Long-term results of middle cerebral artery aneurysm clipping in the Barrow Ruptured Aneurysm Trial

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OBJECTIVE A direct comparison of endovascular versus microsurgical treatment of ruptured middle cerebral artery (MCA) aneurysms in randomized trials is lacking. As endovascular treatment strategies continue to evolve, the number of reports of endovascular treatment of these lesions is increasing. Herein, the authors report a detailed post hoc analysis of ruptured MCA aneurysms treated by microsurgical clipping from the Barrow Ruptured Aneurysm Trial (BRAT).

METHODS The cases of patients enrolled in the BRAT who underwent microsurgical clipping for a ruptured MCA aneurysm were reviewed. Characteristics of patients and their clinical outcomes and long-term angiographic results were analyzed.

RESULTS Fifty patients underwent microsurgical clipping of a ruptured MCA aneurysm in the BRAT, including 21 who crossed over from the endovascular treatment arm. Four patients with nonsaccular (e.g., dissecting, fusiform, or blister) aneurysms were excluded, leaving 46 patients for analysis. Most ($n = 32$; 70%) patients presented with a Hunt and Hess grade II or III subarachnoid hemorrhage, with a high prevalence of intraparenchymal blood ($n = 23$; 50%), intraventricular blood ($n = 21$; 46%), or both. At the last follow-up (up to 6 years after treatment), clinical outcomes were good (modified Rankin Scale score 0–2) in 70% ($n = 19$) of 27 Hunt and Hess grades I–III patients and in 36% ($n = 4$) of 11 Hunt and Hess grade IV or V patients. There were no instances of rebleeding after the surgical clipping of aneurysms in this series at the time of last clinical follow-up.

CONCLUSIONS Microsurgical clipping of ruptured MCA aneurysms has several advantages over endovascular treatment, including durability over time. The authors report detailed outcome data of patients with ruptured MCA aneurysms who underwent microsurgical clipping as part of a prospective, randomized trial. These results should be used for comparison with future endovascular and surgical series to ensure that the best results are being achieved for patients with ruptured MCA aneurysms.

<https://thejns.org/doi/abs/10.3171/2017.10.JNS172183>

KEYWORDS aneurysms; Barrow Ruptured Aneurysm Trial; endovascular treatment; microsurgical treatment; middle cerebral artery; ruptured; subarachnoid hemorrhage; vascular disorders

MIDDLE cerebral artery (MCA) aneurysms represent approximately 20%–30% of all ruptured cerebral aneurysms.²⁵ These lesions pose unique treatment challenges due to complex MCA bifurcation or trifurcation anatomy, the frequent presence of a broad neck, and the high incidence of associated intraparenchymal hemorrhage (IPH). Endovascular treatment strategies for MCA aneurysms have historically been limited by these factors, and to date, MCA aneurysms represent a minority of lesions treated endovascularly in randomized

trials of ruptured cerebral aneurysms.^{12,13} Accordingly, clinical equipoise has not been established between endovascular treatment and microsurgical treatment of these aneurysms.

Although many practitioners continue to recommend microsurgical clipping for the treatment of MCA aneurysms,⁷ reports of MCA aneurysm treatment with endovascular strategies are increasing in the neurosurgical literature.^{2–4,6,8–11,14–16,27} Concern remains, however, regarding the durability and risk for rebleeding after endovascular

ABBREVIATIONS BRAT = Barrow Ruptured Aneurysm Trial; GCS = Glasgow Coma Scale; GOS = Glasgow Outcome Scale; IPH = intraparenchymal hemorrhage; IVH = intraventricular hemorrhage; MCA = middle cerebral artery; mRS = modified Rankin Scale; SAH = subarachnoid hemorrhage.

SUBMITTED August 31, 2017. **ACCEPTED** October 20, 2017.

INCLUDE WHEN CITING Published online April 27, 2018; DOI: 10.3171/2017.10.JNS172183.

intervention in this group of patients.^{17,22} Detailed long-term angiographic and clinical outcome data for patients with ruptured MCA aneurysms are essential for comparison studies moving forward. For these reasons, we sought to determine the long-term outcomes associated with microsurgical treatment of ruptured MCA aneurysms in the Barrow Ruptured Aneurysm Trial (BRAT).

