Interdisciplinary Neurosurgery 18 (2019) 100535

Contents lists available at ScienceDirect

Interdisciplinary Neurosurgery

journal homepage: www.elsevier.com/locate/inat

Neuroanatomical Studies

Etiopathogenesis, clinical presentation and management options of mirror aneurysms: A comparative analysis with non-mirror multiple aneurysms

Niranjana Rajagopal (DNB)[a,*], Arun Balaji (M.S., Mch.)[b], Yasuhiro Yamada (M.D., PhD)[c], Tsukasa Kawase (M.D., PhD)[c], Yoko Kato (M.D., PhD)[c]

[a] *Department of Neurosurgery, Sri Sathya Sai Institute of Higher Medical Sciences, Bangalore, India*
[b] *Department of Neurosurgery, Kovai Medical Center and Hospital, Coimbatore, Tamilnadu, India*
[c] *Department of Neurosurgery, Fujita Health University, Banbuntane Hotokukai Hospital, Nagoya, Japan*

A B S T R A C T

Introduction: Mirror Aneurysms [MA] are a subset of multiple aneurysms which account for nearly 5% of all intracranial aneurysms and approximately 40% of all multiple aneurysms. The purpose of our study was to evaluate the etiopathogenesis, preferential location, clinical characteristics and outcome of mirror aneurysms in comparison with non-mirror multiple aneurysms.

Methods: We retrospectively reviewed the clinical and radiological data of 358 patients with intracranial aneurysms who were treated at our institute between January 2014 and June 2018. The patients were further divided into non-mirror multiple and mirror aneurysm groups. There were 13 patients who had MA and 45 patients with non-mirror aneurysms [NMA].

Results: Multiple aneurysms were found in 16.2% of all patients [58 out of 358]. MA were observed in 3.6% [13 out of 358 patients]. There was a slight female predominance in the MA group [84.6% vs 73.3%]. The commonest location of MA in our series was MCA. There was no statistically significant difference in age, smoking, hypertension or postoperative outcome between the two groups.

Conclusion: Management of mirror aneurysms should be determined individually based on the location, size, and morphology of the aneurysms, as well as the clinical manifestations of the patient. Therefore, emergent treatment of the ruptured aneurysm and staged management of the contra lateral unruptured twin can be considered as a rational treatment strategy to manage mirror aneurysms. The decision of single or multistage approach/surgical or endovascular coiling should be based on the aneurysm location, morphology, rupture status and available expertise

1. Introduction

Intracranial Mirror Aneurysms [MA] are a rare subtype of multiple aneurysms, located in identical or adjacent arterial segments bilaterally. Their incidence varies from 5% to 40% of all patients with multiple aneurysms [1–6]. Though, there have been various studies describing MA and their management, there has been no clear consensus about it till date. The present study does an analysis on the aetiopathogenesis, clinical presentation and management approach to mirror aneurysms [MA] in comparison to the non-mirror multiple aneurysms [NMA]. The purpose of this study was to investigate the safety and evaluate the outcome of various treatment modalities with emphasis on surgical approach to these lesions.

2. Patients and methods

We retrospectively analysed the medical records of patients who were diagnosed with cerebral aneurysms and treated for the same from January 2014 to June 2018 in our hospital. During this period, 358 patients were diagnosed to have intracranial aneurysms. Amongst them, 300 had single and 58 had multiple aneurysms. We further divided the multiple aneurysms into mirror and non-mirror aneurysms. There were 13 patients who had MA and 45 patients with NMA. The criterion for inclusion in the MA group was the presence of twin bilateral intracranial aneurysms located in the corresponding contralateral arteries of the same name or the proximal part of a directly connecting artery. All patients with multiple aneurysms who were not included in the MA group were included in the NMA group.

We collected data about the patients on various parameters such as age, gender, co-morbidities, family history of SAH/aneurysms, smoking

Abbreviations: CFD, computational fluid dynamics; DSA, digital subtraction angiography; DIVA, dual image videoangiography; ICG, indocyanine green; LSA, low shear area; MA, mirror aneurysms; MEP, motor evoked potential; NMA, non-mirror aneurysms; OSI, Oscillatory Shear Index; WSS, wall shear stress

* Corresponding author.
E-mail address: niranjana.rajagopal@gmail.com (N. Rajagopal).

https://doi.org/10.1016/j.inat.2019.100535
Received 28 May 2019; Received in revised form 6 July 2019; Accepted 6 July 2019

history and clinical presentation. We reviewed the radiology images [3D CTA and DSA] and collected information about the location, size, number and morphology of the aneurysms. Two neurosurgeons collaborated the radiology findings individually. We used the Hunt-Hess grade (H—H grade) to assess the preoperative neurologic status of patients who presented with SAH.

Operative records were referred to, for information about the operative approach, single or multi-staged approach and intraoperative rupture, if any. Intraoperatively, we used electrophysiological monitoring such as motor evoked potential [MEP], Doppler and indocyanine green [ICG] video angiography for all the cases. We began using Dual image videoangiography [DIVA] along with ICG in 2016 for all the cases. DIVA utilizes ICG along with near-infrared fluorescence, which are visualised as a single image, thus providing a better assessment of the field depth than a plain ICG, which in turn helps in better understanding of the intraoperative anatomical relationships. DIVA aids in the intra- operative assessment of the occlusion of the aneurysms and the preservation of the blood flow in parent/branching vessels. We used the neuroendoscope in all the cases, which, with its higher magnification and illumination provided additional details about the surrounding structures, which could not be visualised with the microscope alone. Electrophysiological monitoring like MEP made it possible to detect real-time cerebral ischemia intraoperatively. Glasgow outcome scale [GOS] was used to assess the outcome in all patients.

3. Results

Multiple aneurysms (collectively including both mirror and non-mirror multiple aneurysms) were found in 16.2 % [58 out of 358 patients] patients. MA were observed in 3.6% of all patients [13 out of 358 patients] or 22.4% of patients with multiple aneurysms [13 out of 58 patients].

4. Demography

Amongst the 45 patients in the NMA group; there were 33 females [73.3%] and 12 males [26.6%]. In the MA group; there were 11 females [84.6%] and 2 males [15.4%]. The male to female ratio in the 2 groups was 1:2.75 and 1:5.5 respectively. Though the ratio was relatively higher in the MA group, it was not statistically significant. The mean age of presentation in the NMA group was 62.68 +/- 10.8 years and 68.23 +/- 12.6 years in the MA group. There was no statistical significance between the 2 groups [Table 1].

