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Management of Mirror Middle Cerebral Artery Aneurysms: Surgical Results and Morphological Parameters

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ABSTRACT

AIM: To investigate the safety and applicability of two main methods for treating mirror intracranial aneurysms, based on correlations in their geometric characteristics.

MATERIAL and METHODS: We conducted a retrospective analysis on 125 patients who underwent 138 surgical interventions for MCA aneurysms and were treated with microsurgical clipping and endovascular embolization at the Department of Neurosurgery in the University Hospital "St. Iv. Rilski", Sofia, in 2013–2019. In six of these cases, we observed mirror MCA aneurysms.

RESULTS: All six patients with "mirror" aneurysms were female. In one case, a third aneurysm was observed on the anterior communicating artery; hence, a total of 13 aneurysms were treated. The average age of the group was 48.16 years. All patients had known risk factors, such as high blood pressure and tobacco smoking. Four patients presented with aneurysmal subarachnoid hemorrhage (aSAH). All patients underwent surgical treatment in two stages—with obliteration of the intracranial aneurysm leading to subarachnoid bleeding in the first stage and planned surgical intervention within a month in the second stage to exclude unruptured aneurysms. During the one-month interval, there were no SAH incidents. However, we observed one patient with a postoperative neurological deficit and one with recanalization of the aneurysm on follow-up at 3 months, requiring re-embolization. In both cases, endovascular treatment was performed despite the unfavorable anatomical features (aspect ratio ≤1.5 and neck size ≥4 mm). The clinical outcome, in all operated patients, for "mirror" aneurysms of the MCA was reasonable (mRS: 0-2).

CONCLUSION: The choice of treatment for "mirror" aneurysms should be determined on an individual basis by the clinical manifestations and morphological characteristics of intracranial aneurysms. In cases of aSAH, where "mirror" aneurysms are present, both can be treated safely via microsurgical clipping or endovascular embolization after thorough investigation and ensuring prioritization of the offending lesion.

KEYWORDS: MCA aneurysms, Mirror aneurysms, Microsurgical clipping, Endovascular procedures, Geometrical features

INTRODUCTION

Middle cerebral artery (MCA) aneurysms represent 14–20% of all intracranial aneurysms in the general population. In 2013, Morita et al. reported the incidence of unruptured MCA aneurysms at 36–39% (9,24,26). Patients with multiple aneurysms represent about 12.9–26.4% of all intracranial aneurysms. Furthermore, patients with the so-called "mirror" aneurysms are a subset of this group and are about 2–12% of all cases (2,4,6,15,17,19,28). In the present study, the term "mirror" aneurysms was applied and defined as aneurysms located bilaterally and symmetrically on the same-named arterial vessels (6).

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Patients with SAH and multiple intracranial aneurysms have been reported to have a higher rate of neurological deficits and complications than those with single intracranial aneurysms (13,26). Meissner et al. reported that female patients with mirror aneurysms were more likely to have a family history of aSAH, and these aneurysms showed higher risks of reaching larger sizes than patients with "non-mirror aneurysms" (17).

The most common site of this phenomenon is the MCA bifurcation (M1-M2 segment), followed by the non-cavernous part of the internal carotid artery, and the posterior communicating artery (12,17).

This study aimed to investigate the safety and applicability of the two primary methods for treating mirror intracranial aneurysms, based on correlations in their geometric characteristics.

MATERIAL and METHODS

We conducted a retrospective analysis on 125 patients who underwent 138 surgical interventions for MCA aneurysms treated with microsurgical clipping and endovascular embolization at the Department of Neurosurgery in the University Hospital "St. Iv. Rilski", Sofia, in 2013–2019.

Patient stratification, based on the number of aneurysms was as follows: 83 patients (62.4%) presented with a single intracranial aneurysm and the remaining 42 (37.6%) had multiple aneurysms. Of those 42 patients, six (14.2%) were located bilaterally and symmetrically on the M2 segment of the MCA that fit the description of "mirror" aneurysms. An interdisciplinary team of neurosurgeons and interventional radiologists determined the appropriate treatment—microsurgical clipping or endovascular treatment. Each patient was allocated to what was considered the most appropriate treatment choice, associated with the lowest periprocedural risk, and the highest expected degree of aneurysmal occlusion.

Distribution of patients according to the severity of clinical presentation after aSAH (Table I).

