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Technical notes & surgical techniques

Surgical clipping compared to endovascular coiling of ruptured coil able middle cerebral aneurysms: A single-center experience

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ABSTRACT

Objective: The middle cerebral artery (MCA) is the third most common site for ruptured intracranial aneurysms. Aneurysms in this location are known to be challenging to treat endovascularly and are commonly treated with microsurgery. Although advances in endovascular treatment options for cerebral aneurysms have markedly reduced the need for surgery in recent years and decades, there is no compelling scientific evidence that endovascular treatments are superior to surgical treatment. The present study aimed to determine the appropriate treatment modality in ruptured MCA aneurysms.

Methods: We retrospectively evaluated and compared the treatment outcomes of 80 patients with ruptured MCA aneurysms who underwent either endovascular or microsurgical treatment in our center between 2011 and 2016. Post-treatment clinical and radiological outcomes were assessed in all patients. Furthermore, we compared intraoperative complications and the need for re-treatments between the two groups.

Results: According to our findings, complete aneurysm occlusion was achieved in 90.5% and 89.2% of the patients in the clipping and coil group, respectively ($p = 0.850$). Moreover, 14.3% of the patients in the clipping group and 15.8% of the subjects in the coil group developed intraoperative complications ($p = 0.851$), including 3 cases of intraoperative hemorrhage and 3 cases of ischemia in the clipping group as well as 2 cases of thromboembolism and 4 cases of vasospasm during endovascular treatment in the coil group. There was an improvement in the modified Rankin score (mRS) at six months, with no significant difference between the two groups ($p = 0.916$).

Conclusion: The results of coiling only with coil able MCA aneurysms were comparable to the results of clipping with difficult cases. Sufficient follow-up study of recurrence and retreatment are needed to determine the indication for coiling for ruptured MCA aneurysm.

1. Introduction

The middle cerebral artery (MCA) is the third most common site for ruptured intracranial aneurysm [1–3]. Patients with MCA aneurysms have traditionally been considered poor candidates for endovascular treatment and are commonly treated with microsurgical clipping. Due to their relatively superficial location, the approach requires minimal retraction of the brain parenchyma, making them more accessible for surgical treatment [4,5]. Although the endovascular treatment of cerebral aneurysms has markedly reduced the need for surgery, there is no compelling scientific evidence that endovascular treatments are superior to surgical treatment [6,7]. However, due to recent technical advances, MCA aneurysms are now more frequently treated with an endovascular approach. To date, few studies have compared the outcomes of endovascular treatment and surgery in ruptured MCA aneurysms. Although endovascular treatments decrease the need for surgical treatment and shorten the procedure time, there are still associate risks. Possible complications include iatrogenic vascular injury,

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Table 1
Demographic features and angiographic characteristics of aneurysms.

	Microsurgical Clipping N (%)	Endovascular Coiling N (%)	P-value
Demographic			
N	42	38	
Mean age	58.6	58	0.83
female	24 (57.1)	25 (65.8)	0.49
male	18 (42.9)	13 (34.2)	
Hypertension	23 (54.8)	22 (57.9)	0.82
Smoker	17 (40.5)	17 (44.7)	0.82
Fisher grade			
Grade 1	4 (9.5)	5 (13.2)	0.76
Grade 2	12 (28.6)	14 (36.8)	
Grade 3	22 (52.4)	16 (42.1)	
Grade 4	4 (9.5)	3 (7.9)	
Aneurysm location			
MCA bifurcation	32 (76.2)	30 (78.9)	0.61
M1 segment	4 (9.5)	5 (13.2)	
Anterior temporal	6 (14.3)	3 (7.9)	
Aneurysm size			
< 6 mm	17 (40.5)	10 (26.3)	0.44
6–10 mm	19 (45.2)	18 (47.4)	
11–25 mm	5 (11.9)	7 (18.4)	
> 25 mm	1 (2.4)	3 (7.9)	
Aneurysm shape			
Bilobulated	19 (45.2)	18 (47.4)	0.83
Daughter sac	24 (57.1)	19 (50.0)	
Neck	4.51 + 0.7	3.42 + 1.0	< 0.001
Dome/Neck	1.24 + 0.2	1.98 + 0.2	< 0.001

thromboembolic events, or intraprocedural rupture of the aneurysm [8]. The present study aimed to evaluate the most appropriate treatment option in ruptured MCA aneurysms.

