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Original Article

Clipping first policy for middle cerebral artery aneurysm: A single-center cohort study

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ABSTRACT

Background: The management choice for the middle cerebral artery aneurysms (MCAAs) is still controversial. This review aims to describe a single-center "clipping first" policy for MCAA over 40 years of experience and compare the short- and long-term clinical outcomes by aneurysm's location.

Methods: This retrospective cohort study reviews the whole series of a single-center intracranial aneurysm mainly based on the micro-neurosurgical experience of the senior authors (EOA and EKA). More than 968 aneurysm patients were treated at the University Hospital "Hôpital des Spécialités" Ibn Sina of Rabat in Morocco since 1983. We have included aneurysmal subarachnoid hemorrhage patients with the World Federation of Neurosurgical Societies (WFNS) Grade ≤III (64.7% clipped; 6.9% coiled) and those with WFNS Grade ≥IV (27.5% clipped; 0.9% coiled).

Results: From the database of 1069 IAs in 968 patients, we depicted 218 (22.5%) patients carrying 279 (26.1%) MCAA. About 92.1% (n = 257) of the MCAAs were microsurgically clipped, and 96.3% (n = 210) were discharged with good outcomes (modified Rankin Scale [mRS] ≤2). In the *post hoc* test, the mean of intracerebral hemorrhage (ICH) (4.178) among the group of poor outcome patients (mRS >2) was significantly (P = 0.001) high compared to that of 0.827 good outcome patients (mRS ≤2). The negative correlation found between the dome/neck ratio and the mRS (Pearson's r = −0.023, 95%confidence interval [CI] 0.110−−0.156) at admission (Pearson's r = −0.073, 95%CI 0.061−−0.204) and at discharge confirmed that the wider the MCAA neck is, the more susceptible it is to have a poor prognosis.

Conclusion: The good clinical outcome from the microsurgically clipped patients is overwhelming and allows us to conclude that microsurgical treatment should be mostly considered for MCAA management. The patient's poor outcome with MCAA at discharge was significantly associated with ICH at admission in the frequency of 68.9%.

Keywords: Clipping first policy, Microsurgical treatment, Middle cerebral artery aneurysm, Single-center cohort study

INTRODUCTION

Management of the middle cerebral artery aneurysm (MCAA) from microsurgical to endovascular repair has been a topic of interest for nearly half a century.

MCAAs are located along the cerebral vasculature that supplies the eloquent cerebral cortex and require a thorough knowledge of surgical treatment strategies to be approached safely. Great effort must be made to preserve the adjacent arterial branches during aneurysm dissection, including the lenticulostriate perforators.[22,28] Despite the necessity of this surgical predisposition, MCAA has long been considered favorable for clipping because they are accessible, can be easily manipulated after splitting the Sylvian fissure, and avail themselves to other treatment techniques such as clip reconstruction and bypass when conventional clipping techniques fail.[7,12]

This is a topic of pivotal importance because data on endovascular treatment of MCAAs remain scarce and ongoing evaluation is required for a reasonable comparison with a microsurgical long-term outcome as well as to establish appropriate treatment algorithms.[20] Much of the recent progress has come from only two prospective randomized controlled trial studies on ruptured aneurysms. One published in 1999 recognized that subsequent acute or late open surgery was sometimes required in the group of endovascular treatment in their series and also concluded that clinical outcome at 3 months (short-term outcome) was comparable in the endovascular and surgical treatment groups.[26] In the second paper published in 2005, the International Subarachnoid Aneurysm Trial data showed that in patients with ruptured intracranial aneurysms (IAs) suitable for both treatments, endovascular coiling is more likely to result in independent survival at 1 year than neurosurgical clipping; and at the same time, acknowledged the risk of late rebleeding being more common after endovascular coiling than after neurosurgical clipping.[14] This is a great deal of debate surrounding the adequate treatment choice for a better MCAA patient's outcome, and it has been a controversial point widely discussed in the literature.

Furthermore, an Italian multicenter retrospective study published in 2022 concluded that clipping still seems superior to coiling in providing better short- and long-term occlusion rates in MCAAs, and at the same time, it appears as safe as coiling in terms of clinical outcome.[24]

Here, we aim to describe a single-center "clipping first" policy for MCAAs over 40 years of experience and compare the short- and long-term clinical outcomes by aneurysm's location.

MATERIALS AND METHODS

Ethics approval

The data collected during the study were stored in a computer file in conformity with the Moroccan Data Protection Law, Decree n° 2-09-165 of May 21, 2009. This retrospective cohort study involved anonymous data collection, and ethics committee approval was waived.

Summary of experience

Within 40 years (from 1983 to 2022), 1069 IAs in 968 patients were managed in the author's department. The MCAAs were 279 (26.1%) from 218 (22.5%) patients. The neuroradiology department opened in 1985 with the endovascular coiling of aneurysm started in 2005 [Figure 1]. The senior authors (EOA and EKA) operated on most of the patients included in this study who have undergone microsurgical clipping.

Study population

We retrospectively reviewed the hospital records (clinical, radiological, surgical, and outcome) of 218 patients with MCAAs over 40 years (1983–2022). The study only included patients undergoing microsurgical or endovascular MCAA repair.

