morphologic features and tailored microsurgical management strategies*

Surgical recommendations for giant aneurysm:

When dealing with complex middle cerebral artery aneurysms (i.e. large and giant saccular MCA aneurysms), which cannot be treated with conventional surgical techniques, the authors have proven to be fine artists when it comes to creativity and innovation. One of the techniques that has demonstrated its effectiveness in the occlusion of unruptured giant sylvian aneurysms is “the mass reduction clipping technique” described by Ririko Takeda and Hiroki Kurita [59] (Figure 13).

First step is to put a temporary clip into the parent artery in order to decompress the aneurysm. When the dome has been sufficiently decompressed, the first clip should be placed in its center. This clip insertion caused a shift in the aneurysm's structure and decreased the aneurysmal mass, which had previously expanded spherically. In order to enhance the dome's mass reduction, one additional fenestrated straight clip was placed in the middle, adjacent to the first clip. A third light curved clip was placed to reconstruct the neck on its temporal side.

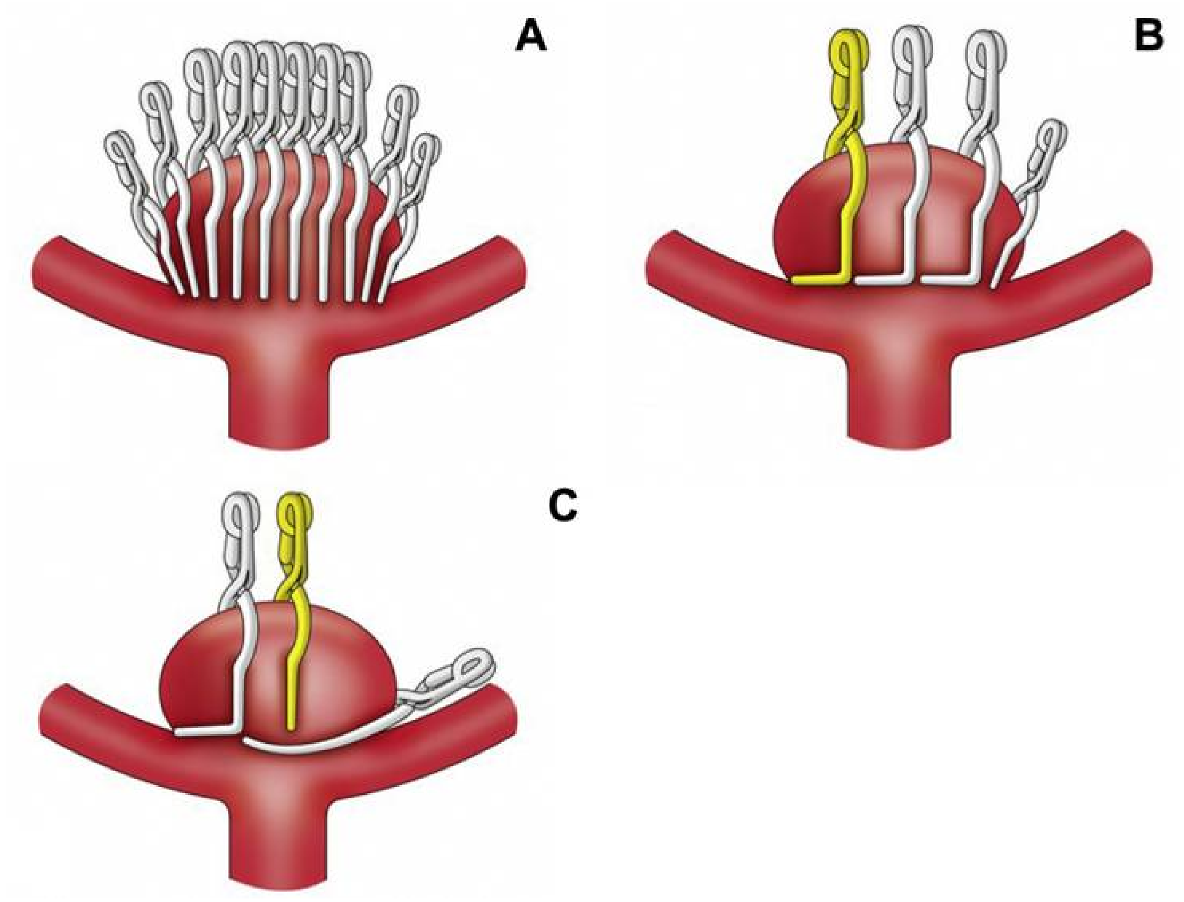

Figure 12 : *Multiple parallel clips are put vertically from dome to neck to perform a reconstruction of the neck in tandem clipping style **[59]**.*

Another technique has been described by Lawton called the "picket fence" clipping technique [60]. This approach is intended for the clipping of big aneurysms when traditional clipping across the neck isn’t possible due to complicated morphology, atherosclerosis, calcification, or branches arising from the dome of the aneurysm. It is also known as a dome fenestration tube. Simple and/or fenestrated parallel straight clips are placed vertically from dome to neck to rebuiled it.