2. Materials and methods

We performed a retrospective review of 80 patients with ruptured MCA aneurysms who underwent microsurgical or endovascular treatment in our center during 2011–2016. The local institutional review board approved the study protocols.

Patients who were referred to our institution with ruptured MCA aneurysms managed according to the following protocol: Aneurysms were evaluated by CT angiography and digital subtraction angiography (DSA). If none of the contraindications (Table 1) were present, our initial recommendation was endovascular treatment by coiling. However our contraindications for endovascular interventions included: patients with Neck width of more than 4 mm (n = 11), Dome/Neck ratio of less than 1.5 mm (n = 10), inadequate vascular access (n = 5) and arterial branch incorporating the aneurysm neck (n = 12).

After coiling, occlusion of the aneurysm was confirmed by follow-up control angiogram. Surgical clipping performed only if patients either had contraindications for endovascular treatment or if the coiling attempt failed. Control angiography was performed one day after surgery to confirm complete occlusion of the aneurysm.

We evaluated demographic characteristics, symptomatology, angiographic findings (including the size and morphology of the aneurysm as well as the degree of occlusion on control angiography (at the longest follow up of 6 months or more), periprocedural complications, and clinical outcomes at six months.

2.1. Preoperative evaluation

We included patients treated for subarachnoid hemorrhage due to ruptured MCA aneurysms. All patients were treated within the first three days of presentation. Patients were treated either if they presented with Hunt & Hess grade 1–3. Patients with higher grade subarachnoid hemorrhages were treated if their clinical condition improved upon ventriculostomy. Patients with Hunt & Hess grade 5 or extensive intracranial hematoma requiring emergent decompressive craniectomy were excluded from the study. All patients underwent cerebral angiography before treatment. CT angiography and 3D reconstruction were performed if additional information regarding angioarchitecture of the aneurysm was required. All treatments were performed by a single attending vascular neurosurgeon. In the endovascular group, the patients were anticoagulated after insertion of the first coil. Antiplatelet regiment (Aspirin 325 g and Clopidogrel 75 mg) was initiated in case of a prolapsed coil tail or stent placement. Depending on the anatomy of the aneurysm and the adjacent vasculature, the patients underwent either coiling only or coiling plus stent.

2.2. Outcome assessment

Peri-procedural complications and the need for re-treatment were compared between the two groups. Angiographic evidence after surgery was classified as complete, near-complete, and incomplete occlusion in patients undergoing microsurgery. In the endovascular group, the angiographic evidence was assessed using the Raymond-Roy occlusion classification. Modified ranking scale (mRS) was assessed on admission, and at least for six months follow-up. Favorable outcome after subarachnoid hemorrhage was defined as an mRS of ≤3.

2.3. Statistical analysis

Descriptive statistics, including the mean and standard deviation, were used to summarize clinical and radiographic findings as well as periprocedural complications and outcomes. T-test, Chi-square, and Fisher exact test were used as appropriate for analytical statistics. $P < 0.05$ was considered statistically significant. All statistical analyses were performed in IBM SPSS Statistics (SPSS, Chicago, IL, USA)