The BRAT was a prospective, randomized study of microsurgical versus endovascular treatment of ruptured cerebral aneurysms, results of which have been published through 6 years of follow-up.²² In this trial, patients with MCA aneurysms who were randomized to endovascular treatment frequently crossed over to the microsurgical clipping group (21 of 31 [68%] crossed over), precluding a direct comparison of endovascular and microsurgical clipping in this cohort. Herein, we report a detailed post hoc analysis of outcomes, including long-term angiographic and clinical outcomes, of patients with ruptured MCA aneurysms who underwent microsurgical clipping. These results can be used as a benchmark for comparison with future series examining endovascular and surgical interventions.

Methods

A post hoc analysis of data from the BRAT was performed for all patients with a ruptured MCA aneurysm. The methodology for the BRAT has been described in detail elsewhere.^{12,21,22} In brief, patients with nontraumatic subarachnoid hemorrhage (SAH) who presented to our institution between March 2003 and January 2007 were randomized either to open microsurgical clipping or to endovascular coiling of their aneurysms. The assigned treatment team was given the right of first refusal for aneurysm treatment, and patients were crossed over between treatment arms when doing so was deemed appropriate. Four patients with nonsaccular aneurysms (1 dissecting, 1 blister, and 2 fusiform) were excluded from analysis. Demographic data, comorbid conditions, aneurysm characteristics, initial Glasgow Coma Scale (GCS) score, Hunt and Hess grade, Fisher grade, and any complicating factors at initial presentation, such as intraventricular hemorrhage (IVH) or IPH, were recorded. Surgical complications that were recorded included intraoperative aneurysm rupture, rebleeding, postoperative stroke, and wound infection. Metrics that were collected included aneurysm obliteration rate, total hospital length of stay, discharge location (e.g., home, skilled nursing facility, acute rehabilitation center), and GCS score at discharge. Qualified outcome scales, including the Glasgow Outcome Scale (GOS) and the modified Rankin Scale (mRS), were administered, and the results were recorded by a research nurse practitioner at discharge and at 6 months, 1 year, 3 years, and 6 years after initial treatment either by telephone contact or at the time of the clinic visit. Aneurysm obliteration was assessed using conventional angiography, CT angiography, or MR angiography by a neuroradiologist not involved with the treatment of these patients.

Fisher grades were reported as grade 1 (focal thin SAH), grade 2 (diffuse thin SAH), and grade 3 (thick SAH). The presence of IPH and IVH was noted separately.

All patients in this cohort were retrospectively classified according to the Barrow Neurological Institute Scale for grading SAH.^{5,26} Data are reported as numbers and percentages. Chi-square analysis was performed for comparison of proportions.

Results

Patient Demographics

The mean age of the 46 patients was 53.7 years (Table 1). Most (n = 32; 70%) patients presented with Hunt and Hess grade II or III SAH. A high prevalence of IPH (n = 23; 50%), and IVH (n = 21; 46%), or both was found in patients in this series.

Most (n = 33; 72%) aneurysms were ≤ 10 mm in greatest diameter, and most (n = 41; 89%) were found at the MCA bifurcation or trifurcation (Table 2). Treatment strategies included primary clipping in 43 cases (93%), whereas clip-wrapping and bypass strategies were used in 3 cases (7%). Clinical follow-up of 3 years or longer was available for 89% (n = 41) of the patients who underwent microsurgical clipping.

Angiographic Outcomes

Angiographic obliteration rates were stratified by time point of collection, with postoperative evaluation and 3-year and 6-year posttreatment results (Table 3). Eight patients with saccular lesions underwent partial treatment (Table 4).

TABLE 1. Characteristics of 46 patients with MCA aneurysms treated by clipping

Variable	Value
Mean age in yrs (range)	53.7 (28.6–79.7)
Smoker	33 (72)
HH grade*	
I	2 (4)
II	17 (37)
III	15 (33)
IV	9 (20)
V	3 (7)
Fisher grade	
1	1 (2)
2	5 (11)
3	40 (87)
IPH	23 (50)
IVH	21 (46)
4th ventricle blood	7 (15)
BNI grade*	
2	10 (22)
3	15 (33)
4	5 (11)
5	16 (35)

BNI = Barrow Neurological Institute; HH = Hunt and Hess.

Values are presented as the number of patients (%) unless stated otherwise.

* Percentages total > 100% due to rounding.