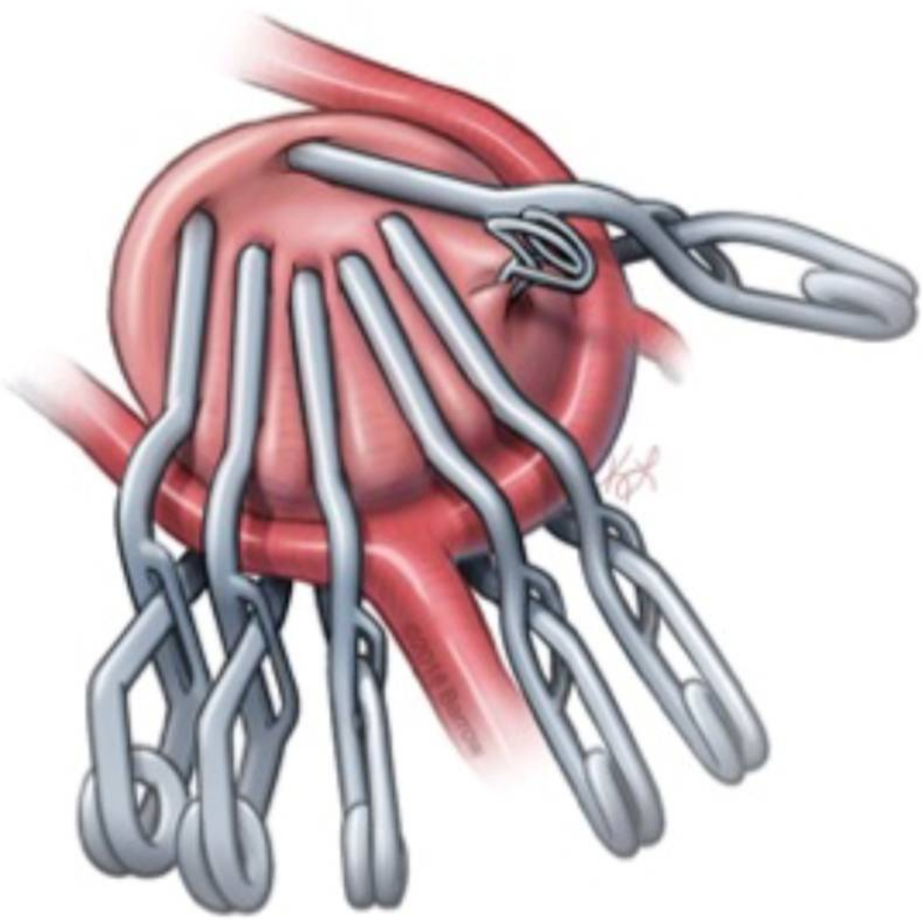

Figure 13 : *Reverse Picked Fence clipping technique*

Suction decompression is an adjuvant technique that has revolutionized the management of giant aneurysms. It promotes an adequate degree of relaxation of the aneurysmal dome, enabling the surgeon to fully dissect the aneurysm. Flamm [61] was the first to publish a technical note about it in 1981. When the aneurysm neck has been sufficiently prepped for clip placement by detaching the surrounding arachnoid, one can assess if a clip would completely occlude the aneurysm without compromising the parent artery. If the aneurysm remains tight despite hypotension, or if the bulky neck will not fit into the largest available clip, a scalp vein needle is prepped (Figure 14). It is then connected to suction apparatus via its plastic catheter. The needle is inserted obliquely into the aneurysm dome, and blood is suctioned through the aneurysm while the needle is in position. This technique aims to decompress the wall of the aneurysm, and therefore one can place easily the clip. We can look up for occlusion by closing on the suction and see if the aneurysm is still fed.

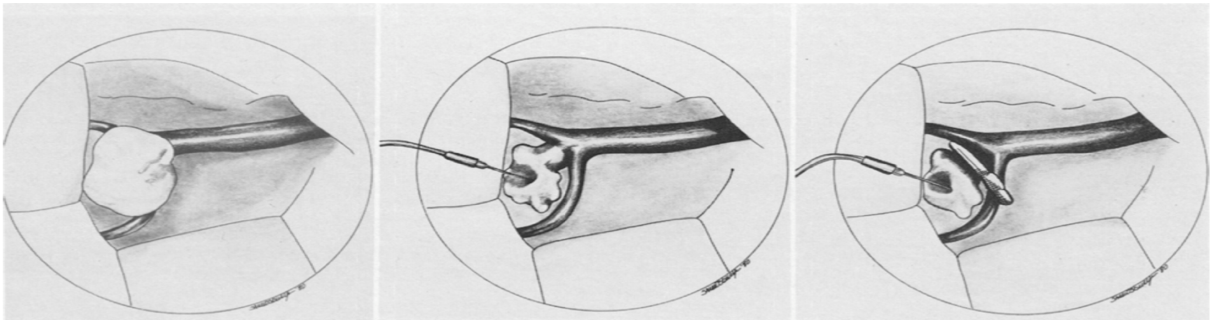

Figure 14 : *" Decompression of the aneurysm by suction allows good visualization of the neck and adjacent vessels. The aneurysm is then clipped with suction still in place".*

Since the introduction of this technique, severe modifications have been made. In 1992, Kyoshima [62] published a revised version of the suction decompression technique previously described by Flamm. The puncture needle is created by modifying an intravenous catheter, which is made from a plastic catheter and an internal needle.

When the internal needle is withdrawn, a valve stops blood from spilling, and a lateral tube allows blood from the aneurysm to be aspirated (Figure 15).

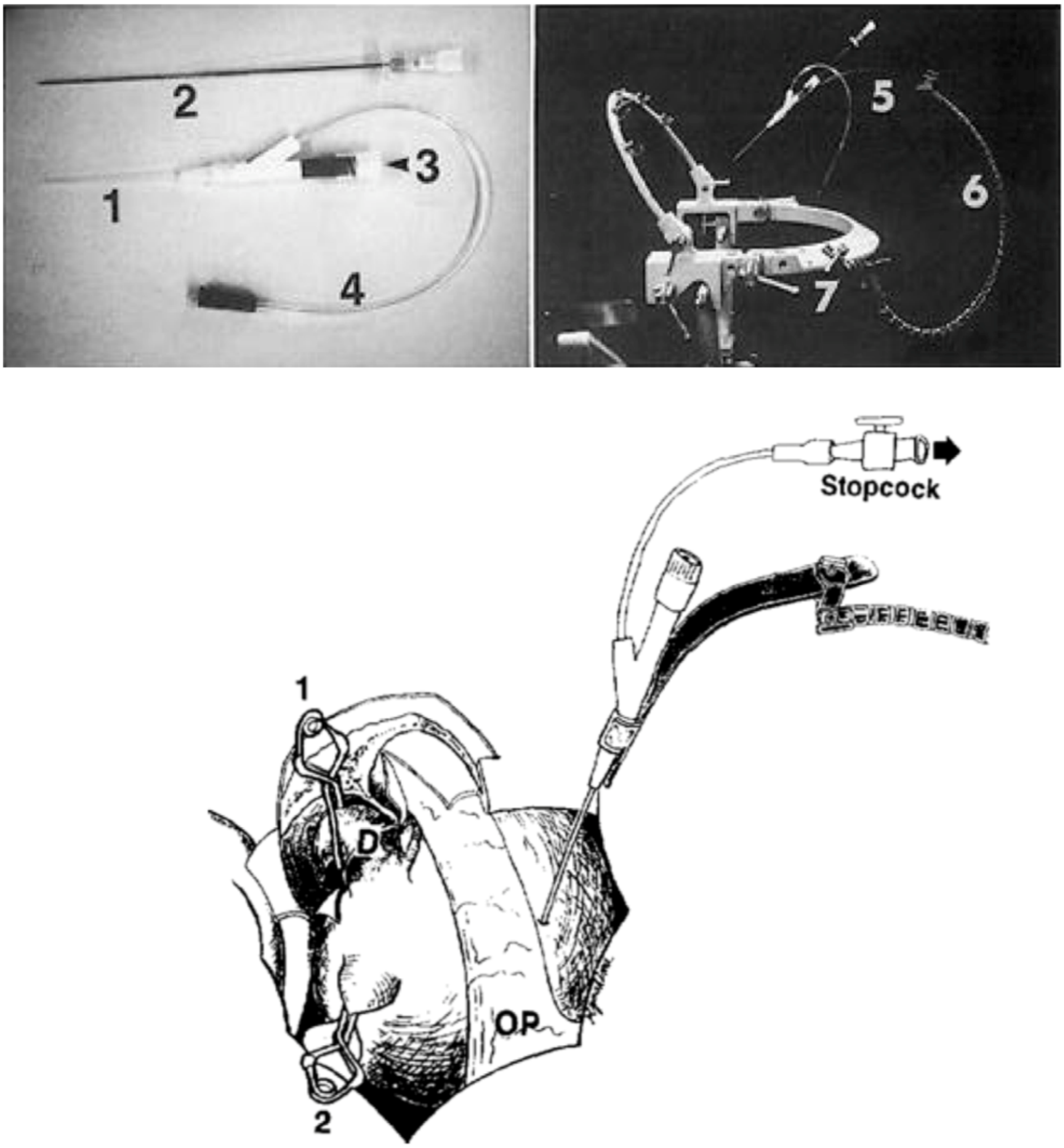

Figure 15 : *Drawing of the puncture needle after removal of the internal needle (Jell) and after attachment to the fixation system Oighl). 1 = catheter: 2 = internal needle; 3 = valve for preventing leakage of blood; 4 = lateral tube; 5 = tapered brain spatula: 6 = lightweight tapered self-retaining retractor of titanium; and 7 = head frame***.**

The following are the benefits of this method:

– The needle's catheter can be firmly maintained by a fixation system, allowing the surgeon to work hands free and modify the catheter position if it disturbs the surgeon's perception.
– Continuous aspiration can be conducted despite temporary trapping of the parent artery when there is retrograde blood flow through the ophthalmic artery, posterior connecting artery, or other branch of the artery that replenishes the aneurysm.
– The tip of the plastic catheter only damages the aneurysm wall at the perforation point. In giant ICA aneurysms, temporary check of the proximal ICA is generally in the extracranial neck of the neck, and intracranial prisoner of proximal control appears to be delicate in this setting.