3. Results

Eighty patients with cerebral aneurysms were included in this study. There were 42 patients in the microsurgical group and 38 patients in the endovascular group. The microsurgical group comprised of 57.1% female and 42.9% male, while the endovascular group included 65.8% female and 34.2% male patients ($p = 0.428$). There was no significant difference in the mean age of the subjects between the two groups (58.6 years in the microsurgical and 58 years endovascular group) ($p = 0.803$). Moreover, 55% of the participants in the microsurgical group and 58% of the subjects in the endovascular group had a history of hypertension ($p = 0.778$). About half the patients in both groups were smokers (41% in the microsurgical group vs. 45% in the endovascular group) ($p = 0.700$). On admission, 9.5%, 28.6%, 52.4%, and 9.5% of the subjects in the microsurgical group and 13.2%, 36.8%, 42.1%, and 7.9% of the patients in the endovascular group showed Fisher scale of 1, 2, 3 and 4 respectively on CT scan ($p = 0.763$). All the aneurysms were saccular. As shown in Fig. 1, there was no significant difference in the aneurysm size between the two groups ($p = 0.480$).

A summary of the patient and aneurysm characteristics is provided in Table 2.

In the six months, we observed favorable outcome in 40 patients (95.2%) in the microsurgical group and in 37 patients (97.4%) who were treated endovascularly ($p = 0.616$) (Fig. 2).

3.1. Microsurgical group

Forty-two patients with a mean age of 58.6 years underwent microsurgical clipping for several reasons. All patients were treated through a pterional approach after dissecting sylvian fissure proximally to distally. Temporary clips were placed when necessary and for less than 5 min.

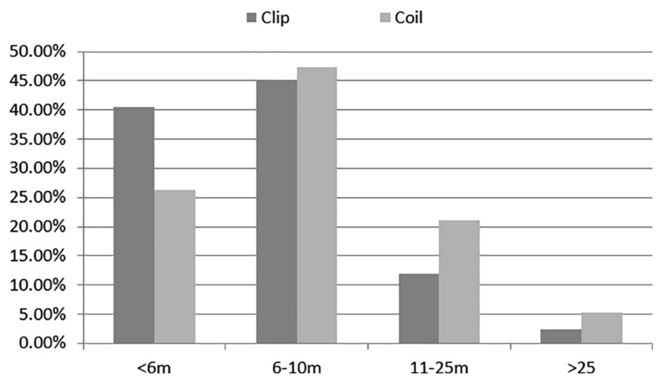

Fig. 1. Aneurysm size in microsurgical clipping and endovascular coiling group.

In this group, 76%, 10%, and 14% of the aneurysms in this group were located in the MCA bifurcation, M1, and anterior temporal artery, respectively. The aneurysm size was below 6 mm in 40%, 6–25 mm in 58%, and above 25 mm in 2%.

Complete occlusion was achieved in 90.5% (n = 38) of patients while 9.5% (n = 4) showed incomplete occlusion. Intraoperative hemorrhage was reported in 3 patients, and three patients had ischemia in one of the MCA branches that were treated conservatively. Four patients had residual aneurysms on control angiography after six months and were admitted for retreatment by coiling (Table 2).

On average, patients in this group were hospitalized for 7.8 ± 3.1 days. The neurological outcomes of the patients according to mRS upon admission and mRS after six months are presented in Fig. 2.

3.2. Endovascular group

Thirty-eight patients with a mean age of 58 years underwent endovascular treatment. The aneurysm size was below 6 mm in 26%, 6–25 mm in 66%, and above 25 mm in 8% of the patients. The majority of aneurysms in this group (78.9%) were located at the MCA bifurcation, while 13.2% were located at the M1 segment, and 7.9% occurred on the anterior temporal artery (p = 0.635). At the six month follow-up, 34 (89.2%) patients had grade I or II, and 4 (10.8%) patients had grade III occlusion according to the Raymond Roy classification. All four patients (10.8%) showing Raymond Roy grade III occlusion were admitted for endovascular retreatment. Fig. 2 shows the outcomes of the patients according to mRS during admission and after six months.

We observed thromboembolic events in 2 patients. One patient with distal MCA branch occlusion was successfully treated with heparin with (therapeutic dose), while the other patient with occlusion in the M2 part of the MCA required mechanical thrombectomy with a stent retriever. Vasospasms of the MCA occurred during endovascular treatment in 4 patients and was successfully treated with an intra-arterial calcium channel blocker (Nimodipine) injection or balloon angioplasty. Other intraoperative complications such as aneurysm rupture during treatment, arterial dissection, or coil migration, were not observed in our patients. The length of hospitalization was 7.6 days in this group.