15 patients [33.33%] in the NMA group and 10 patients [76.9%] in the MA group had Hypertension. Two patients [4.4%] in the NMA group and none in the MA group had a history of smoking. One patient [7.6%] in the MA group and none in the NMA group had a positive family history. One patient [2.2%] in the NMA group and 2 patients [1.5%] in MA group presented with SAH. Of the 3 patients with SAH, 2 of them had a Hunt and Hess score of 1 and the third from the MA group had a score of 2 with occulomotor nerve palsy. 2 patients [4.4%] in the NMA group presented with a headache due to chronic subdural hematoma. The rest of the aneurysms were incidentally detected. None of these values were statistically significant.

Table 1
Demographic characteristics of Mirror and Non Mirror aneurysms.

Characteristics	Mirror aneurysms n, [%]	Non mirror aneurysms n, [%]
Sex		
M	2 [15.4%]	12 [26.6%]
F	11 [84.6%]	33 [73.3%]
M:F	1:5.5	1:2.75
Age [years], mean +/- SD	68.23 ± 12.6	62.68 +/- 10.8
Age group		
< 50	1	6
> 50	12	39
Hypertension	10 [76.9%]	15 [33.33%]
Smoking	0	2 [4.4%]
Family history	1 [7.6%]	0
SAH	2 [15.3%]	1 [2.2%]

Table 2
Location of Mirror aneurysms.

Location	Number	%
MCA [M1 + MCA bifurcation]	10	52
PCom artery	3	15
Anterior choroidal artery	3	15
Ophthalmic artery	2	10.5
Vertebral artery	1	5.2

5. Aneurysm location and outcome

There were 19 MA found in 13 patients. The commonest location of MA in our series was the middle cerebral artery: M1 or at the MCA bifurcation [10 pairs, 52%] followed by 3 pairs[15%] in the PCom, 3 pairs [15%] in the Anterior Choroidal, 2 pairs[10.5%] in the Ophthalmic and 1 pair[5.2%] in the vertebral arteries [Table 2]. The sizes of the MA were similar bilaterally except for 2 cases which presented with SAH, where the ruptured side was significantly larger than its counterpart.

All the patients underwent a single or a multi staged approach based on the location of each aneurysm. In the NMA group, 2 patients underwent a multi-staged bilateral surgical approach as the aneurysms were located bilaterally and the remaining 43 patients underwent Single-stage surgery. In the MA group, all the patients underwent a bilateral multi-staged approach. The aneurysms responsible for the SAH were treated as a priority followed by the others at a later date. 2 out of 19 aneurysms were coiled in the MA group and the rest of them underwent surgery [Table 3].

All the patients were evaluated with a 3D CT angiogram postoperatively. 2 patients in the NMA group were identified to have an incomplete clipping on CT angiogram, for which they underwent re-exploration and clip repositioning during the same admission. One patient in each group had Hydrocephalus for which they underwent Ventriculo-peritoneal shunt. One patient in the NMA group had hemiparesis and another one had a transient third nerve palsy, which gradually improved. Two patients in the NMA group and 1 in the MA group had chronic SDH on evaluation during the 3 months follow up for which they underwent burrhole and evacuation. One patient in the NMA group became comatose post operatively and is in the same condition to date. One patient in the MA group had an intraoperative rupture and died postoperatively. Out of the 45 patients in the NMA group, 41 patients [91%] had a GOS of 5, 3 patients [6.6%] had a score of 4 and 1 patient [2.2%] had a score of 2. Out of the 13 patients in the MA group, 11 patients [84.6%] had a GOS score of 5, 1 [7.6%] had a score of 4, and 1 [7.6%] had a score of 1. There was no statistical significance in the outcome between the 2 groups. All the patients had a regular follow-up ranging from 3 to 48 months [Table 4].

6. DISCUSSION

The incidence of intracranial aneurysms in the general adult population is approximately 1 to 3.2%. Amongst them, the reported percentage of multiple intracranial aneurysms ranges from 2% to 45% [5,7–13]. MA are a subset of multiple aneurysms which account for nearly 5% of all intracranial aneurysms and approximately 40% of all multiple aneurysms [3–6,14,15]. Unruptured intracranial mirror aneurysms are being increasingly detected due to the advancements in imaging modalities, especially the non-invasive techniques and increase in elective screening procedures [2,15].

Table 3
Summary of Mirror aneurysms.

Sl. no	Age/sex	Presentation	Comorbidities	Family history	Smoking	Location of mirror aneurysms	Other aneurysms	Stage	Procedure	Complications	GOS
1	55/F	Incidental	HTN	Nil	Nil	B/l M1, B/l Ant cho	LEFT Pcom	2	Clipping	Nil	5
2	57/F	Incidental	HTN	Yes	Nil	B/l M1 + B/l MCA bifurcation + B/l anterior choroidal	Basilar top	2	Clipping	Nil	5
3	63/F	Incidental	HTN	Nil	Nil	2 sets of B/l M1 aneurysms	Acom + right cavernous ICA	2	Clipping + coiling of the Rt ICA	Nil	5
4	66/M	Incidental	HTN, DM	Nil	Nil	B/l Va	Nil	2	Left clipping + right coiling	Nil	5
5	86/F	Sah, Rt 3rd nerve	HTN	Nil	Nil	B/l Pcom	ACom	2	Clipping	Nil	4
6	86/F	Sah	HTN, DM	Nil	Nil	b/l Pcom + b/l mca bifurcation	Nil	2	Clipping	Intr op rupture and death	1
7	66/F	Incidental	HTN	Nil	Nil	B/l ICA - Oph thalmic	Rt ica-ophthalmic	2	Clipping	Nil	5
8	74/M	Incidental	HTN	Nil	Nil	B/l Ant- cho + B/l M1	Rt ica bifurcation	2	Clipping	Nil	5
9	59/F	Incidental	HTN	Nil	Nil	B/l M1	Left Ant-Cho	2	Clipping	Chronic SDH	5
10	73/F	Incidental	HTN	Nil	Nil	B/l MCA bifurcation	ACom	2	Clipping	HCP	5
11	47/F	Incidental	NIL	Nil	Nil	B/l IC-ophthalmic	None	2	Clipping	Nil	5
12	68/F	Incidental	NIL	Nil	Nil	B/l MCA bifurcation	ACom	2	Clipping	Nil	5
13	87/F	Incidental	NIL	Nil	Nil	B/l PCom	Nil	2	Clipping	Nil	5

Table 4
Outcome analysis between Mirror and Non mirror aneurysms.