For large aneurysms when intracranial access of proximal control looks delicate, temporary clipping of the proximal ICA is usually done extracranially in its cervical segment. However, they discovered that exposing the infraclinoidal section of the carotid artery after removing the anterior clinoid process provides acceptable proximal control of the ICA in recent studies. Furthermore, when intracranial proximal control seems a bit challenging, anterior clinoidectomy is advised to complete occlusion of the aneurysm thus avoiding ICA stenosis. Oxycel packing and head elevation are used to reduce cavernous sinus bleeding.

8) Bypass cases:

Direct clipping was achievable in the majority of instances (38 percent 71 percent) in published series [18], [63], [64]. For a full work up of the angio-architecture, combined 3D DSA, CTA, and MRI data are required [52], [65], [66]. Clipping is not recommended when large M1 aneurysm extends into the frontal lobe and involves the lateral lenticulostriate arteries, and this is actually quite the case where bypass surgery. should be given a thought. Aneurysms with a heavily calcified wall represent another good indication for this technique.

The giant M1A often protrudes into the middle cranial fossa, distorts the anatomy within the Sylvian fissure, displaces the M1 upward and inward, and lacks the lateral lenticulostriate arteries. In these cases, consider clipping, possibly supported by a preoperative bypass [67]–[70].

Preoperative high-flow EC-IC bypass with ELANA (excimer laser-assisted non-occlusive anastomosis) or SELANA technology (suture-free excimer laser-assisted non-occlusive anastomosis) must be considered if MCA or one of its major branches is sacrificed Treatment of giant MCA aneurysms that cannot be clipped [71]. The excimer laser-assisted high-flow bypass anastomosis technique is an innovative tool for cerebrovascular surgery. The use of excimer laser-assisted non-occlusive anastomosis facilitates the establishment of vein-graft-arterial anastomosis without temporarily occluding the recipient artery.

The STA or occipital artery for a low-flow bypass and the radial artery or saphenous vein graft for a high-flow bypass can supply various amounts of blood flow into the MCA region depending on the donor arteries used. The best vessel for a high-flow bypass is determined both by physiology and the habits of the neurosurgeon. A saphenous vein graft is not suggested when an anastomosis is made for a less than two milimeters artery [69], [72]. STA-MCA bypasses are easier to do than high-flow bypasses and remain a successful procedure for long-term patency with much lower procedural morbidity. [73].

9) Cost dilemma:

Giant intracranial aneurysms (GIAs) are most likely associated with the highest treatment costs of all intracranial aneurysms in the literature.

Familiari et al [74] reviewed three retrospective analysis performed in neurovascular centers (Rome, Deggendorf, Berlin) from the international GIA Registry conducted between April 2004 and March 2014.

Patients were eligible if:

- IA > or = 25 mm
- surgical or endovascular treatment

The treatment strategy for each patient wasn't standardized. Therefore, each study center decided on the type of treatment independently. Implants used per patient were more expensive in the endovascular group than in the surgical treatment group:

($20 885 vs $167). Treatment costs were associated with the type of treatment and GIA location but not with patient age, sex, or GIA size. Endovascular GIA treatment produced higher direct costs than surgical GIA treatment mainly due to higher implant costs.

In 2018, Spencer et al published a retrospective analysis in which they reviewed surgical and endovascular treatment of ruptured and unruptured intracranial aneurysms. Total cost, subcategory expenses, and prospective cost drivers were all assessed and reviewed. 514 aneurysms were treated in 469 individuals. Aneurysms were clipped in 53 percent of cases (273 aneurysms), coiling in 20% of cases (102 aneurysms), and flow diverter in 27% of cases (139 aneurysms).

MCA aneurysms were the most common in the clipping group (29.7%), AcomA aneurysms were the most common in the coiling group (30.4%), and ICA aneurysms were the most common in the flow diverter group (63.3%). Coiling was more expensive than flow diversion or cutting. Coiling cases are 1.5 times more expensive than clipping, while flow diversion is 1.2 times more expensive than clipping.

Clinical outcome

Patients with aneurysmal SAH have a death rate of approximatly 30% even with rigorous therapy. After getting aSAH care, only one-third of patients were able to do everyday activities independently, and only 16 were able to accomplish the same activities then before the hemorrhage. Rebleeding, delayed cerebral ischemia (DCI), hydrocephalus, and meningitis are all factors that contribute to poor prognosis [75]. The World Federation of Neurosurgery Societies (WFNS) scale or the modified WFNS grading scale (Table 1) [76], a 15-point Glasgow Coma Scale (GCS) constructed from a 5-point scale of neurological impairments [77]. can be used to assess neurological state on admission. The quantity of blood, might contribute to poor neurological condition on admission. and inducing hydrocephalus. The modified Rankin scale (Table 2) [78] can be used to assess clinical outcomes following aSAH. This is a six-point scale that assesses patients' functional (in)dependency following SAH, depending on their ability to do typical daily activities (0 = no symptoms, 6 = death). The five-point Glasgow Outcome Measure (GOS) (1 = death, 5 = low impairment) [79] is a comparable scale that is also often used.

Table 2 *Comparison between the original and modified WFNS grading scale for aneurysmal subarachnoid hemorrhage [76]*

Grade	Original WFNS	Modified WFNS
I	GCS 15	GCS 15
II	GCS 13-14 w/ focal neurological deficits	GCS 14
III	GCS 13-14 w/o focal neurological deficits	GCS 13
IV	GCS 7-12	GCS 7-12
V	GCS 3-6	GCS 3-6

Table 3 *Modified Rankin Scale [78]*

Score	Description
0	No symptoms at all
1	No significant disability despite symptoms; able to carry out all usual duties and activities
2	Slight disability; unable to carry out all previous activities but able to look after own affairs without assistance
3	Moderate disability; requiring some help but able to walk without assistance
4	Moderately severe disability; unable to walk without assistance and unable to attend to own bodily needs without assistance
5	Severe disability; bedridden, incontinent and requiring constant nursing care and attention
6	Dead

Aims and objectives

To analyze the prevalence, the clinical and radiological data of all patients admitted for MCA aneurysms.

To review clip first policy in management of MCA aneurysm at Hôpital des Spécialités, University Hospital of Rabat from January 2015 to December 2021.

Methods

42 patients with MCA aneurysms treated at Hôpital des spécialités during 7 years (2015 - 2021) were included in the study. The available medical records were used to conduct a retrospective study of the demographic features, clinical characteristics, radiological data, baseline cognitive functioning, type of operational procedures, complications, and postoperative outcome. Severity of clinical presentation was assets using WFNS scale.

