

Aneurysms of The Middle Cerebral Artery Proximal Segment (M1)

- **Anatomical and Therapeutic Considerations**
 - **Revision of A Series.**
- ## Analysis of a series of the pre bifurcation segment aneurysms

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Aneurysms of the middle cerebral artery represent almost a third of all the aneurysms of the circle of Willis anterior sector. Among them, those located at its so-called M1 segment (from its origin up to the bifurcation) range between 2% and 7% of all the aneurysms. It is highly important to know the anatomy of the M1 segment, as well as of the arterial branches that arise from it, since causing its damage during dissection or occlusion of an aneurysm may determine the neurological sequelae.

The authors of the present work, based on a recent anatomical analysis carried out by one of them (FM), have performed a study of the aneurysms of the M1 segment in a series of 1059 aneurysms treated with surgery along 25 years. At the mentioned location 23 aneurysms were found, which represented 2.2% of the total operated aneurysms. The cases, location of the aneurysms and their relation with the early branches of the middle cerebral artery were studied, as well as the surgical difficulties that they pose.

A review of the scanty bibliography referring specifically to the aneurysms in this topography has been carried out.

Keywords: Cerebral aneurysms. Aneurysms of the middle cerebral artery, M1 segment

Introduction

The middle cerebral artery can be considered as the continuation of the carotid artery after the origin of the anterior cerebral artery or one of the two arteries in which the carotid bifurcates. Due to its anatomical disposition, it follows the carotid artery blood flow direction. The

knowledge of this anatomical and physiological fact is very important when deciding how to treat an aneurysm of the middle cerebral artery (1, 2). From the beginning of the endovascular therapy with coils, the aneurysms of such topography have been those which have posed and still pose most difficulties to endovascular surgeons. They are the aneurysms with the

highest percentages of recanalization and they often demand retreatment, often incomplete and not without complications, during the procedure as well as afterwards. It may be due to these difficulties that, in the cooperative work ISAT, the aneurysms of the middle cerebral artery treated with endovascular therapy are fewer in percentage terms (3, 4, 5, 6, 7, 8, 9). The microneurosurgical practice at the laboratory as well as the experience of neurosurgeons with trans-sylvian approaches make the surgical treatment of aneurysms of the middle cerebral artery not to pose major technical difficulties and thus leads to good surgical results. For the reasons above explained, the aneurysms of the middle cerebral artery are considered, in the first instance, for conventional surgery (10, 11, 12, 13).

Most of the aneurysms of the segment are located at the level of the middle cerebral artery bifurcation, that is, at the M1-M2 union. A low percentage are proximal, that is, at the M1 segment, which starts from the origin of the artery up to its bifurcation, and the same can be said about distal aneurysms (M3 and M4 segments). The latter present a different etiology from that of most of the aneurysms and are not the subject of the present study.

The aneurysms of the proximal segment of the middle cerebral artery (M1) are linked at their origin to the so-called 'early branches' of the artery. The predominating arteries are the anterior temporal artery and the small perforating arteries that irrigate the basal ganglia region (14, 15).

Although the percentage of aneurysms of the M1 segment is very low (2% to 7% of the total aneurysms), it is very important to know their relations and their origin according to their topography and direction, in order to know to which artery they are linked, which must be sought and respected during the dissection and clipping or the endovascular occlusion, and so to avoid neurological sequelae, many of them invalidating (14).

The authors of the present work found, in a series of 1059 aneurysms, that those located at the middle cerebral artery were 254 (24%) and among these only 23 (2.2%) were proximal. An analysis of the M1 segment aneurysms of the series, as well as the difficulties that they pose

during treatment has been performed, and a comparative study with bibliography found on the matter has also been carried out.

Results

Throughout a period of 25 years (1986-2010) the senior author in this study (ES) operated a total of 859 aneurysms. Besides, he has actively taken part in the surgeries of other 200 aneurysms performed by neurosurgeons of the service.