We applied the following radiological measurements as morphological parameters of intracranial aneurysms (Table II):

1. Dome/Neck ratio: correlation between the widest part of the aneurysm dome to the size of the aneurysmal neck.
2. Aspect ratio (AR): correlation of the highest part of the aneurysmal fundus to the size of the aneurysmal neck.
3. Height/Width ratio: based on measurements of the aneurysmal fundus
4. Neck size: the size of the aneurysmal neck (in mm).

All patients underwent surgical treatment in two stages, the first stage included obliteration of the intracranial aneurysm leading to subarachnoid bleeding and within a month, the second stage comprising of planned surgical intervention was performed to exclude unruptured aneurysms. During the one-month interval, there were no SAH incidents (Table III).

RESULTS

All six patients with "mirror" aneurysms were female. In one case, an additional aneurysm was observed on the anterior communicating artery; hence, a total of 13 aneurysms were treated. The mean age of the group was 48.16 years. All patients had known risk factors, including high blood pressure and tobacco smoking. Four of these patients presented with aneurysmal subarachnoid hemorrhage (aSAH) (Table IV).

In our study, we performed 12 aneurysmal occlusion procedures, seven of them underwent endovascular procedures with a succession rate of 85.7%. In one procedure, it was impossible to occlude an intracranial aneurysm using the endovascular technique (flow-diverter stent). In four cases, we used stent-assisted coiling, and in two cases, we used a flow modulation device. For the remaining five cases, microsurgical procedures (temporal clip placement) were used to achieve aneurysmal occlusion.

One patient (case 3) with mirror aneurysms of the two MCA and one aneurysm of the anterior communicating artery developed postoperative neurological deficits with monoparesis of the right leg. In this case, the AR was 1.25, and the aneurysmal neck was 4 mm in size. The patient was selected for primary endovascular embolization of the MCA and anterior communicating artery aneurysms in the same sitting position and secondary microsurgical clipping of the right MCA aneurysm (Figure 1A, B).

In case 1a, a wide aneurysmal neck (8.6 mm) was observed, and despite stent-assisted coiling, suboptimal obliteration of

Table I: Demographic Distribution, Risk Factors and Clinical Manifestation

Case	M/F	Age	Risk factors	Clinical manifestation
1	F	71	Hypertension; Non-insulin dependent (type II) diabetes mellitus	SAH
2	F	30	Hypertension; Tobacco smoking	SAH
3	F	46	Hypertension; Tobacco smoking	SAH
4	F	54	Hypertension	SAH
5	F	46	History of previous SAH; Hypertension; Tobacco smoking	No SAH
6	F	42	Hypertension; Cerebral ischemia	No SAH

Table II: Distribution of Patients According to the Severity of the Clinical Manifestation with SAH

Case	GCS	WFNS	Hunt & Hess	mFisher
1	15	1	2	3
2	15	1	2	2
3	14	2	2	3
4	14	2	2	4

Table III: Morphological Parameters of the Intracranial Aneurysms

Case	Doom/Neck ratio	Aspect ratio	Height/ Width ratio	Neck size (mm)
1a*	1.39	1.81	1.3	8.6
1b	1.23	1.41	1.14	6.1
2a*	1.15	2.94	2.55	3.9
2b	1.1	1.21	1.1	2.8
3a*	1	1.25	1.25	4
3b	1.03	1.89	1.83	2.8
4a*	2.96	4.35	1.46	2.8
4b	1.1	2.73	2.48	1.9
5a	0.94	0.98	1.04	5.5
5b	1.06	1.32	1.24	4.6
6a	1.33	1.62	1.21	4
6b	0.58	0.53	0.91	6

**patient with SAH.*

the aneurysm was achieved. In the third month of follow-up, recanalization was evident, which necessitated reembolization with a flow-diverter stent. In case 6b, we measured an AR of 0.53 and an aneurysmal neck size of 6 mm; endovascular embolization, based on these morphological features, was not feasible. Hence, after an initial unsuccessful embolization, the patient elected to forgo further treatment and remained under routine follow-up with no further evidence of aneurysmal growth (Figure 2A-C).

In all the remaining cases, complete occlusion was observed, even after 12 months of follow-up. The clinical outcomes in all patients, treated for “mirror” aneurysms of the MCA, showed a good mRS score (0–2).