GOS	Non Mirror aneurysms (45)	Mirror aneurysms (13)
5	41 [91%]	11 [84.6%]
4	4 [6.6%]	1 [7.6%]
3	0	0
2	1 [2.2%]	0
1	0	1 [7.6%]

6.1. Location, size, shape and rupture of MA

Mirror aneurysms are most commonly located in the middle cerebral artery (MCA), followed by the Internal cerebral artery (ICA) and the Posterior communicating artery (Pcom). They are present in the other vessels as well, but are more uncommon [1,4–6,16–18]. Some authors like Jeong et al. [2], Wang [19] and Juvela et al. [20] reported that the commonest location for MA in their series was PCom followed by MCA. However, in our study, MCA was the commonest location followed by ICA and PCom. (Figs. 1 and 2)

Meissner et al. [21] in his prospective study of 376 MA concluded that a higher percentage of patients with MA had larger (> 10 mm) aneurysms than their non-mirror counterparts with the mirror ones being larger than the non-MA (11.7 mm vs. 10.4 mm). Lee et al. [17] in his retrospective study of 197 MA concluded that, MA were smaller than the non-mirror ones which was in contrast to Meissner et al. However, Hyon Ho Choi et al. [5] in his retrospective analysis of 83 mirror aneurysm patients, found no significant size disparity between the MA. Since MA are subjected to identical systemic conditions, risk factors and hemodynamic forces [22], it logically concludes that mirror aneurysms must be of a similar size and indeed, 17 out of 19 mirror aneurysms [10.5%] in our study showed very little disparity in size.

When a mirror aneurysm patient presents with SAH, it is imperative to find the side of the ruptured aneurysm because it is not possible to treat all the aneurysms in a single stage in every case. The possibility of rupture being higher on the side of larger quantity of blood or clots in a plain CT head and vasospasm with larger and irregularly shaped aneurysms, daughter sac, bottle neck factor on an angiogram are well known identifying markers [5,8,23]. Many authors have reported that larger size, an elongated shape, aspect ratio of ≥ 1.6, area ratio of ≥ 1.5 was important in determining the rupture site in MA [8,24–26] and a few others reported that irregularities in contours and complex aneurysms were more important factors than size, in identifying the site of a rupture [2]. Further studies are required to validate this point. In our study, though there were just 2 patients who presented with SAH, it was noted that the ruptured aneurysms were significantly larger [9 mm vs 4 mm; 7.5 mm vs 2 mm], irregular and complex compared to their unruptured counterparts. However, Zderkiewicz et al. [27] and Orning et al. [28] found that the accuracy of the examination method (neurologic examination, DSA, CT scan, and/or intraoperative evaluation), in terms of revealing the responsible aneurysms, was only 72.16% and 83.3% respectively. Hence, a high index of suspicion and skill is required to diagnose these lesions. If it is not possible to accurately identify the ruptured lesion, then both the lesions in the MA must be treated acutely.

Since hemodynamics of the lesion has a large impact on aneurysm initiation, remodelling, degradation of the wall structure and its mechanical strength, it has a fundamental role in its rupture [8,9]. Hence, hemodynamic assessment by CFD study could give us details about wall shear stress, oscillatory stress and flow patterns which could help us detect lesions that have ruptured along with the ones with high probability of future rupture [29]. Studies show that ruptured aneurysms have lower mean WSS, higher maximum peak systole WSS, lower minimum mid-diastolic WSS, higher OSI, more complex flow patterns and a greater LSA compared to the its unruptured counterparts [8,24–26,30–32] This, along with the other imaging modalities has a

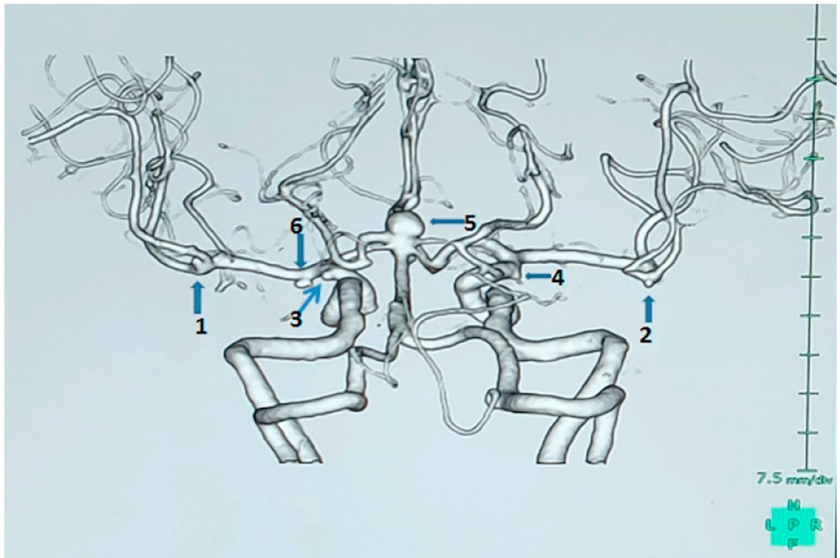

Fig. 1. Reconstructed CT angio images of a case with multiple mirror aneurysms [posterior view]:- **1,2** – bilateral MCA bifurcation aneurysms; **3,4** – bilateral anterior choroidal artery aneurysms; **5** - basilar top; **6** - left M1 aneurysm.

higher probability of diagnosing a ruptured aneurysm and aids us in a multistage management of the unruptured ones.

The predictors of rupture for MA are similar to that of multiple aneurysms. Size and location have been identified as the most important predictors by various authors. Larger size, especially the ones > 7 mm have a significantly higher rate of rupture [8,12,25,33–35]. Many authors have reported ACom artery aneurysms to have the maximum rupture rate [12,16,33,36–38]. However, The ISUIA trial, the meta-analysis by Wermer et al. [36] and other authors [35,39–41] reported that significantly high rupture rates were noted for aneurysms located in the posterior circulation, basilar top aneurysms and in posterior communicating arteries. Lu et al. [33] in his retrospective analysis of 294 aneurysms concluded that the position of the aneurysms along the parent vessel can also predict its rupture. According to him, the midline aneurysms have a higher risk of rupture than the ones on the lateral aspect of the vessel. The other independent aneurysm-dependent risk factors are presence of daughter sac, irregular shape, Aspect Ratio > 1.3, size ratio > 2, dome diameter > 10 mm, a deviated neck, impingement regions and inflow jet sizes, especially in MA [16,25,35,39,41–46]. The PHASES score included parameters like age, hypertension, history of SAH, aneurysm size, aneurysm location, and geographical region for an accurate estimation of risk of rupture [40]. In MA, it is difficult to predict higher risk of rupture if both the aneurysms are of the same size. However the aneurysm that starts growing, the larger lesion and the ones with a main axis parallel to the parent artery have a higher chance of rupture [35].