Clipping was the preferred treatment strategy for each patient with MCAA. Nevertheless, the patient selection for clipping or coiling was done by a multidisciplinary team of neurosurgeons, intensivists, and interventional neuroradiologists following clinical assessment and initial cerebral angiography. In the cases where treatment options were considered equal, priority was given to microsurgical management. Patients with aneurysmal subarachnoid hemorrhage (aSAH) of a good grade (World Federation of Neurosurgical Societies [WFNS] I–III) were, as a rule, treated within 24–72 hours. In other cases of poor pre-operative outcomes (WFNS IV–V) because of co-morbidity or late referral, some of the patients were sent for intensive care unit (ICU) management and were microsurgically or endovascularly treated after they upgraded their neurological status. Depending on the delay in the referral and the WFNS Grade IV or V at the admission, the team (neurosurgeon and intensivist) decide which of the patients go for either microsurgery/endovascular treatment to secure the aneurysm or ICU management before treatment of the ruptured aneurysm. In this setting, the WFNS Grade profile of the included patients in this study was as follows: WFNS Grade I was 26.6% ($n = 58$), WFNS Grade II was 35.3% ($n = 77$), WFNS Grade III was 9.6% ($n = 21$), WFNS Grade IV was 22.0% ($n = 48$), and WFNS Grade V 6.4% ($n = 14$). Moreover, when we split this WFNS Grade profile by the treatment options, we found that the group of patients admitted with WFNS Grade ≤III included 64.7% ($n = 141$) clipping versus 6.9% ($n = 15$) of coiling. The group of patients admitted with WFNS Grade ≥IV included 27.5% ($n = 60$) Clipping versus 0.9% ($n = 2$) Coiling.

In the multiple aneurysm cases, we selectively treated the ruptured aneurysms. The unruptured aneurysms were not treated in the same session unless they happened to be in the same surgical field. The 7.9% ($n = 22$) endovascularly treated aneurysm was mainly the patient's or family's choice. Only

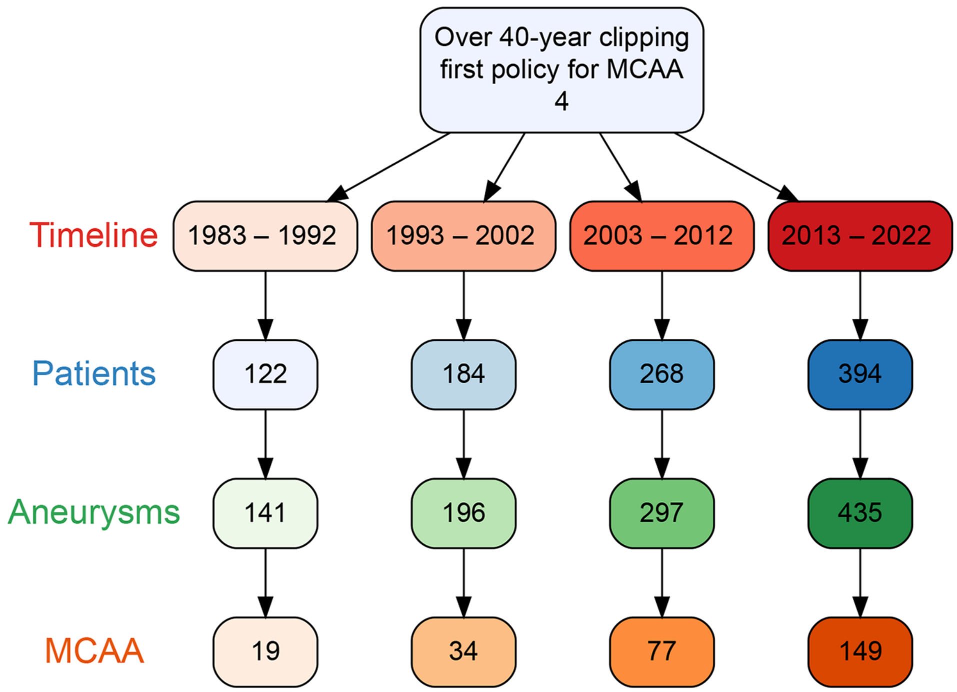

Figure 1: The timeline flowchart showing the number of patients, aneurysms, and middle cerebral artery aneurysms (MCAA).

the patients treated for ruptured MCAAs were included in this study. The participants meeting the inclusion criteria were identified and contacted to complete long-term follow-up data. We excluded all patients with incomplete medical records, all patients who did not respond to our phone calls to complete long-term follow-up data, and all others who did not have a digital subtraction angiographic result in their records [Figure 2].

Data acquisition

Patient-level sociodemographic data (age, gender, past medical history, and risk factors), the WFNS scale, number of aneurysms per location on the MCAA, clinical state, date of management, surgical, endovascular, complications, outcome, and follow-up were assessed. The clinical and radiological condition of all patients was classified according to the WFNS scale and the Fisher grading. Clinical outcome was graded according to the modified Rankin Scale (mRS) at admission, at discharge, and after 60 months of follow-up. Aneurysm-level data such as size, neck, width, height, dome-to-neck ratio, the location of aneurysm, and aspect ratio were collected. These data are collected and tabulated in an Excel spreadsheet. Data analysis was performed using JAMOVI version 3.2.8.

RESULTS

The majority of the 218 MCAAs patients summarized in Table 1 were the surgical results of the senior authors during the 40 years between 1983 and 2022 at the University Hospital “Hôpital des Spécialités” Ibn Sina of Rabat in Morocco.

Patients and aneurysm characteristics

Within this cohort, the mean age was 52.6±14.7, and 60.1% (n = 131) were older than 50 years old, with a female predominance of 56% (n = 122). The median hospitalization duration was 10 days (7–16), with the two most frequent clinical presentations being severe headache + meningeal syndrome 42.7% (n = 93) and impaired consciousness + motor deficit 36.2% (n = 79). The WFNS grade was evenly distributed with 20.6% (n = 45) Intracerebral Hemorrhage (ICH) patients at the admission [Table 1]. The result demonstrated that the MCAA has a substantial characteristic to rupture more frequently in females than in the male group with a mean Aspect Ratio = 4 (95%CI 3.3–4.9) versus 3.5 (95%CI 3.1–3.9), respectively. Meanwhile, wide-neck aneurysms were more frequent in the group of males compared to the female group with a mean Dome/Neck Ratio = 2.8 (95%CI 2.7–3.3) versus 3.3 (95%CI 2.6–4.0), respectively. The first might explain the second: wide-neck aneurysms do rupture less frequently than do the small-neck aneurysms Figure 3.