Upon admission, all subjects had a CT scan of the head. Severity of hemorrhage was graded according to the Fisher scale.

MCA aneurysms were confirmed by DSA with rotational 3D angiography combined with or without CT/MR angiography. Aneurysm size, shape, side, number and site were detailed. Site of the aneurysm was coded by the neurosurgeon into one of the following categories: (1. M1 aneurysm, (2. Bifurcation aneurysm and (3. Distal aneurysm. Follow up status was assessed with the modified Rankin Scale.

The data collected were gathered using excel and SPSS.

Statistical analysis was performed using SPSS for MAC IOS, version 2016 (SPSS, Inc, Chicago, IL, USA). Categorical variables were expressed as number and percentage and the qualitative variables as mean +/- standard deviation.

For comparison between two groups, we used the Chi-square test and non-parametric correlation tests were used to compare two groups. The analysis was significant when $P \leq 0,05$.

Results

A total number of 42 patients were treated for MCA aneurysms from January 2015 to December 2021. Twenty-one males and females. Average age at presentation was 47 (6-88) years. Four patients were under the age of 18 years.

Average interval between the onset of symptoms and the time of consultation was 15 days (1-22 days).

6 patients were smokers and 9 were known to have high blood pressure. No family history of SAH/intracranial aneurysms to report in this study. One patient had a history of ischemic cardiopathy. No medical history what so ever noted in 25 patients.

Thirty-nine patients presented with SAH and 14 patients presented with hemiparesis at the time of admission. Headache was the commonest symptom which was present in all patients with SAH. Only 3 patients (7,1%) had a history of seizures at presentation. At admission 21 patients were grade I of WFNS scale (50%), 9 were grade II and III (21,4%), and 3 were grade IV (7,1%).

Table 4 *Clinical features*

Clinical features	**Nb of patients**	**%**
Sex		
Female	21	50
Male	21	50
Age		
<60 YO	26	62
>60 YO	16	38
Risk factors		
None	25	59,5
Smoking	6	1,4
Hypertension	9	21,4
WFNS		
I	21	50
II	9	21,4
III	9	21,4
IV	3	7,1
Motor deficit		
No	28	66,7
Yes	14	33,3
Epilepsy		
No	39	92, 9
Yes	3	7,1

I. COMPUTED TOMOGRAPHY SCAN FINDINGS:

Preoperative CT revealed Fisher grade 4 in 20 patients (47,6%), grade 2 in 9 patients (21,4%) and grade 3 in 8 patients (19%) and grade 1 in 5 patients (11,9%) (Table 4). Half of the patients had intracranial hematoma and 5 patients had intraventricular hemorrhage (11,9%). Three patients had hydrocephalus preoperatively (7,1%).

Table 5 *Fisher grading*

FISHER GRADE	NB	%
I	5	11,9
II	9	21,4
III	8	19
IV	20	47,6

II. ANGIOGRAPHY:

Cerebral angiography was performed in all patients. Four patients had other associated aneurysms (9,5%). Aneurysm was found in right side in 18 patients (42%) and in left side in 24 patients (58%).

Nineteen patients had aneurysm in MCA bifurcation (45,2%), 15 patients with proximal M1 aneurysms (35,7%), and only two distal aneurysms (4,8%). Therefore, MCA bifurcation was the commonest site of MCA aneurysms in our study.

Mean size of maximum diameter of aneurysm was 7,6mm (2-26,6mm). Aneurysm was <7mm in 19 patients and >25mm in one patient. Fifty seven percent of the aneurysms had wide neck (defined as neck diameter more than

4mm). Radiological vasospasm was present in 42,9% of cases. Four patients suffered from multiple aneurysms (11,1%), either bilateral sylvian aneurysms or any other localization (ICA).

***Table 6** MCA aneurysm caracteristics*

Aneurysm caracteristics	Nb	%
MCA bifurcation	19	45,2
Proximal M1	15	35,7
Distale	2	4,8
Right MCA	16	38,1
Left MCA	23	54,8
MCA aneurysm + other locations	1	2,4

III. MANAGEMENT STRATEGY:

The treatment strategy was assessed by experienced neurosurgeons within the same team. Surgery was performed by the same leading surgeon. Microsurgical clipping was the first-choice treatment (Table 5). 81% of patients were operated (eight of whom received treatment within 72 hours).

The choice of surgical treatment was based on the following criteria:

- Complex aneurysm's angioarchitecture and an existing endoluminal thrombus
- Presence of one or more arteries arising directly from the sac for which a careful dissection and an adequate clipping strategy was required in order to preserve them
- Clinical status (mRS)

Only 1 patient received endovascular treatment justified by its fusiform angioarchitecture of the aneurysm which represent 1,1% of all endovascular cases for the same period.

For patients with bilateral MCA aneurysms, the aneurysm responsible for hemorrhage was identified by blood distribution on CT imaging. The responsible aneurysm was treated firstly. Second-stage treatment was performed for the contralateral aneurysms in the same year. An EVD (External Ventricular Drainage) was placed in one patient with hydrocephalus before operative intervention.

Standard Pterional craniotomy was the procedure most commonly performed. Thirty-four patients underwent clipping alone, either single or multiple. Three patients underwent clipping with additional thrombus removal. Five patients underwent clipping with tandem reconstruction. Five patients had premature aneurysm rupture during dissection. Total exclusion was obtained in 32 patients and partially in only 2 cases due to complex aneurysm architecture.

Table 7 *Management strategy*

Management strategy	**Nb of patients**	**%**
Clipping	**34**	**81**
• *Intraoperative rupture*	5	12
• *Thrombus removal*	3	7,1
• *Reconstruction*	5	12
• *Total exclusion*	32	76,1
• *Partial exclusion*	2	4,7
Embolization	**1**	2,4
Not treated	7	16,6
EVD placement	1	2,4
Total	42	100

IV. CLINICAL OUTCOMES

The mean duration of hospital stay was 24,55 days (range, 2-60 days). In postoperative period, 50% of patients were mRS 0 with no clinical symptoms, 4 were mRS 1 (9,5%), 2 were mRS 2 and 3 were mRS 3, 4 and 5 (Table 6). We report 11 deaths mainly due to severe vasospasm leading to bad initial clinical status prior to surgical management.

Table 8 *Post operative mRS*

Score	Description	Nb of cases	%
0	*No symptoms*	21	50
1	*No significant disability despite symptoms; able to carry out all usual duties and activities*	4	9,5
2	*Slight disability; unable to carry out all previous activities but able to look after own affairs without assistance*	2	4,8
3	*Moderate disability; requiring some help but able to walk without assistance*	1	2,4
4	*Moderately severe disability; unable to walk without assistance and unable to attend to own bodily needs without assistance*	1	2,4
5	*Severe disability; bedridden, incontinent and requiring constant nursing care and attention*	1	2,4
6	*Death*	11	26,2
Total		42	100

Nine patients developed neurological impairment post operatively either due to massive MCA infarct or meningitis in 5 cases. None of the patients developed rebleed during follow up.

Within the 14 patients admitted initially with hemiparesis, 7 patients gained normal motor functions post operatively whereas the other had residual paresis.