DISCUSSION

The etiology of multiple intracranial aneurysms remains unclear; however, smoking, high blood pressure, female sex, and older age are significant risk factors (8,12,16,27,29). Congenital vascular frailty may be an essential factor in

Table V: Mean Geometric Values in Rupture and Unruptured Intracranial Aneurysm in our Study

	Rupture aneurysm	Unruptured aneurysm
Aspect ratio (AR)	2.588	1.461
Doom/Neck ratio	1.625	1.046
Height/Widht ratio	1.64	1.368
Neck size (mm)	4.825	4.212

Table IV: Relationship Between Outcome and Therapeutic Methods in Patients with Mirror Aneurysms

Case	Treatment method	Complication	Degree of occlusion (RROC)	mRS	1 year follow-up (RROC)
1a*	Stent-assisted coiling	no	2	0	3 †
1b	Embolisation with “flow-diverter”	no	3	0	1
2a*	Clipping (n=1)	no	1	1	1
2b	Clipping (n=1)	no	1	1	1
3a*	Stent-assisted coiling ACOM, MCA sin.	monoparesis of the right leg; cognitive changes	1	2	1
3b	Clipping (n=2)	no	1	2	1
4a*	Clipping (n=1)	no	1	1	1
4b	Stent-assisted coiling	no	1	1	1
5a	Embolisation with flow-diverter”	no	3	2	1
5b	Stent-assisted coiling	subfascial hematoma	1	2	1
6a	Clipping (n=2)	no	1	1	1
6b	Embolisation with “flow-diverter”	Unsuccessful embolisation	4	1	4

** patient with SAH,* ***n:*** *number of microsurgical clips,* ***†:*** *reembolisation at 3 months after the operation of the ruptured aneurysm.*

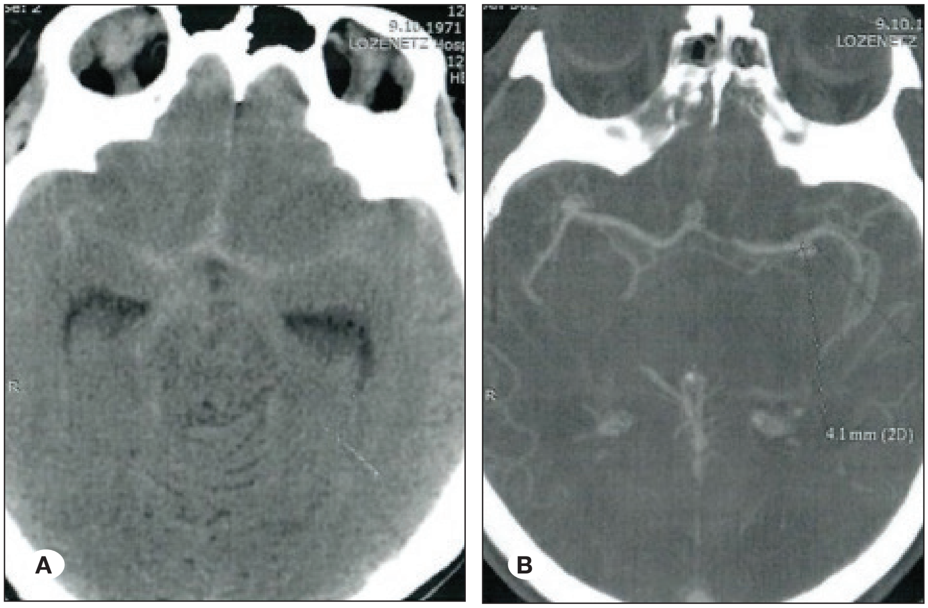

Figure 1: A) Case 3. A massive SAH covering both Sylvian fissures and interhemispheric fissure; 1. **B)** 3D-CT angiography with data for 3 intracranial aneurysms in the right and left middle cerebral arteries and an aneurysm of the anterior communicating artery.