Ninety-two-point, 1% (n = 257) of the MCAAs, were microsurgically clipped, while only 7.9% (n = 22) underwent endovascular coiling [Table 2a]. At discharge, 96.3% (n = 210) left our department with good outcomes (mRS ≤2), and

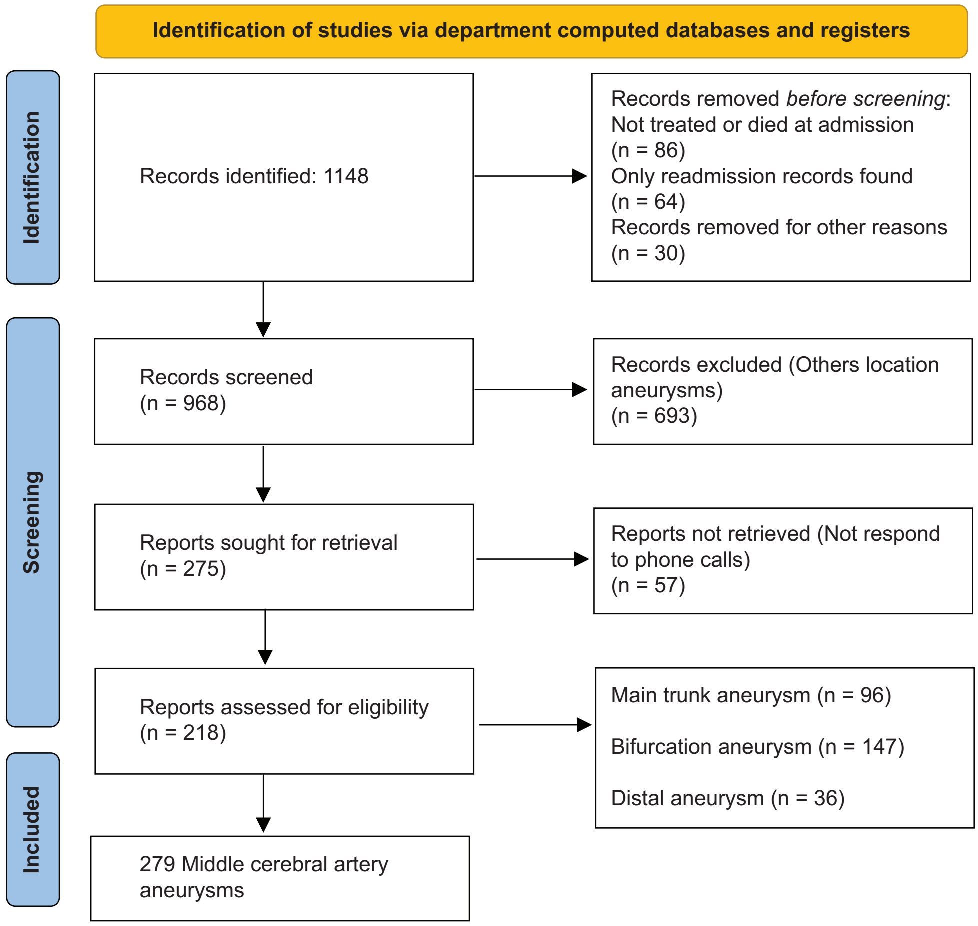

Figure 2: Diagram flow chart of patient selection.

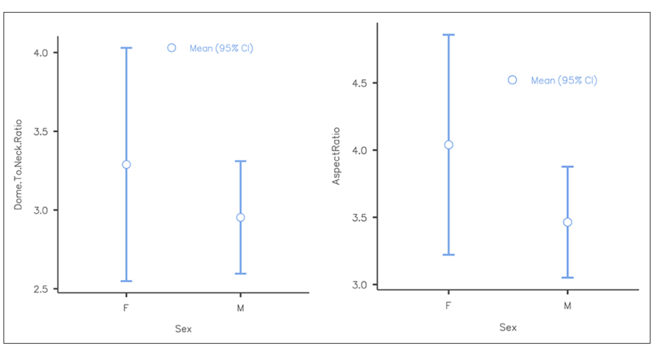

Figure 3: The middle cerebral artery aneurysm has the characteristics to rupture more frequently in females than in the male group (Mean Aspect Ratio = 4 vs. 3.5), respectively. Meanwhile, wide-neck aneurysms were more frequent in the group of males compared to females (Mean Dome/Neck Ratio = 2.8 vs. 3.3), respectively.

85.3% (*n* = 186) were doing well and returned to their daily occupations after 60 months of follow-up. The mortality rate was only 6.4% (*n* = 14).

Table 2b depicts the comparison of the ICH between the groups of mRS at discharge and MCAA locations. The *P*-value (*P* = 0.001) of the One-Way analysis of variance (Welch's) test is significant. At least one mean is significantly different compared to others. The *post-hoc* Test was done, and the mean of ICH (4.178) among the group of poor outcome patients (mRS >2) was significantly high compared to that of (0.827) good outcome patients (mRS ≤2). In other words, the patient's poor outcome with MCAA at discharge was significantly (*P* = 0.001) associated with the presence of ICH at admission in the frequency of 68.9% (*n* = 31). The same comparison (Chi-square test) was done, and there was a statistically significant (*P* = 0.043) association between ICH and aneurysm location. The frequency of ICH in the group of middle cerebral artery (MCA) bifurcation aneurysms (55.6%, *n* = 25) was higher than that of other groups. On the contrary, no significant (*P* = 0.803) association was found between the ICH and the age groups. The group of MCAA patients with ICH at admission was associated with poor prognosis (mRS >3.5) Figure 4.