Out of 1059 aneurysms, 254 were aneurysms of the middle cerebral artery, which represented 24% of the total.

Of these 254 aneurysms, 23 were located in the proximal segment of the middle cerebral artery (M1). This means that aneurysms located in the M1 segment represented 9% of the aneurysms of the middle cerebral artery and 2.2% of the total operated aneurysms. These percentages did not substantially differ from those found in the bibliography.

The M1 segment aneurysms were related at their origin to the anterior temporal artery or to perforating lenticulostriate branches. The anatomical pattern in all the patients in this series showed a long M1 segment with its bifurcation at the opercular level. Most of the aneurysms linked to the anterior temporal artery were directed upwards, whereas those related to the small perforating arteries were directed downwards or towards the sides, embedded in the parenchyma. The whole series was studied with digital angiography of cerebral vessels.

Small aneurysms prevailed (under 10mm) as only 4 giant aneurysms were found. It is worth highlighting that 15 of the aneurysms had a broad neck, this being a determining factor for the choice of treatment to be carried out (surgery with clipping of the vascular malformation).

Regarding the topography of these aneurysms, 12 were located at the origin of the anterior temporal artery, 11 at the lenticulostriate arteries origin.

In 14 patients (out of the 23 aneurysms of the M1 segment) another aneurysm was present. In other three, there were two more aneurysms. Most of the cases of multiple aneurysms had the other aneurysm on the same side of the M1

aneurysm, even in the same artery (middle cerebral artery bifurcation), thus being difficult to determine which one was responsible for the bleeding prior to the surgery. Anyhow, the team's choice is always to attempt the clipping of all the aneurysms during the same surgical act, even in those cases with contralateral malformations.

Topography of multiple aneurysms:

14 patients (2 Aneurysms): M1:14; M1-M2 homolateral:6; Post Communicating Artery homolateral:2; Carotid Bifurcation homolateral:2; Anterior Communicating Artery:1 and Contralateral M1-M2:3 patients.

3 patients (3 Aneurysms): M1:3; one with M1-M2 and Posterior Communicating Artery and the other 2 with Anterior Communicating Artery and contralateral M1-M2.

Except one, the rest of the cases were diagnosed on the basis of the bleedings. The one that did not bleed was investigated for headaches with a CT and an image suspicious for an aneurysm was found.

Concerning the bleedings, five cases presented with parenchymatous haematomas, a bleeding which prevailed upon the subarachnoid haemorrhage. The rest of the cases presented with the typical features of subarachnoid haemorrhage, both clinically and radiologically/

Preoperative clinical condition:

WFNS Scale: Grade I: 7 patients; Grade II: 4 patients; Grade III: 6 patients and Grade IV: 5 patients. In one patient, the aneurysm was found without bleeding.

In all the cases of parenchymatous haematomas, the aneurysms were directed towards one side or downwards, and originated in relation to perforating arteries.

All the patients in the whole series underwent conventional early surgical treatment of the aneurysms (direct clipping), as the authors consider that direct clipping of the middle cerebral artery aneurysms is the best option. In all the cases a classical pterional approach was used. As usual, the M1 segment did not offer dissection difficulties. All the aneurysms in relation to the origin of the anterior temporal artery were of a larger size that those related to the perforating arteries. However the latter made dissection more difficult because of their size

and close relation to the aneurysm

As abovementioned, those originating from the anterior temporal artery or the orbitofrontal artery were directed predominantly upwards. It is worth highlighting that in 4 cases these aneurysms were adhered to the duramater, which forced the surgeon to perform a very careful dissection in order not to provoke the rupture of the malformation right at the beginning of the dissection. It is therefore important to be aware of this contingency in the presence of an aneurysm at the M1 segment related to the said arterial branches, in order to avoid problems during surgery.

All the patients had their postoperative course in the Intensive Care Unit (16 out of 23 in Neurocritical Care Units). Nimodipine and Diphenyl-hydantoin were administered to all the patients. Other medical treatments varied according to the clinical condition.