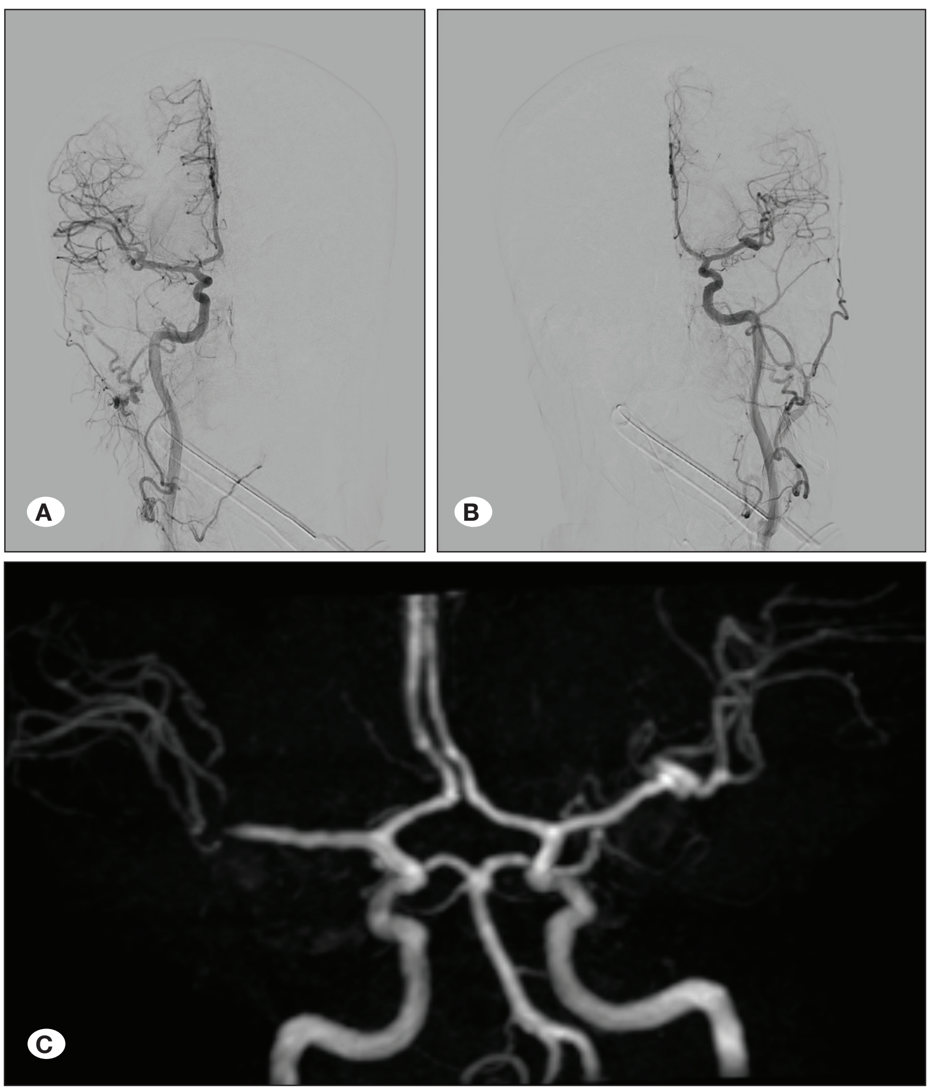

Figure 2: A) Case 6. Clip obliteration of the right middle cerebral artery aneurysm on digital subtraction angiogram (DSA); **B)** unsuccessful embolization of the left middle cerebral artery aneurysm on DSA; **C)** 3D reconstruction of the complex non-embolized aneurysm of the left middle cerebral artery, involving the lower and upper branches of the middle cerebral artery from the aneurysmal neck.

the etiology and pathogenesis of “mirror” aneurysms (29). Various authors have also proposed an embryological predisposition for “mirror” aneurysms (4,23). Baccin et al. described the development of the intracranial arteries of the three embryonic segments—the procephalic, mesencephalic, and rhombencephalic segments—because the intracranial vascular system is composed of different embryonic segments (2). They suggested the concept of “segmental identity,” which explained the vulnerability of different regions of the intracranial vascular tree to specific triggers. Therefore, some diseases may involve specific regions of the vascular system and may spare others. This pathology evolves bilaterally in identical or adjacent arterial segments, suggesting that the lesion is specific during the cephalic segmentation phase (19).

During “mirror” aneurysms management, especially in patients with aSAH, it is crucial to precisely identify the offending lesion. Zderkiewicz et al. found that the accuracy of the examination methods (neurological examination, digital subtraction angiography, computed tomography (CT), and 3D-CT angiography) in terms of determining the source of SAH was only 72.16% (29,32). The correct assessment of the side of aneurysmal rupture determines the subsequent treatment. All patients in the current study were preoperatively evaluated using conventional CT of the head and 3D-CT angiography. It has been shown that the aSAH varies, which necessitates the determination of the exact location when making a preoperative decision. In MCA aneurysms, SAH is usually observed in the ipsilateral Sylvian fissure, with or without an intraparenchymal hematoma. In most cases, the Sylvian fissure on the side of the aneurysmal rupture contains more blood than the contralateral side. However, the aneurysm is usually oriented inward and downward (33). Consequently, blood may be present in the interpeduncular cistern and the contralateral Sylvie fissure, which may lead to erroneous preoperative judgment. This is important when determining the site of rupture in “mirror” aneurysms, since most aneurysms rupture unilaterally, with simultaneous rupture being clinically rare (33).