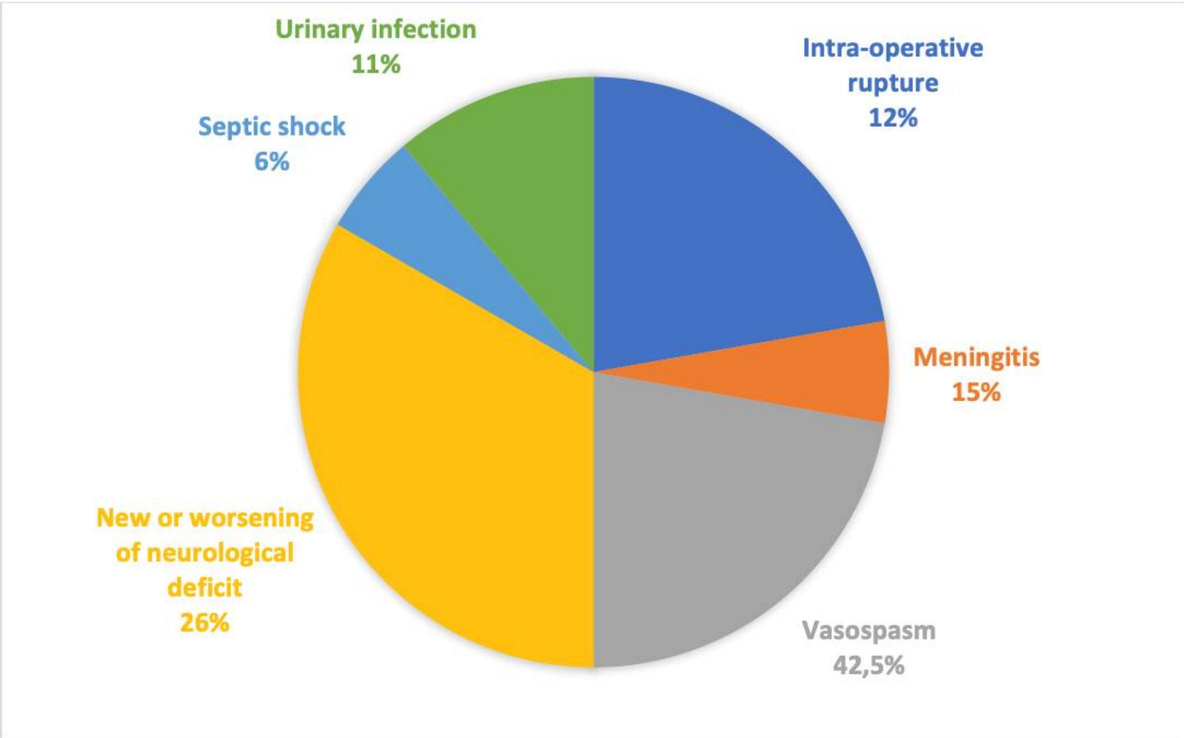

Figure 16 *Complications*

V. ANEURYSM OUTCOMES

Since Clips were applied under direct microscopic vision with time for manipulation and proper placement of definitive clips, no angiogram was needed unless the surgeon was not satisfied. No significant residual aneurysm or recurrence was noted in follow up images.

One patient developed massive MCA infarct following surgery with subsequent brain edema. Decompressive craniectomy was done. The patient remained vegetative and later died of pneumonia.

VI. PREDICTIVE FACTORS

SPSS Khi-square test showed the following predictive factors of poor neurological outcome at last follow-up:

- Increasing age: On clinical progression postoperatively we noted that, patients aged 60 years or more fared better than those under 60 years of age ($P < 0.05$).
- Increasing WFNS grade
- Increasing modified Fisher grade
- Angiographic vasospasm

The choice of treatment has no significant predictive value ($P > 0,05$). The fact that surgery was the major management option for aneurysms in our study is the reason behind it.

Table 9 Predictive factors

Predictive factors	mRS improved	mRS unchanged	mRS worsened	Death	*P* value
Age					
• <60 YO	12	6	2	6	*0,032*
• >60 YO	8	0	3	5	
WFNS					
• I – II	16	4	3	2	*0,045*
• III – IV	1	1	6	9	
FISHER					
• I – II	9	12	2	3	*0,038*
• III - IV	1	0	7	8	
Treatment					
• Clipping	18	8	5	5	*0,405*
• Coiling	0	0	1	1	
Vasospasm					
• Yes	5	1	17	10	*0,01*
• No	8	0	0	1	

Discussion

1. DEMOGRAPHICAL FEATURES:

Aneurysms are more frequent in women in their fourth and fifth decades. In our study, the average age at presentation was 47 (688) years. Eight of the 42 cases were under the age of 30 (19%), which is greater than the average rate of other aneurysms among young people. In our research, we found no evidence of a gender imbalance.

2. PATHOGENESIS:

The high prevalence of circle of Willis aneurysms is believed to be the consequence of increased hemodynamic pressure, particularly at branching locations. The greater occurrence of these aneurysms in individuals with high blood pressure is probably the reason. MCA vascular weakness as a result of atherosclerosis, viral embolism, and connective tissue illness is thought to be a prevalent cause of MCA aneurysms [50] [80]–[85].

Six (1.4 percent) of our patients were smokers, and nine (21.4 percent) were known to deal with high blood pressure. There was no familial history of connective tissue illness or intracranial aneurysm in any of our patients. There was no evidence of infectious pathology at the aneurysm site or a cardiac infectious embolus in any of the patients.

One patient also had aneurysm at a different location, and one patient had several aneurysms, accounting for 4,2 percent of patients with multiple aneurysms. Though this rate is lower than the. one reported by Dashti et al [47] for distal MCA aneurysms (74 percent), it is much higher when compared to the rates reported for other aneurysms.

3. CLINICAL AND RADIOLOGICAL FEATURES:

As described by Hook and Norlen [17] for MCA aneurysms, all 39 patients who suffered from SAH (92%) presented with holocranial headache with no distinct laterality. In their study of MCA aneurysms, Hook and Norlen found that 80% of the patients had localized abnormalities such as hemiparesis, aphasia, facial paralysis, and visual field deficiencies. The bigger size, presence of thrombi creating embolic infarcts, and higher incidence of parenchymal hematoma causing mass effect were thought to be responsible for the increased incidence of focused impairments with MCA aneurysms. At the time of presentation, 33,3% of our patients had a focal impairment, which is significantly lower than the rate reported by Hook and Norlen.

The presence of intracerebral hematoma explains why the majority of our patients (almost 50%) had Fisher grade 4 on admission. The total incidence of hematoma associated with MCA aneurysms has been reported to vary from 30 to 50 percent in the literature. MCA aneurysms associated with hematoma are found in 50 percent of cases, according to Dashti et al [47]. Our serie demonstrate that 64,3% of patient with hematoma developed a focal deficit. This means that the presence of hematoma alone could not explain all cases of focal deficit at presentation. Another explanation could be infarcts due to emboli from intraluminal thrombi rather that mass effect due to hematoma or giant size of an aneurysm.