Two of the 23 patients died. It is worth highlighting that both cases corresponded to severe subarachnoid haemorrhage (WFNS grade IV), where the outcome was related to the severity of the initial clinical condition and not to the surgery itself. Three patients developed permanent neurological sequelae (motor sequelae in two cases and speech sequelae in one case). One of the patients was already having a severe motor deficit at the moment of the surgery, which was linked to a lobar hematoma associated with the subarachnoid haemorrhage. In the two other patients, there was a cerebral infarction of the basal ganglia most likely due to the damage of the perforating arteries during dissection. Two other patients presented with transient motor deficits, but they recovered one month after the surgery. The rest of the patients had a good evolution with no neurological sequelae. They were all controlled during their follow up with angiography or angio-tomography, not evidencing neck remnants in any cases.

Summary of the series:

GOS 1 (full recovery).....	16
GOS 2.....	2
GOS 3.....	3
GOS 5 (died).....	2

Discussion

As is generally known, the vast majority of the cerebral aneurysms are located in the anterior segment of the circle of Willis. In this segment the three most frequent topographies are: the supraclinoid segment of the internal carotid artery, the anterior communicating cerebral artery and the middle cerebral artery. The percentages in each of these locations varies, but in general it could be said that between 25% and 30% are located in each of them (16, 17, 18). Although the cerebral arteries are constant enough in their anatomy and in their relationships, there are anatomical variations and it is also necessary to know about them before undertaking therapeutic gestures. Leaving aside well-known generalities about arteries and aneurysms, the interest of the authors of the present work focuses on the aneurysms located in the middle cerebral artery and more precisely in its proximal segment, also known as M1. It is worth emphasizing that the nomenclature 'M' that designates the segments in which the middle cerebral artery is divided –proximal, pre-bifurcation: M1; post-bifurcation: M2, and beyond: M3 and M4, is derived from an angiographic study with anatomical correlation carried out by a Uruguayan neuroradiologist (Prof. N. Azambuja), who divided the artery in the segments whose denomination is used worldwide nowadays. As they were described in Montevideo (Uruguay), he used the first letter of the city where he developed his study. Since it coincides with "media" (middle, in English) named thus after the middle cerebral artery, the nomenclature was extended to the anterior cerebral artery, and in this case it is referred to as segment A1, A2 (17).

Most of the authors who have carried out anatomical studies of the middle cerebral artery agree on this being one of the least variable arteries. Nevertheless, they describe early bifurcation, trifurcation, quadrifurcation, duplication, single non-bifurcating trunk, hypoplasia, fenestrations, etc. The middle cerebral artery is one of the longest intracranial arteries, considered to be having one of the most extensive irrigation territories in the brain. The artery arises below the anterior perforated

substance, lateral to the optical chiasm. It runs along the sylvian fissure up to the limen insula, where it bends at an angle which can be upto 90° and it is at that point where the bifurcation usually occurs. This first segment of the artery is the one known as M1. It measures between 3 and 30 mm, being an average 15 mm long (1, 2, 14, 19, 20, 21).