One-stage interventions can be divided into endovascular and conventional microsurgical procedures. Hence, microsurgery can be considered a one-stage unilateral craniotomy or bilateral craniotomy (22). If mirror aneurysms have to be treated with a single approach through unilateral craniotomy, strict prerequisites should be met. For example, in bilateral MCA aneurysms, contralateral clipping can be attempted if the contralateral aneurysm is unruptured, has a narrow neck, is positioned in a well-defined and easily accessible subarachnoid space, the contralateral MCA has a short M1 segment, and is projected forward and downward. Anatomical studies have shown that, in cases where the M1 segment is shorter than 14 mm, the contralateral MCA bifurcation can be visualized (18,20,22,29).

Inci et al. showed that if the total length of the contralateral A1 and M1 segments is greater than 45 mm, surgical intervention would not be safe and should not be performed (10). Andrade-Barazarte et al. reported success in clipping aneurysms (N=38) through a contralateral approach in a patient cohort where the mean length of the contralateral A1 and M1 segments were 13.2 mm and 14.2 mm, respectively (2,6). Sousa et al. were successful in visualizing and clipping 65.2% of cases where a contralateral approach was applied (7). However, it should be noted that contralateral clipping is difficult in cases with aneurysmal rupture due to severe cerebral edema, increased intracranial pressure, and the presence of arachnoid adhesions (20).

Wang et al. reported strategies for treating “mirror” aneurysms (70 pairs). The aneurysm responsible for SAH is prioritized, and the contralateral, non-ruptured aneurysm is observed and treated in the second stage (29). Despite advances in endovascular techniques in recent years, strategies for treating “mirror” aneurysms remain controversial. Both one- and two-stage treatments have been associated with good results (11,25,28).

Recent studies have focused on the morphological characteristics of intracranial aneurysms and identified their geometric values as risk factors for MCA aneurysm rupture (31). In a retrospective study (N=48), Xu W et al. found that aneurysm width, AR, and anterior dome projection were independent risk factors for rupture of MCA aneurysms. Of the ratios analyzed, the AR in the group with ruptured aneurysms was significantly higher than in the group without rupture (1.72 vs. 1.32; p=0.004), Dome/Neck ratio (1.53 vs. 1.27; p=0.013), and Height/Width ratio (1.16 vs. 1.04; p=0.099). The mean width of the aneurysmal neck was larger in the ruptured group than in the non-ruptured group (3.46 mm vs. 2.93 mm; p=0.042) (31). Aneurysm width and AR have been reported as important predictors for incidence of MCA aneurysms (14,30). In a study by Xu et al., these two parameters were also determined as independent risk factors (31). Table V presents the assessed geometric mean values of our study.

Treatment of wide-necked aneurysms (≥4 mm) and AR ≤1.5 can be difficult, especially by endovascular technique (31). These results suggest that relatively wide-necked aneurysms and lower AR have a lower risk of rupture and a higher risk of complications during endovascular treatment (3,21,31). The understanding of the morphology of MCA aneurysms may be useful in assessing the risk of rupture and determining the surgical treatment method.

This study has the following limitations. First, there were several disadvantages due to the retrospective nature of the study. Second, the follow-up period, for both microsurgical and endovascular treated aneurysms, was evaluated on the 3rd, 6th, and 12th months. In comparison, the long-term follow-up of the clipped aneurysms was not considered owing to the lack of data. Third, the fewer patients with mirror aneurysms may be considered a limitation, despite the incidence of the pathology in the literature being depicted as 12.9–26.4% of all intracranial aneurysms. Fourth, the conclusions in our study were based on the assessment of 12 surgical interventions at a single institution. The period covered by this study was the boundary between the two tendencies in the treatment modality of this pathology. In the future, it is essential to conduct additional research using a larger sample size; however, this may be difficult owing to the aggressive development of endovascular technology, creating a bias for the preference of treatment choice.

CONCLUSION

The choice of treatment method for "mirror" aneurysms should be determined on an individual basis according to the clinical manifestations and morphological characteristics of intracranial aneurysms. In cases of aSAH, where "mirror" aneurysms are present, both can be treated safely with microsurgical clipping or endovascular embolization after thorough investigation and ensuring prioritization of the offending lesion.

AUTHORSHIP CONTRIBUTION

Study conception and design: HT, AB

Data collection: KN, EF

Analysis and interpretation of results: HT, AB

Draft manuscript preparation: HT

Critical revision of the article: HT, KM

Other (study supervision, fundings, materials, etc...): SS, VK

All authors (HT, AB, SS, KM, KN, EF, VK, HH) reviewed the results and approved the final version of the manuscript.

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