TABLE 2. Characteristics of clipped MCA aneurysms in 46 patients

Variable	No. of Aneurysms (%)
Aneurysm size in mm	
2–5	17 (37)
6–10	16 (35)
11–15	7 (15)
16–20	5 (11)
21–25	1 (2)
Lt-sided aneurysm	18 (39)
Detailed location	
MCA bifurcation or trifurcation	41 (89)
M ₁ (horizontal segment)	3 (7)
M ₂ (sylvian segment)	1 (2)
M ₃ (opercular segment)	1 (2)
Treatment strategy*	
Clipping	43 (93)
Clip wrapping	2 (4)
Clipping plus bypass	1 (2)

* Percentages total < 100% due to rounding.

Notably, most (44 of 45; 98%) postoperative evaluations were performed using digital subtraction angiography. One patient did not undergo postoperative imaging secondary to a poor clinical status and subsequent death (detailed below). Angiographic follow-up was primarily based on CT angiography at the 3-year (22 of 26; 85%) and 6-year (19 of 21; 90%) follow-up. The degree of aneurysm obliteration was adjudicated by a neuroradiologist not involved in the treatment of these patients.

Clinical Outcomes

Of the 46 patients with a ruptured MCA aneurysm in this series, 2 patients required a return to the operating room for reclipping (Table 5). For the first patient, postoperative imaging showed a small residual aneurysm, and this patient underwent reclipping on postoperative day 14. Further angiographic follow-up through 6 years demonstrated complete aneurysm obliteration. The second patient developed an MCA occlusion on postoperative day 3 and underwent subsequent exploration and repositioning of the aneurysm clip. This patient was eventually discharged to hospice.

There were 2 deaths in this series before hospital discharge: one was attributed to refractory intracranial hypertension from initial SAH, and one was due to persistent status epilepticus and subsequent withdrawal of care. No instances of SAH rebleeding occurred throughout the course of 6 years of follow-up. Three additional patients died within 6 months of treatment, including the patient who underwent reclipping and was discharged to hospice. The postoperative hospital course of this patient was complicated by persistent status epilepticus and poor neurological status, and the family ultimately chose to pursue hospice care. A second patient died after readmission for respiratory failure secondary to prior chronic obstructive

TABLE 3. Angiographic obliteration of clipped MCA aneurysms over time

Follow-Up	No. of Patients/Total (%)
Postop	39/45 (87)
3-yr	23/26 (88)
6-yr	20/21 (95)

pulmonary disease, and the third patient died of sepsis secondary to a recurrent urinary tract infection and pneumonia.

The mRS and GOS scores as stratified by Hunt and Hess grade are illustrated in Fig. 1. The proportion of patients in the Hunt and Hess grades I–III group who had a good outcome (mRS score 0–2) at 6 months was significantly greater than that at discharge (20 of 26 [77%] vs 14 of 34 [41%], $p = 0.005$). No further improvement in the proportion of patients with good mRS scores was observed through the 6-year follow-up. In patients with Hunt and Hess grades of IV and V, no significant improvement was observed in the proportion of patients with a good mRS score at discharge through 6 years. Good outcome at last follow-up, defined as an mRS score of 0–2, was present in 70% ($n = 19$) of 27 patients with Hunt and Hess grades I–III and in 36% ($n = 4$) of 11 patients with Hunt and Hess grades IV and V.

When analyzed by GOS scores, the proportion of patients in the Hunt and Hess grades I–III group who had a good outcome at 6 months was significantly greater than that at discharge ($p = 0.001$). In the patients with Hunt and Hess grades IV and V, no significant improvement was found in the proportion of patients with good GOS scores at discharge through 6 years, although there was some improvement at the 6-year follow-up ($p = 0.09$). A good outcome at the last follow-up, defined as a GOS score of 4 or 5, was present in 74% ($n = 20$) of 27 patients with Hunt and Hess grades I–III and in 55% ($n = 6$) of 11 patients with Hunt and Hess grades IV and V.

Endovascular Cohort

A descriptive analysis of patients who underwent endovascular treatment was performed. A comparison of patient characteristics for patients assigned to coiling revealed a larger proportion of patients with IPH in the crossover cohort than in the treated cohort (57% vs 30%; Table 6).