6.2. Etiopathogenesis of mirror-image aneurysms

The aetiology of multiple intracranial aneurysms remains similar to

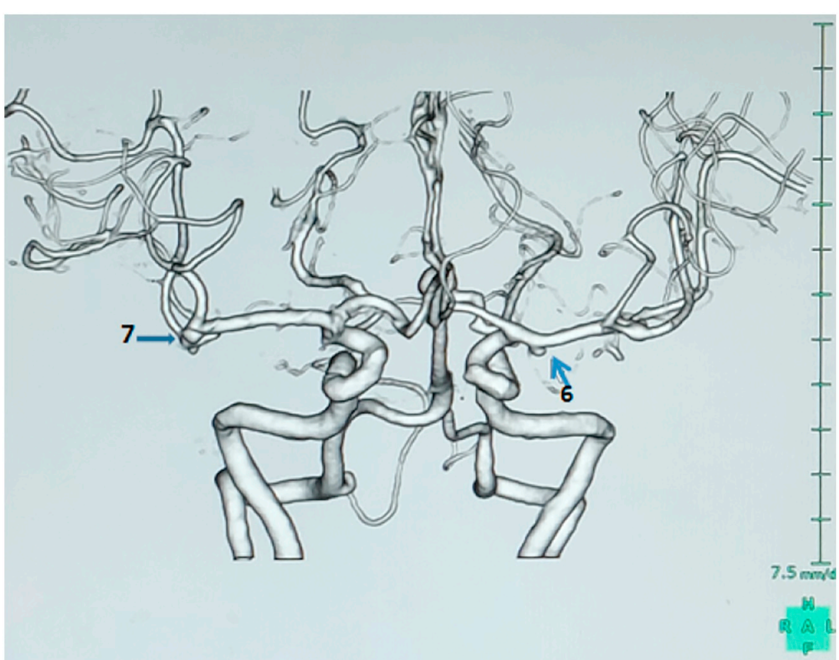

Fig. 2. Reconstructed CT angio images of a case with multiple mirror aneurysms [anterior view]: - **6** - left M1 aneurysm; **7** – right M1 aneurysm.

that of single aneurysm formation such as, female sex, hypertension, smoking and alcohol abuse [7,12,20,37,47,48]. Non-modifiable risk factors include old age, female sex, Japanese or Finnish descent and genetic factors whereas the modifiable ones are cigarette smoking and hypertension [20,36,47,48]. Women have a higher incidence of aneurysms than men in general, especially older women (post menopause), more so in MA. The male to female ratio in our series of MA was 1:5.5 and 1:2.75 in the NMA group. These values are comparable to the other series in MA thus proving the fact [2]. When compared to premenopausal patients, a greater percentage of post-menopausal ladies have multiple aneurysms. It has been postulated that lack of Oestrogen could be a causative factor for this, but there are no studies till date to prove this [2,3,49,50].

Smoking is another important causative factor for formation of multiple or MA. Though in our series, we did not have any statistical significance to prove this association in either of the two groups, various studies have done so [2,3]. Smoking restricts the activity of alpha-1-antitrypsin that suppresses the protease, which accelerates the decomposition of collagen, thus reducing the elastins in blood and increasing the expansion of the arterial wall during systole. Furthermore, smoking also damages endothelial cells in a mechanism similar to atherosclerotic changes, accelerating the formation of atheroma by suppressing the enzymes involved in the functions of platelets and the restoration system for vessel walls, thereby aiding the formation an aneurysm [51,52]. Along with these pathologic changes, smoking is also known to have anti-estrogenic features, thus promoting the formation of an aneurysm in menopausal women [2,3]. Hence, a thorough evaluation to exclude MA must be done in patients presenting with aneurysms in MCA, ICA or Pcom arteries, especially in post-menopausal women and smokers.

Though Hypertension as reported in various studies, is an important risk factor for the formation and rupture of intracranial aneurysms [7,12,20,37,47,48], we did not find a statistical correlation in our series, probably due to the small sample size.

A congenital predisposition and an early embryological derangement of vascular wall formation have been postulated by various authors as the basis for development of MA [6,50,53]. Baccin et al. [1] has discussed in detail about the development of intracranial basal arteries from the 3 embryological segments - Procencephalic, mesencephalic and rhombencephalic. The very fact that this pathology evolves in identical or adjacent arterial segments bilaterally suggests that the insult was specific during the cephalic segmentation phase. If they are present in non-adjacent segments, they probably occur due the insult occurring prior to the cephalic segmentation. It also suggests a familial or a genetic association [1,3,15]. Thus, it is important to evaluate the family history and genetic disorders like autosomal dominant polycystic kidney disease, Marfan's syndrome, Ehlers–Danlos syndrome type IV, fibromuscular dysplasia, Moyamoya disease, sickle cell disease and arteriovenous malformations of the brain [3]. Only one patient in our MA series had a positive family history of aneurysms, whereas none of them any genetic syndromes.

6.3. Management

Mirror aneurysms can be managed by surgery, endovascular approaches or a combination of both, depending on various factors such as age, location, size, morphology, clinical presentation, medical co morbidities, available expertise, cost and infrastructure [14,15,54–58]. Optimal management protocol in unruptured MA is yet controversial and not defined to date.

We know that if there is a rupture, then that aneurysm takes priority in treatment. However, the much-debated issues are, whether the unruptured asymptomatic twin in a mirror aneurysm needs to be treated or not, if required, then when would be the best time to do so and whether intervention is mandatory in asymptomatic MA. The risk of rupture ranges from as low as 0.3 to as high as 16.4% according to various authors [39,59,60], but due to the high mortality rates of about 45% [61] and morbidity rates of about 64% [62] respectively, patients are taken up for early intervention which may be surgical or endovascular [2,8]. Wang et al. [3] in his report about the treatment strategies in MA and many other authors as well [5,6], have opined that the ruptured aneurysm should receive treatment priority and the contralateral unruptured aneurysm can be observed or treated in either single or multi-stage treatment. We followed the same principle in our series too. Therefore, emergent treatment of the ruptured aneurysm [only if the diagnosis of the ruptured aneurysm is definite] and staged management of the contralateral unruptured mirror aneurysm can be considered as a rational treatment strategy to manage mirror aneurysms. However, if there is a doubt about the rupture site, then all the aneurysms must be treated in a single sitting. Conservative management can be considered elderly patients, with no previous history of SAH, aneurysm size < 5 mm and a regular shape [3].

Surgical management of MA may be categorised into single and double staged approach. Single stage approach may be further divided into unilateral and bilateral craniotomies [57,63]. Anterior cerebral artery A1 segmental aneurysms, A1-A2 junctional aneurysms, posterior cerebral artery [P1segment] aneurysms, superior cerebellar artery aneurysms, internal cerebral artery (ICA) bifurcation and paramedian aneurysms have been successfully treated with unilateral craniotomy [23,64,65]. However, it is difficult to clip aneurysms on the opposite side in more distant locations such as the MCA territory. Acik et al. [23] in his study, has opined that MA on MCA can be clipped with a unilateral craniotomy only if the following criteria were fulfilled: mild and moderate brain oedema, A1 + M1 length of < 25 mm and a contralateral aneurysm diameter of < 15 mm [23]. Similar findings have been reported by various other authors too [57,64,66]. Inci et al. [67] found that if there is widespread cerebral oedema, an A1 + M1 length > 35 mm in patients with contralateral large or giant aneurysms and in patients with a contralateral ICA bifurcation angle < 175°, the exploration was not safe and it should not be attempted.