The MCA

MCAAs are usually categorized into three categories according to their origin: the main trunk aneurysms arising from the origin of the temporopolar or the lateral wall of the

Table 1: Characteristics of patients operated for the MCAA.

Variables	*n*=218
Age[a]	52.6±14.7
Age[b]	
≤50 years	87 (39.9)
>50 years	131 (60.1)
Sex[b]	
Female	122 (56)
Male	96 (44)
Hospitalization[c]	10 days (7–16)
Past medical history (PMH)[b]	
AHT and Dt2	114 (52.3)
Smoking	76 (34.9)
Parkinson syndrome	2 (0.9)
PMH unremarkable	26 (11.9)
Clinical presentation[b]	
Severe Headache and Meningeal Syndrome	93 (42.7)
Impaired Consciousness and Motor Deficit	79 (36.2)
Intracranial Hypertension	6 (2.8)
Impaired Consciousness	40 (18.3)
WFNS Grade[b] at admission	
I	58 (26.6)
II	77 (35.3)
III	21 (9.6)
IV	48 (22.0)
V	14 (6.4)
ICH	45 (20.6)
mRS at discharge	
≤2	210 (96.3)
>2	8 (3.7)
mRS at 60-month follow-up	
≤2	186 (85.3)
>2	32 (14.7)
Mortality Rate	14(6.4)

[a]Mean±Standard deviation, [b]Number of patients (percentage), [c]Median [interval interquartile], AHT and Dt2: Arterial hypertension and diabetes, WFNS: World Federation of Neurosurgical Societies, ICH: Intracerebral hemorrhage, MCAA: Middle cerebral artery aneurysm

anterior temporal arteries or in relation to the lenticulostriate arteries arising from the posteromedial wall 34.4% ($n = 96$), the bifurcation aneurysm located at the first major bifurcation of the MCA 52.7% ($n = 147$), and the distal aneurysm located beyond the major bifurcation 12.9% ($n = 36$). A saccular aneurysm was the most frequently encountered at 82.1% ($n = 229$), the fusiform type was 3.2% ($n = 9$), the giant aneurysm at 14.7% ($n = 41$), and 7.2% ($n = 20$) was mirror aneurysms. Among them, 47% ($n = 131$) had the characteristics of a "wide neck" aneurysm with a Dome/Neck ratio <2.

Radio-clinical characteristics by aneurysm location and outcome

Table 3 highlights three major findings. There was no statistically significant ($P = 0.402$) difference in the mean of dome-to-neck ratio distribution between the aneurysm location, the main trunk aneurysms (3.33 ± 2.30), the bifurcation aneurysm (3.26 ± 4.29), and the distal aneurysm (2.41 ± 1.37). However, there was a statistically significant ($P = 0.051$) aneurysm-type distribution according to the

Table 2a: Characteristics of the MCAA.

Variables	*n*=279
Aneurysm location	
Main trunk (M1 segment) aneurysm	96 (34.4)
Bifurcation aneurysm	147 (52.7)
Distal aneurysm	36 (12.9)
Aneurysm type	
Mirror MCAA	20 (7.2)
MCAA+AVM	3 (1.1)
Saccular	229 (82.1)
Fusiform	9 (3.2)
Giant	41 (14.7)
Multiple aneurysm	
Two aneurysms (1 MCAA)	35 (83.3)
Three aneurysms (1 MCAA)	7 (16.7)
Radiological characteristics	
Dome-to-neck ratio	
<2 mm	131 (47)
>2 mm	148 (53)
Aspect ratio	
<1.6 mm	85 (30.5)
>1.6 mm	194 (69.5)
Treatment	
Clipping	257 (92.1)
Coiling	22 (7.9)

MCAA: Middle cerebral artery aneurysm, AVM: Arteriovenous malformation, the aneurysm is qualified as "wide neck" when the dome-to-neck ratio <2 mm. When the aspect ratio is>1.6, the aneurysm should be treated because it has the characteristics of rupture.

Table 2b: Comparison of ICH between the groups of mRS and MCAA locations.

Variables	aSAH	aSAH and ICH	*P*-value
Age			
≤50 years	65 (37.6)	16 (35.6)	0.803
>50 years	108 (62.4)	29 (64.4)	0.803
Location			
Main trunk (M1 segment)	24 (13.9)	9 (20.0)	0.043
Bifurcation aneurysm	128 (74.0)	25 (55.6)	0.043
Distal aneurysm AHT and Dt2	21 (12.1)	11 (24.4)	0.043
mRS at discharge			
Good outcome (mRS ≤2)	172 (99.4)	14 (31.1)	<0.001
Poor outcome (mRS >2)	1 (0.6)	31 (68.9)	<0.001

ICH: Intracerebral hematoma, aSAH: Aneurysmal subarachnoid hemorrhage, mRS: Modified Rankin Scale, MCAA: Middle cerebral artery aneurysm, AHT: Arterial hypertension