At the M1 segment originate what we call the early branches of the middle cerebral artery. Their number is variable. Among the early branches, the most frequent are the temporopolar, the anterior temporal and the orbitofrontal ones. In addition to this, and of minor caliber, are the perforating arteries that irrigate the basal ganglia region (1, 2, 19, 21). It is exactly in relation with the early branches where the aneurysms of the M1 segment usually originate. Their location and direction will be in accordance with the artery they are related to. Despite the scanty bibliography available on aneurysms of the M1 segment of the middle cerebral artery and the low number of this kind of aneurysms treated by the authors of the present study, it is clear that, in principle, the aneurysms of this segment should not pose major difficulties for their treatment (14, 22, 23, 24, 25). As regards the choice of the ideal treatment for these aneurysms, it is necessary to emphasize that, up to date, conventional surgery remains the treatment of choice, with low risk, a very high percentage of complete occlusion and with a low percentage of neurological sequelae. Besides what is already known about the middle cerebral artery, the artery that because of its anatomical disposition and the direction of the flow continues from the carotid, the nondespicable percentages of the aneurysm reopening either with appearance of the neck or due to coil compaction at the base when the endovascular therapy was the choice, lead to opt conventional surgery in principle for the treatment of these aneurysms. It is worth emphasizing that with the constant advances in endovascular therapy and with the help of the placement of stents or other devices at the origin of the aneurysm may, in a probably not so distant future, tip the scales in favor of the endovascular therapy over surgery for these aneurysms (6, 8, 10, 13, 26). However, nowadays evidence shows that surgery in

trained hands has an almost null mortality and a very low morbidity (10, 27, 28, 29); this is said for the aneurysms of middle cerebral arteries in general. The small group that the proximal aneurysms represent (M1 segment), pose a different challenge to the neurosurgeon. A priori, they could be considered simpler to treat (clipping under microscope), provided that it is not necessary to dissect the main divisional branches of the middle cerebral artery. However, by no means is to be under-estimated the fact that these aneurysms arise in relation to the origin of some early artery of the middle cerebral artery. It should not be thought that these early branches are of scanty functional value. As it has been demonstrated in anatomical studies (1, 20) and as the authors analyze the recent study directed by Dr. F. Martínez-, these early branches irrigate eloquent areas of the brain (19). Their damage while dissection (coagulation, for example) as well as their inclusion in the clip that closes the neck of the aneurysm can determine an ischemic lesion with functional repercussion, either transient or permanent. Therefore, when an early aneurysm is diagnosed, surgery must be undertaken with the conviction that it is necessary to seek and respect these early branches during dissection. The main arteries (early temporal, orbitofrontal) usually have a caliber that makes them easily identifiable under the magnified vision of the microscope. An aneurysm originating in one of these arteries must always be dissected for the artery not to remain included in the clip (18, 22, 30, 31). It is worth emphasizing that, unlike other locations, in most of the cases found by the authors these arteries arise at the neck of the aneurysm itself, hence the dissection must be distal to them and, on placing the clip, it is necessary not only to respect them but also avoid their compression, which can lead to a later thrombosis. Even more difficult is the case where an aneurysm arises from a perforating branch, which usually irrigates the ganglio-basal region. These arteries are very small although in relation to the aneurysm and they have a thicker caliber than usual. Since they are small, if surgery is not performed under the microscope with high magnification they may not be identified and thus may get included in the clip, with the

consequent infarction of an area in the basal ganglia region, which may or may not lead to deficits and poor clinical results (15, 16, 17). In addition to this, in the small series of the authors, approximately 70% of the aneurysms had a broad neck (neck/fundus ratio), which is important at the time of placing a clip. It is a well-known fact that a broad-necked aneurysm can determine a compromise in the parent artery or of the branch where it originates at the moment of placing a clip (22, 30, 31). This risk is higher if the related artery is of smaller caliber (17).

Therefore, a good knowledge of the anatomy is indispensable, as well as a careful study of the imaging is required, which must be of good quality in order to identify the branch in which the aneurysm originates and the other branches present at the proximal sector, in order not to damage them during the dissection of the sylvian cistern and to always identify the branch that gives origin to the aneurysm. This branch must be dissected and separated from the neck of the malformation so that it 'does not suffer' at the moment of placing the clip.

On occasions, as it happens in aneurysms of the middle cerebral artery bifurcation, it is necessary to perform transient or temporary proximal clippings in order to facilitate the dissection. Other times it may be necessary to puncture and empty the aneurysm, so as to complete the separation of the efferent branches and to facilitate, through the loss of tension in the aneurysm, the definitive clip placement, with no damage or tightening of the vessels. Therefore, it is necessary that any surgery for cerebral aneurysms and even more those of middle cerebral arteries, includes a neuro-anesthesiologist trained in cerebral protection as well as neuro-physiological monitoring for the control of the cerebral function, both during the temporary clipping and after the placement of a definitive clip. In such way, the surgeon works comfortably and offers the patient better outcomes (28, 30, 31).