The projection of the aneurysms is another factor to help determine a unilateral or bilateral approach. Rodriguez-Hernandez et al. [57] stated that aneurysms with inferior and anterior projections can be easily visualised in the surgical corridor, whereas those with lateral placement can be difficult to visualise. Inci et al. [67] reported that clipping of anterosuperiorly projecting aneurysms to be easier than the other types. Andrade-Barazarte et al. [68] in his retrospective analysis has opined that the feasibility of a contralateral approach in clipping aneurysms arising from the ophthalmic artery or a superior hypophyseal artery depends on the prechiasmatic distance, interoptic distance and relationship of the ICA with the anterior clinoid process. Kakizawa et al. [69] in his retrospective study, found that the direction of the aneurysm from the ICA wall on the anteroposterior angiogram and the distance from the medial side of the estimated distal dural ring to the proximal aneurysm neck on the lateral angiogram were useful to calculate the difficulty of contralateral approach. Oshiro et al. [64] reported that clipping of contralateral PComA was possible only in 50% of cases even if they projected medially or posteromedially. He also opined that anterior choroidal artery aneurysms originating from the posterior or posterolateral aspect of ICA could be clipped quite successfully from the contralateral approach.

Though single stage management is advocated and practised by some [19,23,53,65,67,68,70], others have opined that single stage surgery increases the neurovascular manipulation, surgical time, morbidity and mortality. Many state that a multistaged approach has a better outcome [14,57,71–73]. However, multistage treatment does have disadvantages like increase in the risk of rupture of the unclipped aneurysms, lengthier hospital stay, high costs and aggravation of psychological burden. Post-operative hyperdynamic therapy, if the presentation is SAH, is also not possible in multistage approach as it carries an increased risk of rupture of the unclipped aneurysms [14,23,71,74].

If the decision of a single stage unilateral approach for MA is undertaken, then the following microsurgical aspects must be kept in mind: highly specific patient selection, complete opening of subarachnoid spaces while approaching contra lateral aneurysm, avoiding excessive brain retraction, approach must be on the side of larger or complex aneurysm, contra lateral aneurysm size should be < 15 mm and the shape of the aneurysm must be regular [56,57,64,65,67,75,76].

Despite recent advances in knowledge and techniques, treatment strategies for MA remain controversial. Both single and multi-stage treatments are associated with good results. Hence, treatment has to be customised accordingly in every case [3,19,21,58].

Some authors like Mehrotra [6], Wang [19] and others [2,3,23] have opined that clipping conferred excellent neurological outcome whereas the others have similar opinion about coiling [3,5,55,77,78]. Both the trials, International Study of Intracranial Aneurysms (ISUIA) and the International Subarachnoid Aneurysm Trial (ISAT) have also reported better outcomes with endovascular coiling when compared with microsurgical clipping [79,80]. In MA especially, a single-stage treatment with coiling may be more practical than one with clipping. Though there are arguments that, in comparison with endovascular coiling, bilateral surgical clipping is more invasive, may take longer time and may entail much more blood loss; it is not like coiling has no disadvantages. Coiling for very small aneurysms is technically challenging and often requires adjunctive techniques such as balloon-assisted or stent-assisted coiling, which requires subsequent antiplatelets and anticoagulation for many months after the procedure. Patients undergoing coiling are prone to thromboembolic events along with contrast-induced nephropathy. The procedure also causes more rebleeds in the treated aneurysm than clipping, and is associated with higher intraprocedural rupture rates in small aneurysms compared with the larger ones [6,53,54,81–83]. These conclusions however, are clinically relevant and practically applicable only if all conditions are suitable for the selected technique and this is not the case in many instances. The actual decision making depends age, location, size, morphology of the aneurysm, clinical presentation, medical comorbidities, available expertise, cost and infrastructure [14,15,54–58].

7. Limitations of the study

Our study had several limitations. Firstly, the entire data collection was retrospective and from a single institution where the management criteria (modality and plan selection) were open to inconsistencies. Second, the sample size was small and fell short of being a statistically significant number. Third, the study was based on cross-sectional data, thus it is not possible to determine if the unruptured aneurysms had high or low rupture risk. Finally, in our series, there was not an equal distribution of coiling and clipping cases, which led to the data being skewed and thus we could not compare the outcome of both procedures.

8. Conclusions

There is no standard protocol for treatment of MA till date. We need randomised control trials comparing all the treatment modalities to decide the best intervention. Until such time, management should be determined individually based on the location, size, and morphology of the aneurysms, as well as the clinical manifestations of the patient. Therefore, emergent treatment of the ruptured aneurysm [only if the diagnosis of the ruptured aneurysm is definite] and staged management of the contralateral unruptured mirror aneurysm can be considered as a rational treatment strategy to manage mirror aneurysms. However, if there is a doubt about the rupture site, then all the aneurysms must be treated in a single sitting. The decision of single or multistage approach/surgical or endovascular coiling should be based on the aneurysm location, morphology, rupture status of the aneurysm and available expertise. Management options must be jointly evaluated by surgeons and interventionists along with consideration of the patient preference and the best possible strategy must be devised to enhance clinical outcome.

Financial support and sponsorship

None.

Declaration of Competing Interest

We have no conflict of interest.