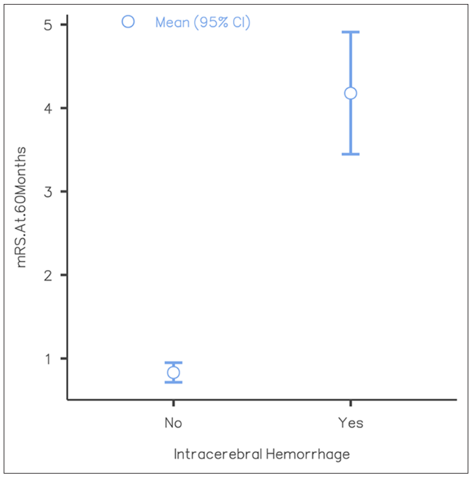

Figure 4: The group of middle cerebral artery aneurysm patients with intracerebral hemorrhage at admission was associated with poor prognosis (modified Rankin Scale >3.5).

location, with the bifurcation aneurysm being the most represented: saccular aneurysm was 86.1% (n = 173), the fusiform aneurysm was 3.0% (n = 6), and the giant aneurysm was 10.9% (n = 22). The death rate was 18.9% (n = 7) for the main trunk aneurysm, 9.5% (n = 19) for the bifurcation aneurysm, and 17.1% (n = 7) for the distal aneurysm.

The multivariate analysis [Table 4] has shown that death occurs in the group of patients with a dome-to-neck ratio ≤2.6 (wide neck aneurysm) Odds Ratio 1.00, 95%CI 0.66–1.43. The negative correlation found between the dome-to-neck ratio and the mRS (Pearson's r = −0.023, 95% CI 0.110−−0.156) at admission, Pearson's r = −0.073, 95%CI 0.061−−0.204 at discharge, and (Pearson's r = −0.080, 95% CI 0.053−−0.211) at 60 months of follow-up confirmed that the smaller the dome-to-neck ratio is, the greater the mRS get. In other words, the wider the aneurysm neck is, the more susceptible it is to have a poor prognosis [Figure 5].

More importantly, there was a statistically significant (P = 0.048) association between the mRS and the death ratio.

DISCUSSION

Key findings

By carefully examining the data, it is found that four key findings emerged: (i) the MCAA has a substantial characteristic to rupture more frequently in females than in the male group with a mean Aspect Ratio = 4 (95%CI 3.3–4.9) versus 3.5 (95% CI 3.1–3.9), respectively. (ii) For the majority of the MCAAs, 92.1% were microsurgically clipped, and 96.3% were discharged with good outcomes (mRS ≤2). (iii) There was a significant association (P = 0.001) between the group of MCAA patients (Mean = 4.178) admitted with ICH and poor outcome patients (mRS >2), but there was no significant (P = 0.803) association found between the ICH and the age groups. (iv) The favorable outcome (mRS ≤2) after a long-term follow-up was associated with the group of small-neck aneurysm (dome-to-neck ratio >2.2) for the MCAA microsurgically treated in 85.3% of cases with OR = 14.60; 95% CI 4.83–18.74; P = 0.048. Death occurs in the group of patients with a dome-to-neck ratio ≤2.6 (wide neck aneurysm) odds ratio of 1.00; 95% CI 0.66–1.43.

Implications

The results of this study will shed light on the understanding of the "clipping first" policy for MCAA repair and emphasize the importance of its short- and long-term outcome appraisal.

Some authors reported the MCA as a common site of cerebral aneurysms and 82.6% occur at the bifurcation.[5] Our results emphasized, first of all, the importance of MCAA distribution; 52.7% were found at MCA bifurcation, with 82.1% being of saccular type. Moreover, when comparing the radiological characteristics and the frequency of ruptured MCAAs within the gender, the wide-neck aneurysms were more frequent in the male group, and the likelihood of aneurysm rupture was more important in the female group, Aspect Ratio = 4 (95%CI 3.3–4.9). We did not find in the literature any reported MCAA study reporting such a condition. Hou *et al.*[10] reported that 83.6% of patients with MCAAs underwent microsurgical repair, and only 11.9% of the patients underwent endovascular treatment. This is similar to our result (92.1% of the MCAAs were microsurgically clipped while only 7.9% of the patients underwent endovascular coiling), and the reasons can be multifactorial. The first reason to be considered is the technical constraint, and early intracranial ruptured aneurysms (before the introduction of the endovascular treatment 22 years later in 2005) were microsurgically treated. As a result, neurosurgeons are more prone to adopt the seemingly safer open surgical approach they are already used to. Finally, the introduction of endovascular treatment with many promises without any proof of better outcomes at long-term follow-up had put the senior author in a wait-and-see position. In fact, during the last two decades, no randomized controlled trial or systematic review was able to conclude the superiority of one method over the other in a long-term follow-up.

Nevertheless, our study has found good outcomes after a long-term follow-up (96.3% of patients were discharged with mRS ≤2) of microsurgical treatment for MCAA. This is consistent with the findings of Kim *et al.*[11] and Schwartz *et al.*[20] which suggests that occlusion rates were significantly higher in the clipping cohort (RROC = 1: 96.3% vs. 78.9%; P= 0.04) and concluded there is an association between both treatment modalities with

Table 3: Radiological and clinical characteristics by aneurysm location.