Mean size of the MCA aneurysms in our study was 7,6mm (2 - 26,6mm) which is more than the reported size for distal MCA aneurysms by Horiuchi et al (2 - 10 mm (mean 4.9 3 mm)) [70] and Dashti et al [46]. It is also more than the mean size of proximal MCA aneurysms as we learned by Dashti et al study [47] . The incidence of giant aneurysms was 45.2% in our patients, which is greater than the same authors' stated incidence. Despite the fact that these aneurysms might get larger before rupturing or showing clinical symptoms, the risk of rupture is still substantial even when the size is less than 5mm.

4. SURGICAL OPTIONS:

Because of their great size, multilobed fundus, broad neck, fusiform shape, and emergence of distal branches from the fundus, middle cerebral artery aneurysms have a tricky angio-architecture. The presence of a hematoma complicates the anatomy even further. These features make it challenging to treat these aneurysms. Management of such patienst should be determined on a case-by-case manner. Clipping was always explored first in our study whenever possible. As a result, only one of our patients was evaluated for endovascular therapy due to factors such as a large neck, complicated architecture, and distant branches issuing from the neck, which were observed in the majority of our patients.

All of our patients received a transsylvian pterional/frontotemporal craniotomy. We discovered that clipping alone could suitable in 78.5% (33 patients), either with a single clip or many clips in tandem manner. Partial clipping was performed on patients with multilobulated aneurysms with distant branches emerging from the fundus (4,7% 2 individuals). Incision of the aneurysm's dome and further evacuation were necessary for giant aneurysms with intraluminal thrombus. If hematomas had already appeared along the temporal gyrus or the sylvian fissure, they were drained first before clipping. It's possible that applying the clips with just a partial evacuation of the hematoma over the neck would suffice. Once the final clip has been placed, the hematoma can be further evacuated. MCA aneurysms are rarely treated with endovascular therapy. Despite the positive outcomes reported by Iijima et al [86], Lubicz et al [87] and Susuki et al [53], the majority of these aneurysms were small and had a narrow neck.

5. OUTCOME:

66,7% of our patients had good mRS (0-3) during follow up which is comparable to the results of series by Baskaya et al [88] and Yasargil et al [53] on MCA aneurysms.

We found that 65% of patients who presented with WFNS grade I had an mRS of 0 and 1 at follow up. Patients younger than 60 years old improved mRS score post operatively at follow-up. 46,15% of those cases improved their mRS (P value < 0,05). Therefore, we can conclude that there is a significant correlation between younger age and good neurological outcome after surgery. Same goes for FISHER scale (P value = 0,038) and vasospasm (P value = 0,01). We had 17 cases of worsening mRS grade regardless of the management and whether the patient was operated or not.

Other variables such as sex, the presence of hematoma, the shape of the aneurysm, and the surgical procedures used had little bearing on the result.

Limitations

First of all, due to the fact that our study is retrospective, many data remain missing and the patients could not be followed up in a timely manner under our control. Some data were missing, making it difficult to perform statistical tests. Our small number of patients does not allow us to generalize the study since it requires a large-scale randomization.

In addition, other difficulties we faced were the archiving of patient data. No long term clinical and radiological data were found in their file, thus limiting our study's long-term outcomes beyond clinical discharge, in addition to patients who were lost to follow-up and invalid phone numbers.

Conclusion

Subarachnoid hemorrhage is a life-threatening condition that occurs in about 1 per 10,000 people per year. There are growing concerns regarding which of the following treatment procedures, endovascular coiling or neurosurgical clipping, yields the maximum observed clinical benefits for the patients.

MCA aneurysms represent 27% of all aneurysms encountered in our daily practice. Due to their position within the sylvian fissure, concomitant hemorrhage, generally bigger size, and complicated architecture with several branching arteries coming from the aneurysm, these aneurysms are challenging to deal with. Despite these considerations, clipping and reconstruction remains the best surgical approach in the majority of patients, while additional options such as coagulation or wrapping, as well as excision with revascularization, must be explored in some circumstances.

The surgical therapy has had a positive overall outcome. The presence of vasospasm and the preoperative WFNS grade were shown to be substantially linked with the ultimate result.

Iconography

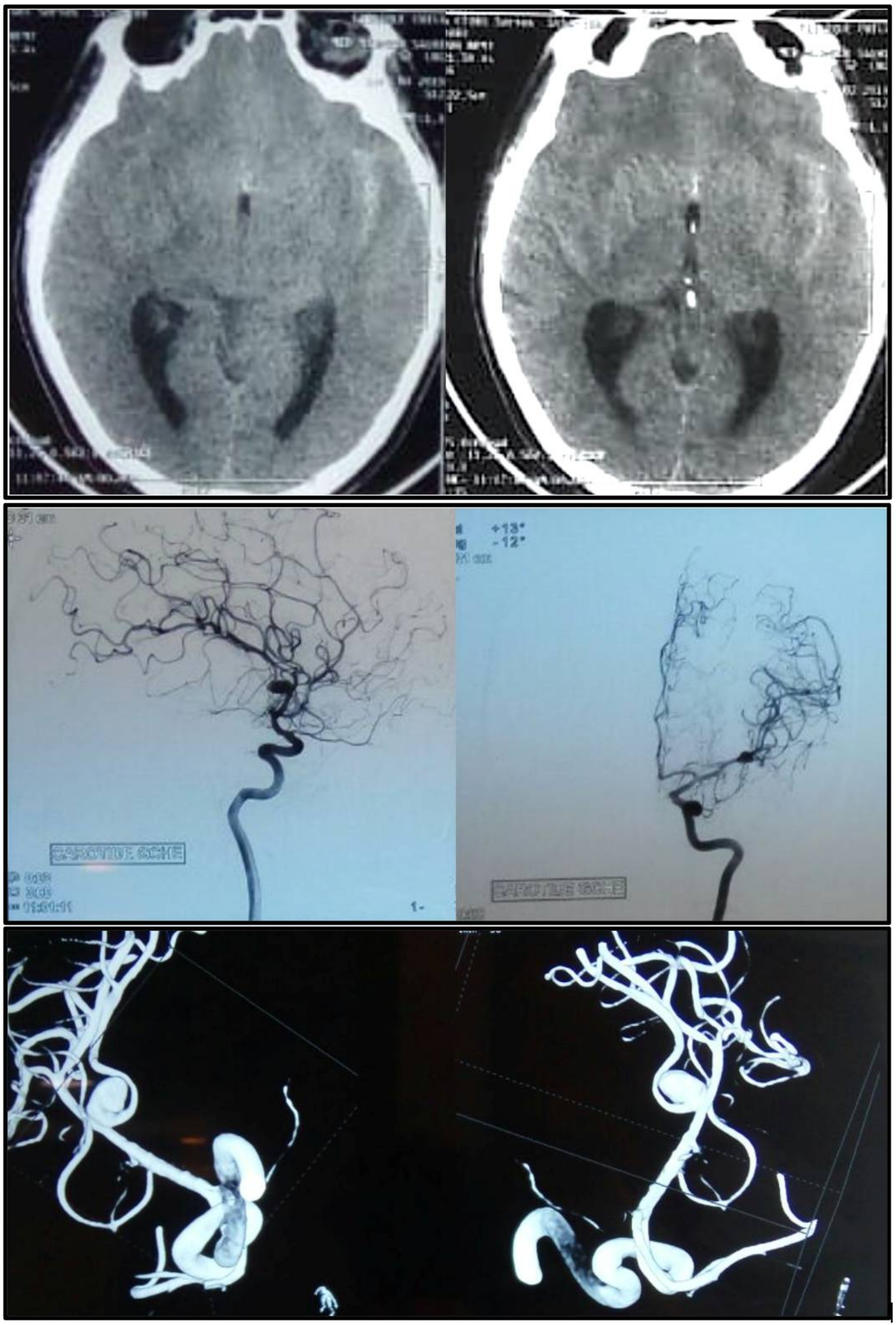

Figure 17 *Case of a 57 yo patient admitted for severe headache. CT scan shows SAH in left sylvian fissure due to a left MCA aneurysm confirmed by DSA.*