References

[1] C.E. Baccin, T. Krings, H. Alvarez, A. Ozanne, P. Lasjaunias, Case report multiple mirror-like intracranial aneurysms. Report of a case and review of the literature, Acta Neurochir. 148 (2006) 1091–1095.
[2] Kim S. Clinical Analysis of Intracranial Mirror-Image Aneurysms : A 20-year Single Center Experience. vol. 11(3).
[3] W.-X. Wang, Z. Xue, L. Li, C. Wu, Y.-Y. Zhang, X. Lou, et al., Treatment strategies for intracranial mirror aneurysms, World Neurosurg 100 (2017) 450–458. Apr.
[4] A. Sharma, N. Gupta, M. Gupta, S. Sharma, Dreadful twins: twin unruptured aneurysms of bilateral intracranial arteries, Saudi J Med Med Sci | Publ by Wolters Kluwer-Medknow (2016) 215–217.
[5] H.H. Choi, Y.D. Cho, D.H. Yoo, J. Lee, J.H. Mun, S.J. An, et al., Intracranial mirror aneurysms: anatomic characteristics and treatment options, Korean J. Radiol. 19 (5) (2018) 849–858.
[6] A. Mehrotra, P. Sharma, K.K. Das, K.S. Bhaisora, J. Sardhara, S. Gupta, et al., Mirror aneurysms among multiple aneurysms: lesser of the two evils, World Neurosurg 92 (2016) 126–132. Aug.
[7] R. Jabbarli, T.F. Dinger, M. Darkwah Oppong, D. Pierscianek, P. Dammann, K.H. Wrede, et al., Risk factors for and clinical consequences of multiple intracranial aneurysms, Stroke 49 (4) (2018) 848–855. Apr.
[8] R. Doddasomayajula, B.J. Chung, F. Mut, C.M. Jimenez, F. Hamzei-Sichani, C.M. Putman, et al., Hemodynamic characteristics of ruptured and unruptured multiple aneurysms at mirror and ipsilateral locations, Am. J. Neuroradiol. 38 (12) (2017) 2301–2307.
[9] M. Asiltürk, A. Abdallah, Clinical outcomes of multiple aneurysms microsurgical clipping: evaluation of 90 patients, Neurol. Neurochir. Pol. 52 (1) (2018) 15–24 Jan.
[10] C.B. Theodotou, B.M. Snelling, S. Sur, D.C. Haussen, E.C. Peterson, M.S. Elhammady, Genetic associations of intracranial aneurysm formation and subarachnoid hemorrhage, Asian J Neurosurg 12 (3) (2017) 374–381.
[11] O. Ahmed, P. Kalakoti, M. Hefner, H. Cuellar, B. Guthikonda, Seven intracranial aneurysms in one patient: treatment and review of literature Case Report INTRODUCTION, J Cerebrovasc Endovasc Neurosurg 17 (2) (2015) 113–119.
[12] N. Ajiboye, N. Chalouhi, R.M. Starke, M. Zanaty, R. Bell, Unruptured cerebral aneurysms: evaluation and management, Sci. World J. 2015 (2015) 1–10.
[13] X. Shen, T. Xu, X. Ding, W. Wang, Z. Liu, H. Qin, Multiple intracranial aneurysms: endovascular treatment and complications, Interv. Neuroradiol. 20 (2014) 442–447.
[14] Choque-Velasquez J, Colasanti R, Fotakopoulos G, Elera-Florez H, Hernesniemi J. A challenging case from the Andean slopes managed with 1-stage surgery. World Neurosurg. 97:565–70.
[15] T.K. Maiti, S. Konar, A. Nanda, Multiple mirror aneurysms: does the embryological perspective merit a special mention? Neurol. India 63 (5) (2015) 784.
[16] G.-X.X. Wang, L.-L.L. Liu, L. Wen, Y.-X.X. Cao, Y.-C.C. Pei, D. Zhang, Morphological characteristics associated with rupture risk of multiple intracranial aneurysms, Asian Pac J Trop Med 10 (10) (2017) 1011–1014 Oct.
[17] Y.-J.J. Lee, T. Parreira, C.C. Matouk, R. Menezes, D.M. Mandell, K.G. terBrugge, et al., Clinical characteristics and preferential location of intracranial mirror aneurysms: a comparison with non-mirror multiple and single aneurysms, Neuroradiology 57 (1) (2014) 35–40 Jan 3.
[18] C. Fu, J. Chen, Z. Liu, P. Wang, C. Duan, J. Zhao, Kissing aneurysms of the distal anterior cerebral artery: a case report and literature review, Exp Ther Med 15 (4) (2018) 3471–3476 Feb 9.
[19] J. Zhao, R. Wang, D. Zhang, S. Wang, Y. Zhao, H. Niu, A comparative study of 43 patients with mirror-like intracranial aneurysms: risk factors, treatment, and prognosis, Neuropsychiatr. Dis. Treat. 10 (2014) 2231 Nov 19.
[20] S. Juvela, Risk factors for multiple intracranial aneurysms, Stroke 31 (2) (2000) 392–397 Feb.
[21] I. Meissner, J. Torner, J. Huston, M.L. Rajput, D.O. Wiebers, L.K. Jones, et al., Mirror aneurysms: a reflection on natural history, J. Neurosurg. 116 (6) (2012) 1238–1241 Jun.
[22] B.G. Thompson, R.D. Brown, S. Amin-Hanjani, J.P. Broderick, K.M. Cockroft, E.S. Connolly, et al., Guidelines for the management of patients with unruptured intracranial aneurysms: a guideline for healthcare professionals from the American Heart Association/American Stroke Association, Stroke 46 (8) (2015) 2368–2400.
[23] V. Acik, G. Cavus, E. Bilgin, A. Arslan, Y. Gezercan, A.İ. Okten, Surgical treatment of mirror middle cerebral artery aneurysms: bilateral and unilateral approach, World Neurosurg 108 (2017) 774–782 Dec.
[24] A.A. Divani, M. Elmahdy, Y. Zhang yingzhang, X. Yang yangxinjian, Z. Tian, Y. Zhang, et al., Rupture risk assessment for mirror aneurysms with different