Variables	Main trunk (M1 Segment) aneurysm	Bifurcation aneurysm	Distal aneurysm	*P*-value
Dome/neck ratio	3.33±2.30	3.26±4.29	2.41±1.37	0.402
Aspect ratio	4.01±2.96	3.89±4.71	3.09±1.81	0.510
Type of aneurysm				
Saccular	25 (67.6)	173 (86.1)	31 (75.6)	0.051
Fusiform	2 (5.4)	6 (3.0)	1 (2.4)	0.051
Giant	10 (27)	22 (10.9)	9 (22%)	0.051
Treatment				
Clipping	35 (94.6)	182 (90.5)	40 (97.6)	0.263
Coiling	2 (5.4)	19 (9.5)	1 (2.4)	0.263
mRS at Admission				
I	-	2 (1)	3 (7.3)	0.005
II	29 (78.4)	185 (92)	34 (82.9)	0.005
III	6 (16.2)	12 (6)	2 (4.9)	0.005
VI	2 (5.4)	2 (1)	2 (4.9)	0.005
mRS at Discharged				
0	7 (18.9)	70 (34.8)	10 (24.4)	0.295
I	24 (64.9)	100 (49.8)	26 (63.4)	0.295
II	4 (10.8)	26 (12.9)	3 (7.3)	0.295
III	1 (2.7)	2 (1)	-	0.295
VI	1 (2.7)	3 (1.5)	2 (4.9)	0.295
mRS at 60 months				
0	7 (18.9)	65 (32.3)	8 (19.5)	0.215
I	19 (51.4)	89 (44.3)	23 (56.1)	0.215
II	3 (8.1)	26 (12.9)	3 (7.3)	0.215
III	1 (2.7)	2 (1)	-	0.215
VI	7 (18.9)	19 (9.5)	7 (17.1)	0.215

mRS: Modified Rankin Scale

Table 4: Univariate and Multivariate Logistic Regression Analysis for 279 MCAA.

	Outcome		*Univariate*			*Multivariate*		
	Alive M(SD)	Died M(SD)	OR	96%CI	*P*-value	OR	96%CI	*P*-value
Dome-to-neck ratio	3.2 (3.9)	2.6 (2.1)	0.92	0.75–1.05	0.379	1.00	0.66–1.43	0.997
Aspect ratio	3.9 (4.4)	3.1 (2.2)	0.93	0.78 – 1.04	0.326	0.93	0.68–1.29	0.651
mRS at admission	2.0 (0.3)	2.8 (1.6)	3.36	1.97–7.54	0.001	3.27	1.84–7.46	0.001
mRS at discharged	0.9 (0.9)	1.4 (1.6)	1.43	1.07–1.91	0.013	1.07	0.68–1.57	0.765
mRS at 60 months	0.9 (0.8)	5.9 (0.5)	6.48	3.86–16.59	0.001	14.60	4.83–18.74	0.048

M: Mean, SD: Standard Deviation, mRS; Modified Rankin Scale, OR: Odds ratio, CI: Confident interval, MCAA: Middle cerebral artery aneurysm

excellent clinical and radiological outcomes when applied with an interdisciplinary treatment approach. Furthermore, MCAA is more likely to present with an intraparenchymal hematoma in the temporal or frontal lobe. Hematomas extending into both the temporal and frontal operculi are pathognomonic of a ruptured MCAA.[8,9,13,28] This is why these authors[1,6,16,21] agreed on 18.6–38% of the death ratio among surgically treated patients with an ICH due to a ruptured MCAA. This is regardless of temporal ICH, intrasylvian hematoma, or ICH with diffuse SAH. In addition, Nowak *et al.*[15] have advocated active surgical management of ICH patients: hematoma evacuation and aneurysm clipping during the same operation. Their study reported an 84.2% death rate in the group of ICH patients not operated, while those who were considered for surgery had a surgical mortality of 18.6%. We believe that those reported results are of significance for our study also emphasized a significant association (P = 0.001) between the group of MCAA patients (Mean = 4.178) admitted with ICH and poor outcome patients (mRS >2).

The larger the size of the ruptured MCAA, the poorer the long-term outcome; 29% of patients with very small ruptured MCAA, 33% with small MCAA, 31% with large MCAA, and 43% with giant MCAA had poor outcomes. Patients