To date, angiographic follow-up is more limited for patients treated with coiling than for those treated with clipping, with 6 of 10 patients (60%) with a 3-year follow-up and only 1 of 10 patients (10%) with a 6-year follow-up. Complete obliteration at the time of treatment was recorded for 7 of 10 patients (70%). Of the 7 patients with completely treated aneurysms, 1 had recurrence at 1 year and required re-treatment, and 2 had progression to 90%–99% obliteration (1 at 3 years and 1 at 6 years). Three patients have not undergone further angiography. Of the 3 patients (30%) with 90%–99% occlusion at the time of treatment, 2 had progression of the residual at 3 years. The remaining patient had not undergone further angiographic imaging at the 6-year follow-up.

TABLE 4. Characteristics of 8 patients with partially treated saccular aneurysms of the MCA treated by clipping

Case No.	HH Grade	Fisher Grade	BNI Grade	IPH	Aneurysm Type	Aneurysm Size (mm)	Treatment Strategy	Angiographic Follow-Up*		
								Postop	3-Yr	6-Yr
1	II	2	3	No	Saccular	5	Clipping	90–99% occluded	Completely treated	NA
2	II	3	4	No	Saccular	11	Clipping	90–99% occluded	Completely treated	Completely treated
3	III	4	4	Yes	Saccular	11	Clipping	90–99% occluded	Completely treated	Completely treated
4	III	4	5	Yes	Saccular	5	Clipping	90–99% occluded	Completely treated	Completely treated
5	IV	4	5	Yes	Saccular	5	Clipping	90–99% occluded	90–99% occluded	NA
6	V	4	5	Yes	Saccular	17	Clipping	90–99% occluded	Completely treated	Completely treated
7	III	4	5	Yes	Saccular	5	Clipping	Completely treated†	90–99% occluded	90–99% occluded
8	IV	3	3	Yes	Saccular	7	Clipping	Completely treated	90–99% occluded‡	Completely treated

NA = not available.

* Digital subtraction angiography or CT angiography.

† Limited evaluation because of vasospasm at this time point.

‡ Questionable remnant on digital subtraction angiography, not seen on CT angiography at 6-year follow-up.

Discussion

MCA aneurysms require unique consideration when deciding on open microsurgical versus endovascular treatment strategies, particularly in cases of rupture. The anatomy of these aneurysms requires varied treatment strategies. There has been a low representation of MCA aneurysms in randomized trials of ruptured aneurysm treatment.^{12,13} In the BRAT, although 31 patients with ruptured MCA aneurysms were randomized to coiling, 21 were crossed over to the clipping group because of the need for clot evacuation, unfavorable angiographic anatomy, or a combination of these factors. In the ISAT (International Subarachnoid Aneurysm Trial), MCA aneurysms represented only 14.1% (303 of 2143) of the total cohort, which may represent an underlying selection bias due to the lack of perceived clinical equipoise at the time of the trial.¹³

As endovascular treatment strategies continue to

evolve, reports are increasing about the treatment of ruptured MCA aneurysms with endovascular strategies.^{4,6,9,10,12,14,16,17,27} In the largest series in the endovascular literature to date, Mortimer et al.¹⁴ reported their experience with 242 patients who underwent endovascular coiling for 244 ruptured MCA aneurysms. Complete occlusion was achieved for most (76.2%; $n = 186$) of the 244 ruptured aneurysms; a neck remnant was found in 17.2% ($n = 42$), and an aneurysm remnant was found in 2.5% ($n = 6$). They reported a favorable outcome classified by a GOS score of 4 or 5 in 79.8% (193 of 242) of their patients; however, the overall mortality was 13.6% (33 of 242). There were 3 instances of rebleeding in their series, all within 24 hours, and all 3 patients died.

Although some selection bias might be present in their series, Mortimer et al.¹⁴ noted that they practice a “coil-first” policy at their institution and that only 51 patients with ruptured MCA aneurysms were treated with primary clipping during roughly the same period. Twenty-one of these patients were noted to have poor anatomy for endovascular treatment or had already undergone an unsuccessful attempt at coiling, whereas the remainder of those who underwent clipping did so because of surgeon preference or the lack of availability of an interventional neuro-radiologist. The authors concluded that “satisfactory rates of occlusion” are achievable with endovascular treatment of MCA aneurysms; however, this conclusion is difficult to accept when nearly 20% (48 of 244 [19.7%]) of ruptured aneurysms were found postprocedure to have been incompletely treated and when this proportion increased to 33% (71 of 219 [32.4%]) at initial follow-up. Although 72.4% of the 58 incompletely treated ruptured aneurysms at initial follow-up were due to a neck remnant ($n = 42$) rather than an aneurysm remnant ($n = 16$), one must consider that neck remnants still pose a risk to the patient, as they are prone to progress and are susceptible to rerupture.^{1,17} These results are at odds with the primary goal of ruptured aneurysm treatment, which is to prevent rerupture. Indeed, 3 patients in the Mortimer et al.¹⁴ series experienced rerupture after treatment, and all 3 patients died as a result.