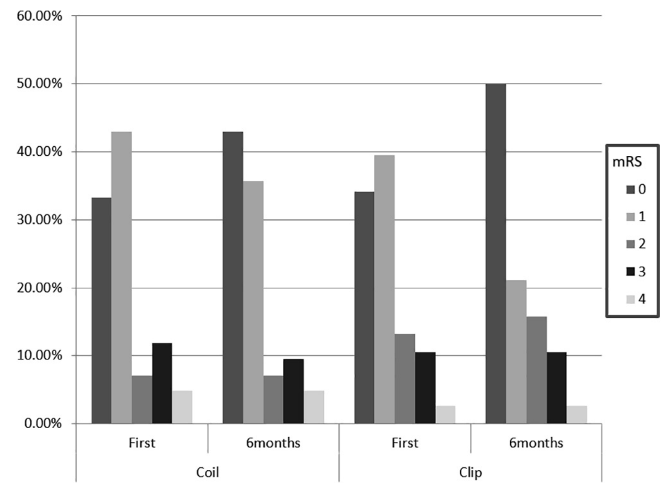

Fig. 2. The neurological outcomes of the patients according to mRS upon admission and mRS after six months.

Ten patients required stent-assisted coiling and were discharged with Aspirin and Plavix therapy. None of these patients experienced in-stent stenosis.

4. Discussion

As endovascular techniques are evolving, it is necessary to revise the role of these techniques in the treatment of cerebral aneurysms [7,9]. Considering the morphology and complex branching pattern of MCA aneurysms, endovascular treatment is a challenging procedure. Among previous studies, there is still no clear consensus on whether one particular treatment option for MCA aneurysms is superior over the other [10].

4.1. Randomized controlled trials

Few prospective randomized clinical trials have compared surgical and endovascular treatment of cerebral aneurysms. To date, no randomized controlled study has compared the safety and efficacy of microsurgical and endovascular treatment of MCA aneurysms specifically [4].

The International Subarachnoid Aneurysm Trial (ISAT) compared microsurgical clipping or endovascular coiling for ruptured cerebral aneurysms. Of 2,143 patients, 1,073 were randomized to endovascular coiling and 1,070 to microsurgical clipping. In the microsurgical group, 2.9% (n = 30) and 0.9% (n = 9) patients, required early and late retreatment, respectively. In the endovascular group, early and late retreatment was required in 8.8% (n = 97) and 8.6% (n = 96) of cases, respectively. Interestingly, the mean time to late retreatment in the microsurgical group was 5.7 months, while endovascularly treated patients required late retreatment after an average of 20.7 months [8].

In 2019, Spetzler et al. reported their ten year results on safety and efficacy of clipping versus coiling the Barrow Ruptured Aneurysm Trial

Table 2
Complications and outcome of both treatment methods.

	Endovascular Coiling N (%)	Microsurgical Clipping N (%)	P
Intraoperative Rupture	0 (0%)	3 (7.1)	0.851
Procedure-Related Complications	2 (5.2)*	3 (7.1) ¥	0.851
Complete or Near-Complete Occlusion on Follow-Up Angiogram	34 (89.2)	38 (90.5)	0.850
Retreatment Rate	4 (10.5)	4 (9.5)	0.859

* Thromboembolic events.
¥ Ischemia in one of the branches of MCA.

(BRAT) for saccular aneurysms in patients presenting with subarachnoid hemorrhage.

There was a statistically significantly different in need for retreatment in clipped saccular aneurysms (2 of 241,0.8%) and coiled saccular aneurysms (23 of 115,20%) ($p < 0.001$). Also, there was a statistically significant difference between the obliteration rate between two groups after a 10-year follow-up and clipped group experienced more obliteration rate in compare with a surgical group (93% vs. 22%, $p < 0.001$). However, after ten years of follow-up, there was no statistically significant difference in poor outcome (mRS score > 2) or deaths between both treatment methods [11]. According to results of BRAT studies it seems that our follow-up period was inadequate that can be considered in further studies.