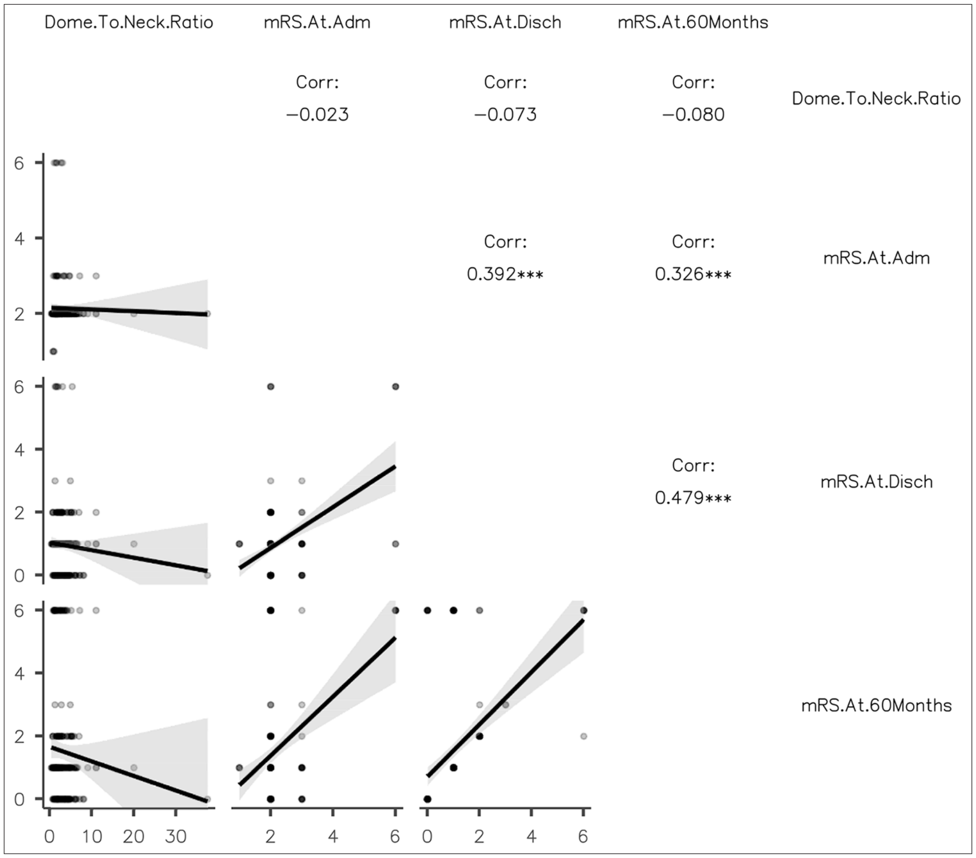

Figure 5: The negative correlation found between the dome-to-neck ratio and the modified Rankin Scale (mRS) (Pearson's r = –0.023; 95%CI 0.110––0.156) at admission, Pearson's r = –0.073; 95% CI 0.061––0.204 at discharge, and (Pearson's r = –0.080; 95% CI 0.053––0.211) at 60 months of follow-up confirmed that the wider the aneurysm neck is, the more susceptible it is to have a poor prognosis. mRS: modified Rankin Scale, CI: Confidence interval, Corr: Correlation coeficient, Adm: Admission, Disch: Discharge. * p < .05, ** p < .01, *** p < .001

with large and giant MCAA had significantly more ICH (59%) than did those with smaller MCAA (34%).[4,17,23,25] The results were almost the same while dealing with a cohort of endovascular-treated MCAA, but at a mean follow-up period of 11 months, with an adequate occlusion of 92% and a good clinical outcome (modified Rankin score ≤2) in 96% of patients.[18,19] This research has addressed this gap within long-term follow-up (60 months), and the smaller the aneurysm was dome-to-neck ratio >2.2), the higher the patient likelihood to have a favorable outcome (mRS ≤2) in 85.3% of cases with OR = 14.60; 95% CI 4.83–18.74 (*P* = 0.048).

Contributions

This is an important study, and it adds tremendously to the literature by first reporting the positive correlation between the radiological characteristics of MCAAs and gender, then explaining in the discussion the three multifactorial reasons for the "clipping first" policy in the era of overwhelming endovascular treatment. Third, this study underlines and updates the three categories of MCAA distribution, and most aneurysms were located at the bifurcation of the MCA in a proportion of 52.7%, thus leading to a high frequency of ICH in the group of MCA bifurcation aneurysms (55.6%). Finally, our study is nevertheless a valuable contribution to the field as it suggests a favorable outcome in more than 85% of cases after a long-term follow-up (>60 months) for MCAA patients microsurgically treated.

Novelty and Limitations

In this work, our main interest lies in the idea of preserving the place of open surgery for the MCAA repair, as it had been in our department for the last four decades, the first choice for the management of this condition. This study was conducted in response to the need to provide robust conclusions drawn from rigorous data analysis in the neurovascular field to support and generalize the concept of the "clipping first" policy.

There are several notable limitations of this study, such as the retrospective study design and the choice of clipping technique, which was based only on the surgeon's judgment. Our database (retrospective study) did not allow us to separately report those patients that have improved their neurological status before surgery. With the availability of endovascular treatment in the past two decades in our department, all patient's treatment decisions were based on an interdisciplinary approach, selection for a particular treatment modality cannot be completely excluded. However, this reflects current practice. There are few MCAAs in which true balance exists in the treatment modalities. Based on these data, it remains difficult to prefer conventional microsurgical clipping over endovascular treatment for MCAAs clearly. In fact, comparing these two treatment modalities was not the aim of this study. Nevertheless, both treatment modalities have been reported by many authors[2,3,27] to produce favorable outcomes in terms of occlusion rates and neurological outcomes. Both options have their place in the treatment of MCAAs, and the days when the treatment of MCAAs was the exclusive domain of microsurgery have long passed. We believe that endovascular treatment is a viable and attractive, minimally invasive alternative to the established microsurgical clipping, that should be worthy of further evaluation in future prospective, randomized trials.

CONCLUSION

These findings support the conclusion that microsurgical repair for MCAAs leads to excellent short- and long-term outcomes. The four decades "clipping first" policy concept was then a successful patient-centered experience with well-known and codified surgical approaches. Nevertheless, there appears to be increasing interest in the endovascular treatment for MCAAs.