In response to recent series of endovascular treatment of ruptured MCA aneurysms, several authors have reported

TABLE 5. Hospital course and clinical outcomes of 46 patients with ruptured MCA aneurysms treated by clipping

Variable	No. of Patients (%)
Intraop rupture	12 (26)
Vasospasm treatment	
Intraarterial nicardipine	8 (17)
Angioplasty	3 (7)
Ventriculostomy	40 (87)
VPS requirement	13 (28)
Reclipping	2 (4)
Bone flap removal	6 (13)
SAH rehemorrhage	0 (0)
Death	2 (4)
Discharge location	
Home	17 (37)
Rehabilitation facility	17 (37)
Skilled nursing facility	9 (20)
Hospice	1 (2)

VPS = ventriculoperitoneal shunt.

FIG. 1. **A and B:** Outcomes by mRS scores over time. **C and D:** Outcomes by GOS scores over time. HH = Hunt and Hess.

their institution's results of a "clip-first" policy for MCA lesions.^{19,24} In a series of 282 ruptured MCA aneurysms treated with microsurgical clipping, Rodríguez-Hernández et al.¹⁹ reported good outcomes (mRS scores 0–2) in 70.2% of these patients. This finding is comparable to the results in our series. Perhaps more importantly, long-term angiographic follow-up in the Rodríguez-Hernández et al. series demonstrated no instances of late posttreatment rebleeding, need for re-treatment, evidence of regrowth of completely obliterated aneurysms, or progression of aneurysm remnant with a mean follow-up duration of 3.9 years. Our data support these conclusions, as there were no instances of rebleeding in our series, with a mean angiographic follow-up duration of 3.7 years in surviving patients. All cases of partial treatment of microsurgically clipped aneurysms in this series, either postoperatively or at follow-up through 6 years, are presented in Table 4. The importance of durability in microsurgical clipping should not be underestimated in patients with ruptured aneurysms.

A separate and often-cited advantage of microsurgical clipping of ruptured MCA aneurysms is the ability to evacuate an IPH or perform a decompressive hemicraniectomy promptly in the same surgical setting.^{18,20,23} In our series, one-half of the 46 patients had IPH associated with aneurysm rupture, and 7 (14%) of them required a decompressive craniotomy. Notably, in the series of endovascularly treated ruptured MCA aneurysms by Mortimer et al.,¹⁴ 8.2% (20 of 244) of patients underwent surgery for IPH evacuation or decompressive craniotomy after endovascular treatment of the aneurysm. They reported a good outcome (defined as a GOS score of 4) in 40% (n = 8) of the 20 patients and a 45% mortality rate (n = 9). Future

TABLE 6. Characteristics of 31 patients with MCA aneurysms assigned to coiling

Variable	Assigned-Actual Treatment	
	Coil-Clip (n = 21)	Coil-Coil (n = 10)
Mean age in yrs (range)	55.9 (38.9–79.7)	59.4 (46.8–79.3)
HH grade		
I	1 (5)	1 (10)
II	8 (38)	3 (30)
III	7 (33)	2 (20)
IV	3 (14)	3 (30)
V	2 (10)	1 (10)
Fisher grade		
1	1 (5)	0 (0)
2	3 (14)	1 (10)
3	17 (81)	9 (90)
IPH	12 (57)	3 (30)
IVH	11 (52)	7 (70)
Aneurysm size in mm		
2–5	8 (38)	4 (40)
6–10	7 (33)	3 (30)
11–15	4 (19)	3 (30)
16–20	1 (5)	0 (0)
21–25	1 (5)	0 (0)

Values are presented as the number of patients (%) unless stated otherwise.

studies outlining patient outcomes using this staged treatment strategy are necessary, as delayed treatment of IPH and intracranial hypertension carries inherent risk.