Another fact to take into consideration in aneurysms of the proximal segment of the middle cerebral artery is that, in a nondespicable percentage of the cases, the aneurysm is embedded in the cerebral parenchyma. This is more frequent in the aneurysms which originate

in relation to perforating arteries. More than never in these cases the dissection must be always cisternal and without the use of retractors. The separation from the parenchyma can lead to premature rupture of the aneurysm, even before visualizing it or having dominated the neck (22, 27, 29). It is recommended to start the cisternal dissection distal from the aneurysm (for example, at an opercular level), to seek the middle cerebral artery or its efferent branches and to continue along the cistern in proximal direction up to the aneurysm. Even, as it is reached, it is necessary to continue proximally, in order to dominate the artery proximally in case a transitory clipping is necessary. If the dissection is always kept cisternal and without the use of retractors, accidents like bleedings of the malformation can be a rare occurrence. It can be argued that in cases of acute surgery with bleedings, the dissection and vision are not easy. In these cases, a slow and careful dissection is recommended, always following the artery and with continuous irrigation in order to wash away the blood from the cistern and to clear its visualization.

In the aneurysms that originate from the proximal branches of larger caliber, and mainly in the big aneurysms that relate to the anterior temporal or the orbitofrontal arteries, it may be suspected that the bottom of the aneurysm could be in contact with the dura mater or, as happened in one of the cases operated by the authors, be firmly adhered to it. In other three cases of the series there was contact with the dura mater, but the adherence was not firm and it was possible to separate it with dissectors without incidents. In cases like this, the dissection must be very carefully performed right from the opening of the dura mater, which should never be sharply separated from the arachnoid, since this maneuver may cause the aneurysmal rupture, with profuse bleedings, even before starting the cisternal dissection.

Conclusions

As a conclusion, it can be said that the aneurysms of the proximal segment of the middle cerebral artery (M1) represent a small sub-group within the vascular malformations

of this artery. The knowledge about the artery and its early branches is fundamental at the moment of planning and undertaking the surgery of these aneurysms. They should never be considered easy to treat beforehand, since in a high percentage of the cases they are broad-necked. Moreover, they are always related to some early branch of the artery, and in general the origin of these branches is firmly linked to the neck, or even its visualization is hidden by the aneurysm itself. Extreme care must be taken during the dissection, seeking the branch that gives origin to the aneurysm and clipping the malformation distal to that artery in a way not to damage it. Ignorance regarding these facts will unfailingly lead to cerebral lesions, which can lead to permanent neurological sequelae.

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Comments

Middle cerebral artery aneurysms are common neurosurgical problem. Surgery on these aneurysms can sometimes be quite tricky and also dangerous. Wide base, large size and irregular dome are aneurysm related factors that can affect conduct of surgery. Wide exposure, diligent isolation of perforators, prevention of vessel kinking and obliteration and selection of the most appropriate clip are essential for success. More extensive the subarachnoid hemorrhage, more friable is the aneurysm and the chances of intraoperative bleed are higher. The preoperative neurological grade can also determine the course of surgery. Surgery in a patient having hemiplegia is much more difficult when compared to a patient who is neurologically intact. The thinness of the wall of the aneurysm and the extent of vasospasm will vary with the clinical grade of the patient. Majority of these aneurysms are located at the bifurcation or trifurcation of the middle cerebral artery. Pre-bifurcation aneurysms, as reported by the authors, are relatively rare. The intimacy with perforators makes surgery on these aneurysms more challenging. The authors have a large experience with aneurysm surgery. This experience with this unique group of aneurysm will certainly be useful.