Ethical approval

Institutional Review Board approval is not required. This is a retrospective cohort (non-interventional) study.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Bhide AA, Yamada Y, Kato Y, Kawase T, Tanaka R, Miyatani K, *et al.* Surgical management of complex middle cerebral artery aneurysms: An institutional review. Asian J Neurosurg 2020;15:959-65.
2. Brinjikji W, Lanzino G, Cloft HJ, Rabinstein A, Kallmes DF. Endovascular treatment of middle cerebral artery aneurysms: A systematic review and single-center series. Neurosurgery 2011;68:397-402.
3. Choi SW, Ahn JS, Park JC, Kwon DH, Kwun BD, Kim CJ. Surgical treatment of unruptured intracranial middle cerebral artery aneurysms: Angiographic and clinical outcomes in 143 aneurysms. J Cerebrovasc Endovasc Neurosurg 2012;14:289-94.
4. Day AL, Gaposchkin CG, Yu CJ, Rivet DJ, Dacey RG Jr. Spontaneous fusiform middle cerebral artery aneurysms: Characteristics and a proposed mechanism of formation. J Neurosurg 2003;99:228-40.
5. Degollado-García J, Rodríguez-Rubio HA, Bonilla-Suastegui A, Serrano-Rubio A, Nicolas-Cruz CF, Nathal E. Limitation of fenestrated clips during clipping of middle cerebral artery aneurysm: Technical note. Surg Neurol Int 2023;14:204.
6. Ding D, Buell TJ, Raper DM, Chen CJ, Mastorakos P, Liu KC, *et al.* Sylvian arteriovenous malformation resection and associated middle cerebral artery aneurysm clipping: Technical nuances of concurrent surgical treatment. Cureus 2018;10:e2166.
7. Fraser JF, Smith MJ, Patsalides A, Riina HA, Gobin YP, Stieg PE. Principles in case-based aneurysm treatment: Approaching complex lesions excluded by International Subarachnoid Aneurysm Trial (ISAT) criteria. World Neurosurg 2011;75:462-75.
8. Heros RC, Fritsch MJ. Surgical management of middle cerebral artery aneurysms. Neurosurgery 2001;48:780-5.
9. Hopf NJ, Stadie A, Reisch R. Surgical management of bilateral middle cerebral artery aneurysms via a unilateral supraorbital key-hole craniotomy. Minim Invasive Neurosurg 2009;52:126-31.
10. Hou K, Xu K, Liu H, Li G, Yu J. The clinical characteristics and treatment considerations for intracranial aneurysms associated with middle cerebral artery anomalies: A systematic review. Front Neurol 2020;11:564797.
11. Kim BJ, Kim JS, Jeon KD, Lee SI. Spontaneous complete occlusion of middle cerebral artery aneurysm: Case report. J Cerebrovasc Endovasc Neurosurg 2012;14:309-14.
12. Lawton MT, Quinones-Hinojosa A, Sanai N, Malek JY, Dowd CF. Combined microsurgical and endovascular management of complex intracranial aneurysms. Neurosurgery 2003;52:263-74.
13. Lee KS, Zhang JJY, Nguyen V, Han J, Johnson JN, Kirollos R,

et al. The evolution of intracranial aneurysm treatment techniques and future directions. Neurosurg Rev 2022;45:1-25.

14. Molyneux AJ, Kerr RS, Yu LM, Clarke M, Sneade M, Yarnold JA, *et al.* International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: A randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. Lancet 2005;366:809-17.
15. Nowak G, Schwachenwald D, Schwachenwald R, Kehler U, Müller H, Arnold H. Intracerebral hematomas caused by aneurysm rupture. Experience with 67 cases. Neurosurg Rev 1998;21:5-9.
16. Ogilvy S, Crowell RM, Heros RC. Surgical management of middle cerebral artery aneurysms: Experience with transsylvian and superior temporal gyrus approaches. Surg Neurol 1995;43:15-22; discussion 22-4.
17. Rinne J, Hernesniemi J, Niskanen M, Vapalahti M. Analysis of 561 patients with 690 middle cerebral artery aneurysms: Anatomic and clinical features as correlated to management outcome. Neurosurgery 1996;38:2-11.
18. Saal-Zapata G, Ghodke B, Walker M, Pregúntegui-Loayza I, Rodríguez-Varela R. Endovascular treatment of medium and large intracranial aneurysms with large volume coils: A single-center experience. Surg Neurol Int 2022;13:9.
19. Sato H, Haraguchi K, Takahashi Y, Ohtaki S, Shimizu T, Matsuura N, *et al*. Endovascular coil embolization of proximal middle cerebral artery aneurysms has better outcomes than other middle cerebral artery aneurysms: A retrospective study. Interv Neuroradiol 2020;26:268-74.
20. Schwartz C, Aster HC, Al-Schameri R, Müller-Thies-Broussalis E, Griessenauer CJ, Killer-Oberpfalzer M. Microsurgical clipping and endovascular treatment of middle cerebral artery aneurysms in an interdisciplinary treatment concept: Comparison of long-term results. Interv Neuroradiol 2018;24:608-14.
21. Shimoda M, Oda S, Mamata Y, Tsugane R, Sato O. Surgical indications in patients with an intracerebral hemorrhage due to ruptured middle cerebral artery aneurysm. J Neurosurg 1997;87:170-5.
22. Sriamornrattanakul K, Akharathammachote N, Wongsuriyanan S. Early exposure of the dorsal surface of M1 segment via the distal transsylvian approach for clipping of anteroinferior-projecting middle cerebral artery bifurcation aneurysms. Asian J Neurosurg 2022;17:23-30.
23. Stapleton CJ, Walcott BP, Fusco MR, Butler WE, Thomas AJ, Ogilvy CS. Surgical management of ruptured middle cerebral artery aneurysms with large intraparenchymal or sylvian fissure hematomas. Neurosurgery 2015;76:258-64.
24. Sturiale CL, Scerrati A, Ricciardi L, Rustemi O, Auricchio AM, Norri N, *et al*. Clipping versus coiling for treatment of middle cerebral artery aneurysms: A retrospective Italian multicenter experience. Neurosurg Rev 2022;45:3179-91.
25. Tsonev H, Bussarsky A, Sirakov S, Minkin K, Ninov K, Filipova E, *et al.* Management of mirror middle cerebral artery aneurysms: Surgical results and morphological parameters. Turk Neurosurg 2023;33:406-12.
26. Vanninen R, Koivisto T, Saari T, Hernesniemi J, Vapalahti M. Ruptured intracranial aneurysms: acute endovascular treatment with electrolytically detachable coils--a prospective randomized study. Radiology 1999;211:325-36.
27. Vitale G, Talenti G, Gabrieli J, Cester G, Della Puppa A, Causin F. Endovascular rescue treatment through stent positioning after surgical clipping of intracranial aneurysms complicated by parent artery obstruction. BMJ Case Rep 2017;2017:pp. bcr-2017.
28. Zhu W, Liu P, Tian Y, Gu Y, Xu B, Chen L, *et al*. Complex middle cerebral artery aneurysms: A new classification based on the angioarchitecture and surgical strategies. Acta Neurochir (Wien) 2013;155:1481-91.

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