outcomes in the same patient, Front. Neurol. 7 (2016) 219.
[25] J. Fan, Y. Wang, J. Liu, L. Jing, C. Wang, C. Li, et al., Morphological-hemodynamic characteristics of intracranial bifurcation mirror aneurysms, World Neurosurg 84 (1) (2015) 114–120.e2 Jul.
[26] Z.-Q. Huang, Z.-H. Meng, Z.-J. Hou, S.-Q. Huang, J.-N. Chen, H. Yu, et al., Geometric parameter analysis of ruptured and unruptured aneurysms in patients with symmetric bilateral intracranial aneurysms: a multicenter CT angiography study, Am. J. Neuroradiol. 37 (8) (2016) 1413–1417. Aug 1.
[27] E. Zderkiewicz, Z. Pawlik, M. Czochra, A. Tabora, Clinical signs pointing to the source of hemorrhage in multiple intracranial aneurysms, Med. Sci. Monit. 8 (2) (2002) CR83–6 Feb 22.
[28] J.L. Orning, S.F. Shakur, A. Alaraj, M. Behbahani, F.T. Charbel, V.A. Aletich, et al., Accuracy in identifying the source of subarachnoid hemorrhage in the setting of multiple intracranial aneurysms, Neurosurgery (2017) 1–7.
[29] P. Berg, O. Beuing, Multiple intracranial aneurysms: a direct hemodynamic comparison between ruptured and unruptured vessel malformations, Int. J. Comput. Assist. Radiol. Surg. 13 (1) (2018) 83–93 Jan 21.
[30] J.L. Thenier-Villa, A. Riveiro Rodríguez, R.M. Martínez-Rolán, M. Gelabert-González, P.M. González-Vargas, R.A. Galarraga Campoverde, et al., Hemodynamic changes in the treatment of multiple intracranial aneurysms: a computational fluid dynamics study, World Neurosurg (2018) 1–8 Jul 11.
[31] G. Lu, L. Huang, X.L. Zhang, S.Z. Wang, Y. Hong, Z. Hu, et al., Influence of hemodynamic factors on rupture of intracranial aneurysms: patient-specific 3D mirror aneurysms model computational fluid dynamics simulation, Am. J. Neuroradiol. 32 (7) (2011) 1255–1261.
[32] H. Meng, V.M. Tutino, J. Xiang, A. Siddiqui, High WSS or Low WSS? Complex interactions of hemodynamics with intracranial aneurysm initiation, growth, and rupture: toward a unifying hypothesis, Am. J. Neuroradiol. 35 (2014) 1254–1262.
[33] H.-T.T. Lu, H.-Q.Q. Tan, B.-X.X. Gu, Li M.-H.H. Wu-Wang, Risk factors for multiple intracranial aneurysms rupture: a retrospective study, Clin. Neurol. Neurosurg. 115 (6) (2013) 690–694 Jun 1.
[34] M. Shojima, A. Morita, H. Nakatomi, S. Tominari, Size is the most important predictor of aneurysm rupture among multiple cerebral aneurysms: post hoc subgroup analysis of Unruptured Cerebral Aneurysm Study Japan, Neurosurgery 82 (6) (2018) 864–869.
[35] H. Maslehaty, C. Capone, R. Frantsev, I. Fischer, R. Jabbarli, J.F. Cornelius, et al., Predictive anatomical factors for rupture in middle cerebral artery mirror bifurcation aneurysms, J. Neurosurg. 128 (6) (2018) 1799–1807.
[36] M.J.H. Wermer, I.C. Van Der Schaaf, A. Algra, Risk of Rupture of Unruptured Intracranial Aneurysms in Relation to Patient and Aneurysm Characteristics An Updated Meta-Analysis, 38 (4) (2007) 1404–1410.
[37] M. Kaminogo, M. Yonekura, S. Shibata, Incidence and outcome of multiple intracranial aneurysms in a defined population, Stroke 34 (1) (2003) 16–21.
[38] B. Weir, L. Disney, T. Karrison, Sizes of ruptured and unruptured aneurysms in relation to their sites and the ages of patients, J. Neurosurg. 96 (1) (2002) 64–70.
[39] T. UCAS Japan Investigators, T. Kirino, N. Aoki, N. Hashimoto, M. Sakai, A. Teramoto, et al., The natural course of unruptured cerebral aneurysms in a Japanese cohort The members of the UCAS Japan writing committee-Akio Morita A bs t r ac t, N. Engl. J. Med. 366 (2013) 2474–2482.
[40] J.P. Greving, J.H. Wermer, R.D. Brown, A. Morita, S. Juvela, M. Yonekura, et al., Development of the PHASES score for prediction of risk of rupture of intracranial aneurysms: a pooled analysis of six prospective cohort studies, The Lancet Neurology 13 (2014).
[41] H. Jiang, J. Shen, Y.-X. Weng, J.-W. Pan, J.-B. Yu, Z.-A. Wan, et al., Morphology parameters for mirror posterior communicating artery aneurysm rupture risk assessment, Neurol. Med. Chir. (Tokyo) 55 (6) (2015) 498–504.
[42] P.S. Amenta, S. Yadla, P.G. Campbell, M.G. Maltenfort, S. Dey, S. Ghosh, et al., Analysis of nonmodifiable risk factors for intracranial aneurysm rupture in a large, retrospective cohort, Neurosurgery 70 (3) (2012) 693–701 Mar 1.
[43] R. Kleinloog, N. de Mul, B.H. Verweij, J.A. Post, G.J.E. Rinkel, Y.M. Ruigrok, Risk factors for intracranial aneurysm rupture: a systematic review, E-published ahead of print, Neurosurgery 82 (4) (2018) 431–440.
[44] D. Backes, M.D.I.I. Vergouwen, B.K. Velthuis, I.C. van der Schaaf, A.S.E. Bor, A. Algra, et al., Difference in aneurysm characteristics between ruptured and unruptured aneurysms in patients with multiple intracranial aneurysms, Stroke 45 (5) (2014) 1299–1303 May 1.
[45] M. Shojima, M. Oshima, K. Takagi, R. Torii, M. Hayakawa, K. Katada, et al., Magnitude and Role of Wall Shear Stress on Cerebral Aneurysm Computational Fluid Dynamic Study of 20 Middle Cerebral Artery Aneurysms, (2004).
[46] M. Tremmel, S. Dhar, E.I. Levy, J. Mocco, H. Meng, Influence of Intracranial Aneurysm-to-Parent Vessel Size Ratio on Hemodynamics and Implication for Rupture: Results from a Virtual Experimental Study, vol. 64(4), (2009), pp. 622–631.
[47] R.D. Brown, J.P. Broderick, Review Unruptured Intracranial Aneurysms: Epidemiology, Natural History, Management Options, and Familial Screening, vol. 13, (2014).
[48] H.E. Ellamushi, J.P. Grieve, H.R. Jäger, N.D. Kitchen, Risk factors for the formation of multiple intracranial aneurysms, J. Neurosurg. 94 (2001).
[49] R. Leblanc, Familial cerebral aneurysms. A bias for women, Stroke 27 (6) (1996) 1050–1054 Jun.
[50] M.V. Casimiro, A.W. McEvoy, L.D. Watkins, N.D. Kitchen, A comparison of risk factors in the etiology of mirror and nonmirror multiple intracranial aneurysms, Surg. Neurol. 61 (6) (2004) 541–545 Jun.
[51] J.P. Strong, G.T. Malcom, M.C. Oalmann, Environmental and genetic risk factors in early human atherogenesis: lessons from the PDAY study. Pathobiological determinants of atherosclerosis in youth, Pathol. Int. 45 (6) (1995) 403–408 Jun.
[52] R. Ross, Cell biology of atherosclerosis, Annu. Rev. Physiol. 57 (1) (1995) 791–804 Oct.