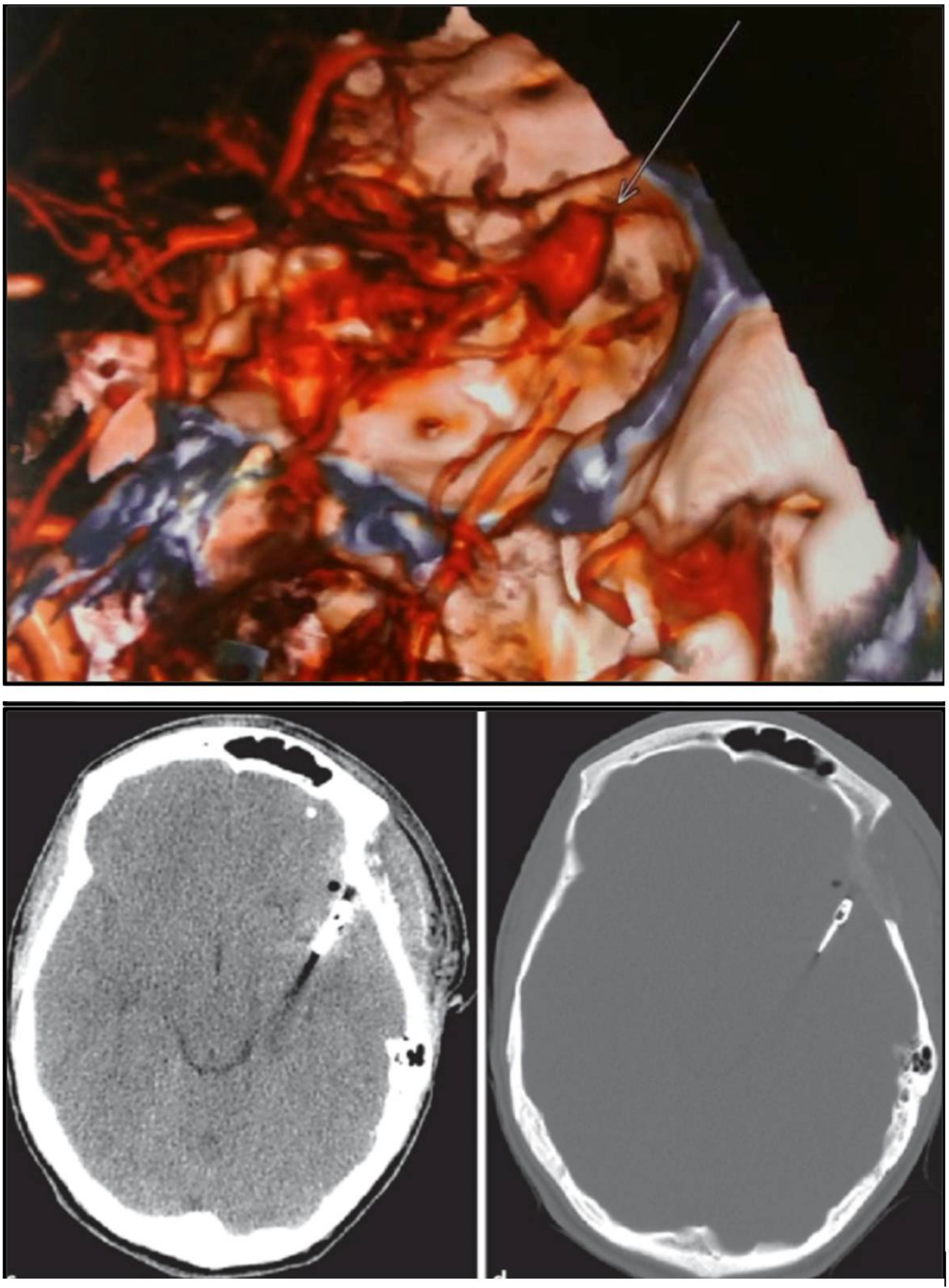

Figure 18 *case of a 25 YO woman admitted to our department with motor aphasia, grade 4/5 right hemiparesis, a Glasgow Coma Scale of 11, and WFNS grade III. Angio-MRI showed a left MCA aneurysm treated microsurgically. (White arrow: aneurysm).*

Abstract

ABSTRACT

Title :CLIPPING AS FIRST TREATMENT POLICY IN THE MANAGEMENT OF MIDDLE CEREBRAL ARTERY ANEURYSMS SINGLE INSTITUTION EXPERIENCE

Keywords: Middle Cerebral Artery Aneurysms, Clip, Endovascular Therapy

Introduction:
Management strategies for intracranial aneurysms have changed dramatically over the past decades. Both with the publication of the International Subarachnoid Aneurysm Trial (ISAT) and the improvement of endovascular techniques, centers have been increasingly adopting endovascular treatment as the primary procedure. Unfortunately, ISAT did not focus on patients with middle cerebral artery aneurysms and optimal treatment modalities are still controversial. However, microsurgical treatment remains well established as the preferred strategy for definitive obliteration of MCA aneurysms.

Objective:
Review of clip first policy in management of MCA aneurysm at Hôpital des Spécialités CHU Rabat from January 2015 to December 2021.

Patients and methods:
We performed a retrospective study of patients managed at our center from January 2015 to December 2021. This analysis included 42 patients with ruptured and unruptured MCA aneurysms treated by the same leading neurosurgeon at the Department of neurosurgery of Hôpital des Spécialités, University of Medicine of Rabat, Morocco. Patients' characteristics and presentation, aneurysms morphology and number were gathered. Chosen management modalities and the patients neurological and radiological outcomes were studied.

Results
Age range was 6 to 88 years with mean age of 47 years. Average interval between the onset of symptoms and the time of consultation was 15 days (1-22 days). At admission 21 patients were grade I of WFNS scale (50%), 9 were grade II and III (21,4%), and 3 were grade IV (7,1%). Motor deficit was present in14 cases (33,3%). Only 3 patients presented epilepsy at admission (7,1%). Four patients suffered from multiple aneurysms (11,1%), either bilateral sylvian aneurysms or any other localization. Wide-necked aneurysm accounted for 57%. Mean size of maximum diameter of aneurysm was 7,6mm (range 2-26,6mm). Microsurgical clipping was the first-choice treatment as 81% of patients were operated (eight of whom received treatment within 72 hours). Only 1 patient received endovascular treatment. In postoperative period, 50% of patients were mRS 0 and we noted 26,2% death mainly due to vasospasm.

Conclusion
The rise of endovascular procedures has led to a significant decline of the surgical caseload.
Nevertheless, surgery should remain the treatment of choice for MCA aneurysms when endovascular management should be considered as alternative therapy.