Our series provides the first detailed account of clinical and angiographic outcomes of ruptured MCA aneurysms treated by microsurgical clipping as part of a prospective clinical trial. Although this analysis provides robust data on this topic, our study is not without limitations. First, the study is a post hoc analysis of results from a prospective clinical trial, which carries the same limitations as any retrospective study. Second, a direct comparison with endovascularly treated lesions in the BRAT was impossible because of the high proportion of crossovers from endovascular to microsurgical treatment for patients with ruptured MCA aneurysms (68%; 21 of 31), which carries inherent selection bias. We have included a descriptive analysis of patients who underwent endovascular treatment in the BRAT; however, results must be interpreted in the context of the selection paradigm and treatment modalities available at the time of the trial. Third, angiographic follow-up at 6 years was limited to 21 of 41 surviving patients, including 2 patients with partial occlusion at 3 years. Angiographic follow-up is even more limited in the coiling group to date, which limits our ability to draw significant conclusions from this small subgroup. Follow-up through 10 years is planned for patients enrolled in the BRAT, which will provide clinical and angiographic follow-up for additional time points.

Conclusions

As endovascular treatment strategies evolve, debate continues regarding optimal treatment strategies for patients with ruptured MCA aneurysms. To date, the comparison of endovascular and microsurgical treatment strategies in randomized trials is severely limited, requiring the comparison of reported outcomes from endovascular and microsurgical series in the literature. We provide detailed long-term clinical and angiographic outcomes of patients with ruptured MCA aneurysms who underwent clipping as part of a prospective trial. These results should be used as a benchmark for future studies examining outcomes for this unique group of patients.

Acknowledgments

We thank the staff of Neuroscience Publications at Barrow Neurological Institute for assistance with manuscript preparation.

References

- Benaissa A, Pierot L: Rebleeding of a neck remnant in a case of ruptured aneurysm initially treated with coils. *J Neurointerv Surg* 8:e17, 2016
- Bhogal P, AlMatter M, Bänzner H, Ganslandt O, Henkes H, Aguilar Pérez M: Flow diversion for the treatment of MCA bifurcation aneurysms—a single centre experience. *Front Neurol* 8:20, 2017
- Briganti F, Leone G, Cirillo L, de Divitiis O, Solari D, Capabianca P: Postprocedural, midterm, and long-term results of cerebral aneurysms treated with flow-diverter devices: 7-year experience at a single center. *Neurosurg Focus* 42(6):E3, 2017
- Cho YD, Lee WJ, Kim KM, Kang HS, Kim JE, Han MH: Endovascular coil embolization of middle cerebral artery aneurysms of the proximal (M1) segment. *Neuroradiology* 55:1097–1102, 2013
- Dengler NF, Diesing D, Sarrafzadeh A, Wolf S, Vajkoczy P: The Barrow Neurological Institute Scale revisited: predictive capabilities for cerebral infarction and clinical outcome in patients with aneurysmal subarachnoid hemorrhage. *Neurosurgery* 81:341–349, 2017
- Diaz OM, Rangel-Castilla L, Barber S, Mayo RC, Klucznik R, Zhang YJ: Middle cerebral artery aneurysms: a single-center series comparing endovascular and surgical treatment. *World Neurosurg* 81:322–329, 2014
- Fargen KM, Soriano-Baron HE, Rushing JT, Mack W, Mocco J, Albuquerque F, et al: A survey of intracranial aneurysm treatment practices among United States physicians. *J Neurointerv Surg* 10:44–49, 2018
- Iosif C, Mounayer C, Yavuz K, Saleme S, Geyik S, Cekirge HS, et al: Middle cerebral artery bifurcation aneurysms treated by extrasaccular flow diverters: midterm angiographic evolution and clinical outcome. *AJNR Am J Neuroradiol* 38:310–316, 2017
- Kadkhodayan Y, Delgado Almandoz JE, Fease JL, Scholz JM, Blem AM, Tran K, et al: Endovascular treatment of 346 middle cerebral artery aneurysms: results of a 16-year single-center experience. *Neurosurgery* 76:54–61, 2015
- Kim KH, Cha KC, Kim JS, Hong SC: Endovascular coiling of middle cerebral artery aneurysms as an alternative to surgical clipping. *J Clin Neurosci* 20:520–522, 2013
- Lozupone E, Piano M, Valvassori L, Quilici L, Pero G, Visconti E, et al: Flow diverter devices in ruptured intracranial aneurysms: a single-center experience. *J Neurosurg* 128:1037–1043, 2018
- McDougall CG, Spetzler RF, Zabramski JM, Partovi S, Hills NK, Nakaji P, et al: The Barrow Ruptured Aneurysm Trial. *J Neurosurg* 116:135–144, 2012
- 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* 366:809–817, 2005
- Mortimer AM, Bradley MD, Mews P, Molyneux AJ, Renowden SA: Endovascular treatment of 300 consecutive middle cerebral artery aneurysms: clinical and radiologic outcomes. *AJNR Am J Neuroradiol* 35:706–714, 2014
- Murias Quintana E, Vega Valdés P, Morales Deza E, Gil Garcia A, Cuellar H, Costilla García S, et al: Analysis of endovascular treatment of ruptured aneurysms of the middle cerebral artery compared to other anatomical locations. *Interv Neuroradiol* 22:649–653, 2016
- Pierot L, Cognard C, Ricolfi F, Anxionnat R: Immediate anatomic results after the endovascular treatment of ruptured intracranial aneurysms: analysis in the CLARITY series. *AJNR Am J Neuroradiol* 31:907–911, 2010
- Pierot L, Cognard C, Ricolfi F, Anxionnat R: Mid-term anatomic results after endovascular treatment of ruptured intracranial aneurysms with Guglielmi detachable coils and Matrix coils: analysis of the CLARITY series. *AJNR Am J Neuroradiol* 33:469–473, 2012
- 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* 38:2–11, 1996
- Rodríguez-Hernández A, Sughrue ME, Akhavan S, Habdank-Kolaczowski J, Lawton MT: Current management of middle cerebral artery aneurysms: surgical results with a “clip first” policy. *Neurosurgery* 72:415–427, 2013