4.2. Retrospective studies

In 2009, Suzuki et al. reported a retrospective study of endovascular treatment in 115 patients with MCA aneurysms (ruptured and unruptured) treated between 1990 and 2007. They reported complete occlusion in 46% and neck remnants in 41%, incomplete occlusion in 3%, and failed treatment attempt in 7%. Moreover, the authors showed the feasibility of treating large and giant MCA aneurysms in an endovascular fashion. However, long-term radiographic outcomes were only provided in 60% of patients [12].

In a more recent study, Schwartz et al. compared the long-term results of clipping and endovascular treatment for MCA aneurysms between 2005 and 2015. While the occlusion rates in clipped aneurysms were significantly higher (96.3% vs. 78.9%), the authors found that the long term clinical outcome was significantly better in the endovascular group [13].

4.3. Systematic reviews and meta-analyses

Brinjikji et al. performed a systematic review, analyzing endovascular treatment outcomes of unruptured and ruptured MCA aneurysms, including 12 studies with a total of 1,030 patients. Overall morbidity and mortality rates were 5.1% and 6% for unruptured and ruptured aneurysms, respectively. Overall complete or near complete occlusion rate was 82.4% [10].

A systematic review by Zijlstra et al. compared the outcomes of surgical and endovascular treatment of MCA aneurysms of 51 studies. The study concluded that both treatment options have comparable outcomes. However, the authors indicated that endovascular treatment appeared to be associated with more favorable outcomes in ruptured MCA aneurysms, while microsurgical clipping showed better outcomes for unruptured aneurysms [14].

A meta-analysis by Smith et al. in 2015 compared the treatment outcomes of unruptured MCA aneurysms either treated with coiling ($n = 1,530$) and clipping ($n = 765$). The study revealed dramatically higher occlusion rates (97% vs. 52%) in the clipping group as well as higher risk for unfavorable clinical outcome in coiled patients (2.1% vs. 6.5%). The authors, therefore, concluded that microsurgical treatment is superior over endovascular coiling in unruptured MCA aneurysms. However, it should be considered that this study included articles from 1990 to 2011. During this period, endovascular techniques evolved and improved dramatically. Therefore, the applicability of these findings to current endovascular techniques and devices may be limited [7].

4.4. Recurrent aneurysms and incomplete occlusion in MCA aneurysms

One of the major points of criticism of endovascular treatment is the risk of recurrent aneurysm formation. Larger sample size studies reported recurrence rates ranging from 2% to 27% [12,13,15–18]. In the abovementioned systematic review, Brinjkiji et al. reported complete or near complete obliteration of endovascularly treated MCA aneurysms in 82.4%. Incompletely occluded aneurysms had 9.3% minor recurrence and major recurrence requiring retreatment in 9.6%.

In comparison, multiple studies reported complete occlusion rates in clipped aneurysms to be around 90–98% [19–22]. However, this difference may partially be attributable to the fact that clipped aneurysms tend to have a less frequent angiographic follow-up. Aneurysms that show complete occlusion on the first follow-up angiography are commonly assumed cured. For that reason, asymptomatic recurrences after clipping may remain undetected. In our case series, all retreatments in both groups had to be performed due to incomplete occlusion of the aneurysm. Four patients in each group required retreatment after the six-month control angiography. This indicates comparable or possibly superior results as compared to the current literature.

4.5. Periprocedural complications

Ruptured aneurysms are generally more prone for complications than unruptured ones [23–25]. In our study, we observed intraoperative hemorrhage in 2 patients during microsurgical treatment as well as two thromboembolic events and four vasospasms in the endovascular group. While most complications in microsurgical clipping occur due to swelling of brain parenchyma associated with subarachnoid hemorrhage, intraoperative hemorrhage, as well as clipping of the parental vessel [25–27], thromboembolic events are more common with endovascular treatment [8,10,28]. Other complications, including intraprocedural rupture, vasospasm, and persistent hydrocephalus, are seen with both treatment modalities [8,26,27].