RÉSUMÉ

Titre : LE CLIPPAGE COMME STRATEGIE THÉRAPEUTIQUE PRINCIPALE DANS LA GESTION DES ANEVRISMES DE L'ARTERE CEREBRALE MOYENNE : EXPERIENCE D'UNE INSTITUTION

Auteur :

Mots clés : Anévrismes de l'artère cérébrale moyenne, clippage, traitement endovasculaire.

Introduction :

Les stratégies de traitement des anévrismes intracrâniens ont changé de façon spectaculaire au cours des dernières décennies. Tant avec la publication de l'International Subarachnoid Aneurysm Trial (ISAT) qu'avec l'amélioration des techniques endovasculaires, les centres adoptent de plus en plus le traitement endovasculaire comme principale méthode. Malheureusement, l'ISAT ne s'est pas intéressé aux patients présentant un anévrisme de l'artère cérébrale moyenne et les modalités de traitement optimales sont encore controversées. Cependant, le traitement microchirurgical demeure bien ancré comme la stratégie privilégiée pour l'oblitération définitive des anévrismes de l'ACM.

Objectif :

Analyse du traitement chirurgical comme stratégie de choix dans la gestion des anévrismes de l'ACM à l'Hôpital des Spécialités de Rabat de Janvier 2015 à Décembre 2021.

Patients et méthodes :

Nous avons réalisé une étude rétrospective des patients pris en charge dans notre centre de janvier 2015 à décembre 2021. Cette analyse inclut 42 patients présentant des anévrismes de l'ACM rompus et non rompus traités par le même neurochirurgien principal au département de neurochirurgie de l'Hôpital des Spécialités, Université de Médecine de Rabat, Maroc. Les caractéristiques et la présentation clinique des patients, la morphologie et le nombre d'anévrismes ont été recueillis. Les modalités de prise en charge choisies et les résultats neurologiques et radiologiques des patients ont été étudiés.

Résultats

La fourchette d'âge variait de 6 à 88 ans avec un âge moyen de 47 ans. L'intervalle moyen entre l'apparition des symptômes et le moment de la consultation était de 15 jours (1-22 jours). A l'admission, 21 patients avaient un grade I de l'échelle WFNS (50%), 9 avaient un grade II et III (21,4%), et 3 avaient un grade IV (7,1%). Un déficit moteur était présent dans 14 cas (33,3%). Seuls 3 patients avaient présenté des crises épileptiques à l'admission (7,1%). Quatre patients souffraient d'anévrismes multiples (11,1%), qu'il s'agisse d'anévrismes sylviens bilatéraux ou de toute autre localisation. Les anévrismes à collet large représentaient en moyenne 57%. La taille moyenne du diamètre maximal de l'anévrisme était de 7,6 mm (intervalle 2-26,6 mm). Le traitement de premier choix était le clippage microchirurgical, puisque 81 % des patients ont été opérés (dont huit ont été traités dans les 72 heures). Seul un patient a reçu un traitement endovasculaire. En période postopératoire, 50% des patients avaient un mRS 0 et nous avons noté 26,2% de décès principalement dus au vasospasme.

Conclusion

Le développement des techniques endovasculaires a conduit à une baisse significative du recours à la chirurgie. Néanmoins, le traitement chirurgical doit demeurer le traitement de choix pour les anévrismes de l'ACM alors que le traitement endovasculaire doit être considéré comme une alternative thérapeutique.

ملخص

العنوان : المشبك كأول طريقة علاجية لتمددات الشريان الدماغي الأوسط تجربة مؤسسة واحدة

من طرف : سلمى المريشي

الكلمات الأساسية :تمددات الشريان الدماغي الأوسط، مشبك، العلاج داخل الأوعية الدموية.

تغيرت استراتيجيات علاج التمدد الوعائي الدموي في الدماغ بشكل كبير خلال العقود الماضية .بفضل نشر التجربة الدولية للتمددات الوعائية الدموية تحت العنكبوتية (ISAT)وتحسين تقنيات داخل الأوعية الدموية ، اعتمدت المراكز بشكل متزايد العلاج داخل الأوعية الدموية كإجراء أساسي .لسوء الحظ ، لم يركز ISATعلى المرضى الذين يعانون من تمدد الشريان الدماغي الأوسط، كما أن الطرق المثلى لعلاجه لا تزال مثيرة للجدل .ومع ذلك ، يظل العلاج الجراحي الدقيق الاستراتيجية المفضلة ضد تمددات الشريان الدماغي الأوسط.

أهداف :

مراجعة لتقنية المشبك في علاج تمدد الشريان الدماغي الأوسط بمستشفى الاختصاصات المركز الاستشفائي الجامعي بالرباط من يناير 2015إلى دجنبر .2021

مرضى وطرق :

أجرينا دراسة بأثر رجعي للمرضى الذين تمت معالجتهم في مركزنا من يناير 2015إلى دجنبر .2021شمل هذا التحليل 42مريضا يعانون من تمدد الشريان الدماغي الأوسط الممزق وغير الممزق و الذين عولجوا من قبل نفس جراح الأعصاب في قسم جراحة الأعصاب و الدماغ في مستشفى الاختصاصات ، جامعة الطب بالرباط ، المغرب .تم جمع خصائص المرضى و أعراضهم ، و كذا شكل التمددات الوعائية الدموية وعددهن .تمت دراسة طرق العلاج والنتائج العصبية والإشعاعية للمرضى.

النتائج :

تراوحت أعمار المرضى بين 6و 88سنة، وبلغ متوسط العمر 47سنة .كان متوسط الفاصل الزمني بين ظهور الأعراض و وقت الاستشارة الطبية 15يوما (1-22)يوما .(عند الاستشفاء ، كان 21مريضا من الدرجة الأولى من مقياس WFNS (50%) ، و تسعة من الدرجة الثانية والثالثة (21,4%)، و ثلاثة من الدرجة الرابعة .(7,1%)لوحظ عجز حركي لدى 14حالة 33,3)في المائة .(فقط ثلاث مرضى كان لديهم الصرع عند الاستشفاء .(7,1%)سجلت تمددات متعددة عند أربعة مرضى (11,1%)، سواء تمدد ثنائي للشريان السيلفي أو أي موضع آخر .و مثل التمدد الوعائي الدموي واسع العنق نسبة .57%كان متوسط حجم القطر الأقصى للتمدد الوعائي الدموي 7,6مم)النطاق 2-26,6مم .(كان المشبك الجراحي المجهري هو الخيار الأول للعلاج حيث تم استخدامه لدى 81٪ من المرضى)ثمانية منهم تلقوا العلاج في غضون 72 ساعة .(تلقى مريض واحد فقط العلاج داخل الأوعية الدموية .بعد الجراحة ، كان 50٪ من المرضى mRS 0ولاحظنا وفاة 26,2٪ خاصة بسبب تشنج وعائي.

استنتاج :

أدى ارتفاع الإجراءات داخل الأوعية الدموية إلى انخفاض كبير في عدد الحالات الجراحية .بالرغم من ذلك ، يجب أن تظل الجراحة العلاج المفضل لتمدد الشريان الدماغي الأوسط مع اعتبار إجراء الأوعية الدموية الداخلي علاجا بديلا.

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