20. Ryu DS, Shim YS: Importance of hematoma removal ratio in ruptured middle cerebral artery aneurysm surgery with intrasylvian hematoma. **J Cerebrovasc Endovasc Neurosurg** **19**:5–11, 2017
21. Spetzler RF, McDougall CG, Albuquerque FC, Zabramski JM, Hills NK, Partovi S, et al: The Barrow Ruptured Aneurysm Trial: 3-year results. **J Neurosurg** **119**:146–157, 2013
22. Spetzler RF, McDougall CG, Zabramski JM, Albuquerque FC, Hills NK, Russin JJ, et al: The Barrow Ruptured Aneurysm Trial: 6-year results. **J Neurosurg** **123**:609–617, 2015
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** **76**:258–264, 2015
24. Steklacova A, Bradac O, Charvat F, De Lacy P, Benes V: “Clip first” policy in management of intracranial MCA aneurysms: Single-centre experience with a systematic review of literature. **Acta Neurochir (Wien)** **158**:533–546, 2016
25. van Munster CE, von und zu Fraunberg M, Rinkel GJ, Rinne J, Koivisto T, Ronkainen A: Differences in aneurysm and patient characteristics between cohorts of Finnish and Dutch patients with subarachnoid hemorrhage: time trends between 1986 and 2005. **Stroke** **39**:3166–3171, 2008
26. Wilson DA, Nakaji P, Abila AA, Uschold TD, Fusco DJ, Oppenlander ME, et al: A simple and quantitative method to predict symptomatic vasospasm after subarachnoid hemorrhage based on computed tomography: beyond the Fisher scale. **Neurosurgery** **71**:869–875, 2012
27. Zhao X, Li Z, Fang X, Liu J, Wu D, Lai N: Treatment of ruptured middle cerebral artery aneurysms by endovascular approach: a single-center experience. **Int J Neurosci** **127**:433–438, 2017

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Spetzler, Mooney. Acquisition of data: Simon, Brigeman. Analysis and interpretation of data: Mooney, Simon, Brigeman. Drafting the article: Mooney. Critically revising the article: Spetzler, Nakaji, Zabramski, Lawton. Reviewed submitted version of manuscript: Spetzler, Mooney. Statistical analysis: Mooney. Administrative/technical/material support: Mooney. Study supervision: Spetzler.

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