4.6. Thromboembolic events

Thromboembolic events are commonly described as a point of criticism in endovascular therapy when compared to clipping. A recent meta-analysis described the incidence of thromboembolic events as 1.8% and 10.7% in surgical and endovascular treatment of aneurysms [22]. Moreover, patients with ruptured aneurysms are described to be more prone to experience thromboembolic complications, especially when treated with a balloon or stent [12,28]. However, despite higher occurrence rates in endovascular intervention, thromboembolic events do not appear to have a significant impact on clinical outcome [22,28]. In our study, both thromboembolic events could be successfully treated by heparin administration or mechanical thrombectomy.

4.7. Anatomical considerations

In some cases, due to the special geometry of the aneurysm relative to the adjacent arteries, primary coiling may not result in complete occlusion of the aneurysm and require the use of a stent or balloon to achieve complete occlusion. Therefore, it is critical to carefully review the vascular anatomy and aneurysm geometry when deciding whether to treat an aneurysm microsurgically or endovascularly. One of the most important predictors for the success of endovascular coiling is the dome to neck ratio [29–32]. A dome to neck ratio < 2 has been considered as a wide-necked aneurysm and described to considered challenging for endovascular treatment [30]. However, with technical advances such as the introduction of stent-assisted coiling, endovascular treatment of wide-neck aneurysms has become increasingly common [18,33,34]. In our study, we decided for microsurgical treatment in aneurysms with dome to neck ratios < 1.5. Due to challenging aneurysmal geometry, we used stents in 10 patients in the endovascular group and discharged these patients with dual antiplatelet therapy.

The main goal of cerebral aneurysm treatment is the complete exclusion of the aneurysm from the cerebral circulation without causing neurological deficits. Therefore, careful planning and consideration of vascular anatomy related to the aneurysm are mandatory to provide safe and efficient treatment. An important factor in the choice of treatment is the cooperation of the endovascular team and the experience of the surgical team. We believed that the fact that one specialist performed all treatments in our study helped to select the best treatment modality.

4.8. Limitations

Its retrospective character limits the conclusions of our study. Another limiting factor is the relatively small sample size and the short follow-up. Conclusions about long-term outcomes can therefore not be drawn. Furthermore, the selection of treatment was based on individual patient characteristics and not randomly which may introduce unintended bias.

5. Conclusion

According to our findings, both treatment options are associated with excellent clinical outcomes. Endovascular treatment of MCA aneurysms, if the patients are appropriately selected, is a safe and effective method. Proper patient selection is of significant importance. Careful evaluation of the aneurysm neck and size, as well as the geometry of the adjacent vasculature on preprocedural angiography, is mandatory to select a suitable treatment option.

6. Compliance with ethical standards

Funding: No funding was received for this research.

Conflict of interest: Authors declared that they have no conflict of interest.

Ethical approval: All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration.

Informed consent: Informed consent was obtained from all individual participants included in the study.

CRediT authorship contribution statement

Mohammad Ghorbani: Conceptualization, Data curation, Supervision, Methodology, Investigation, Writing - original draft, Writing - review & editing. **Christoph J. Griessenauer:** Methodology, Writing - review & editing, Formal analysis. **Christoph Wipplinger:** Methodology, Formal analysis, Writing - review & editing. **Mohsen Nouri:** Methodology, Writing - original draft, Writing - review & editing, Formal analysis. **Sina Asaadi:** Data curation, Writing - original draft, Writing - review & editing. **Ebrahim Hejazian:** Investigation, Writing - original draft, Writing - review & editing. **Reza Mollahoseini:** Supervision, Writing - original draft, Writing - review & editing. **Abolghasem Mortazavi:** Data curation, Project administration, Supervision, Writing - original draft, Writing - review & editing.

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