[53] Y. Xu, S. Chen, B. Lei, W. Zhang, W. Wang, One-Stage Operation for Rare Multiple Mirror Intracranial Aneurysms: A Case Report and Literature Review Nadir Çoklu Ayna İntrakraniyal Anevrizmalar İçin Tek Aşamalı, (2014), pp. 598–601.
[54] P. Jeon, B.M. Kim, D.J. Kim, D.I. Kim, S.H. Suh, Treatment of multiple intracranial aneurysms with 1-stage coiling, AJNR Am. J. Neuroradiol. 35 (6) (2014) 1170–1173.
[55] K. Oh, Y.C. Lim, Single-session coil embolization of multiple intracranial aneurysms, J Cerebrovasc Endovasc Neurosurg 15 (3) (2013) 184–190.
[56] R.E. Clatterbuck, R.J. Tamargo, Contralateral approaches to multiple cerebral aneurysms, Neurosurgery 57 (1 Suppl) (2005) 160–163 Jul. (discussion 160-3).
[57] A. Rodríguez-Hernández, A. Gabarrós, M.T. Lawton, Contralateral clipping of middle cerebral artery aneurysms, Oper Neurosurg 71 (1 Suppl Operative) (2012) Sep. (ons116-ons124).
[58] A. James Ling, P.S. D'Urso, A. Madan, Simultaneous microsurgical and endovascular management of multiple cerebral aneurysms in acute subarachnoid haemorrhage, J. Clin. Neurosci. 13 (7) (2006) 784–788. Aug 1.
[59] S. Juvela, M. Porras, K. Poussa, Natural history of unruptured intracranial aneurysms: probability of and risk factors for aneurysm rupture, J. Neurosurg. 93 (3) (2000) 379–387 Sep.
[60] O. Heiskanen, Risk of bleeding from unruptured aneurysms in cases with multiple intracranial aneurysms, J. Neurosurg. 55 (4) (1981) 524–526 Oct.
[61] D.O. Wiebers, J.C. Torner, I. Meissner, Impact of unruptured intracranial aneurysms on public health in the United States, Stroke 23 (10) (1992) 1416–1419 Oct.
[62] P.J. Kelly, J. Stein, S. Shafqat, C. Eskey, D. Doherty, Y. Chang, et al., Functional recovery after rehabilitation for cerebellar stroke, Stroke 32 (2) (2001) 530–534 Feb.
[63] G.L. Kongable, G. Lanzino, T.P. Germanson, L.L. Truskowski, W.M. Alves, J.C. Torner, et al., Gender-related differences in aneurysmal subarachnoid hemorrhage, J. Neurosurg. 84 (1996).
[64] E.M. Oshiro, D.A. Rini, R.J. Tamargo, Contralateral approaches to bilateral cerebral aneurysms: a microsurgical anatomical study KEY WORDS • cerebral aneurysm • bilateral supratentorial aneurysm • contralateral approach • microsurgery • anatomical study, J. Neurosurg. 87 (1997).
[65] J.H.A. McMahon, M.K. Morgan, M.A.J. Dexter, The surgical management of contralateral anterior circulation intracranial aneurysms, J. Clin. Neurosci. 8 (4) (2001) 319–324 Jul 1.
[66] A. Rajesh, A. Praveen, A.K. Purohit, B.P. Sahu, Unilateral craniotomy for bilateral cerebral aneurysms, J. Clin. Neurosci. 17 (10) (2010) 1294–1297 Oct 1.
[67] S. Inci, A. Akbay, T. Ozgen, Bilateral middle cerebral artery aneurysms: a comparative study of unilateral and bilateral approaches, Neurosurg. Rev. 35 (4) (2012) 505–518 Oct 12.
[68] H. Andrade-Barazarte, J. Kivelev, F. Goehre, B.R. Jahromi, F. Hijazy, N. Moliz, et al., Contralateral approach to internal carotid artery ophthalmic segment aneurysms: angiographic analysis and surgical results for 30 patients, Neurosurgery 77 (1) (2015) 104–112.
[69] Y. Kakizawa, Y. Tanaka, Y. Orz, K. Hongo, S. Kobayashi, Parameters for contralateral approach to ophthalmic segment aneurysms of the internal carotid artery, 47 (5) (2000) 1130–1136.
[70] J. Vajda, Multiple intracranial aneurysms: a high risk condition, Acta Neurochir. 118 (1–2) (1992) 59–75.
[71] Y. Xu, S. Chen, B. Lei, W.-H. Zhang, W.-Y. Wang, One-stage operation for rare multiple mirror intracranial aneurysms: a case report and literature review, Turk Neurosurg 24 (4) (2014) 598–601.
[72] D. Murrone, B. Romanelli, A. Ierardi, Surgical case series of multiple aneurysms: a single-centre experience of 16 years, Int. J. Surg. Case Rep. 42 (2018) 191–195.
[73] E. Akgul, H.B. Onan, H.T. Balli, N.E. Cetinalp, A patient with eight intracranial aneurysms: endovascular treatment in two sessions, Case Rep Neurol Med 2016 (2016) 1–7 Sep 7.
[74] D. Wachter, I. Kreitschmann-Andermahr, J.M. Gilsbach, V. Rohde, Early surgery of multiple versus single aneurysms after subarachnoid hemorrhage: an increased risk for cerebral vasospasm? J. Neurosurg. 114 (4) (2011) 935–941. Apr.
[75] de Sousa AA, Filho MAD, Faglioni W, Carvalho GTC. Unilateral pterional approach to bilateral aneurysms of the middle cerebral artery. Surg. Neurol. 2005 Jan 1;63:S1–7.
[76] H. Andrade-Barazarte, J. Kivelev, F. Goehre, B.R. Jahromi, K. Noda, T.F. Ibrahim, et al., Contralateral approach to bilateral middle cerebral artery aneurysms: comparative study, angiographic analysis, and surgical results, Neurosurgery 77 (6) (2015) 916–925.
[77] Y.D. Cho, J.H. Ahn, S.C. Jung, C.H. Kim, W.S. Cho, H.-S. Kang, et al., Single-stage coil embolization of multiple intracranial aneurysms: technical feasibility and clinical outcomes, Clin. Neuroradiol. 26 (3) (2016) 285–290 Sep.
[78] G. Mariniello, F. Briganti, F. Tortora, M. Marseglia, F. Maiuri, Bilateral mirror aneurysms at the origin of the posteroinferior cerebellar artery: case report and review of the literature, J Neurointerv Surg 2 (2) (2010) 157–159.
[79] M. Koźba-Gosztyła, B. Czapiga, W. Jarmundowicz, Aneurismal subarachnoid hemorrhage: who remains for surgical treatment in the post-ISAT era? Arch. Med. Sci. 3 (3) (2015) 536–543.
[80] J. Raymond, F. Guillemin, F. Proust, A.J. Molyneux, A.J. Fox, J.S. Claiborne, et al.,

Unruptured intracranial aneurysms, Interv. Neuroradiol. 14 (1) (2008) 85–96 Mar 1.
[81] N.A. Sai Kiran, B.R. Jahromi, J.C. Velasquez, F. Hijazy, F. Goehre, R. Kivisaari, et al., Double-clip technique for the microneurosurgical management of very small (< 3 mm) intracranial aneurysms, Neurosurgery 11 (Suppl. 2) (2015) 1 Jan.
[82] R. Mohammadian, M. Asgari, N. Sattarnezhad, R. Mansourizadeh, F. Mohammadian, M. Shimia, et al., Endovascular treatment of very small and very large ruptured aneurysms of the anterior cerebral circulation: a single-center experience, Cerebrovasc. Dis. 35 (3) (2013) 235–240.
[83] J. Zhang, X. Lv, C. Jiang, Y. Li, X. Yang, Z. Wu, Endovascular treatment of cerebral aneurysms with the use of stents in small cerebral vessels, Neurol. Res. 32 (2) (2010) 119–122 Mar 19.