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Microsurgical and Endovascular Treatment Outcomes in Pericallosal Artery Aneurysms: A Single Center Retrospective Analysis

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ABSTRACT

AIM: To summarize the clinical outcomes, follow-up results and to discuss the optimal therapeutic strategy for pericallosal artery aneurysms (PAAs).

MATERIAL and METHODS: From January 2013 to May 2017, the charts of 49 patients with PAAs, representing 2.43% of 2,018 consecutive patients with intracranial aneurysms (IAs) were reviewed. The clinical and radiological data of these patients were retrospectively analyzed.

RESULTS: There were no technical failures in the clipping group, but one patient in the coiling group presented rebleeding during the operation, resulting in a poor prognosis. Although the difference was not significant, the coiling group had a better complete recovery rate than the clipping group [overall: coiling, n=20 (87.0%) vs clipping, n=11 (68.8%), p=0.33; unruptured PAAs: coiling, n=12 (92.3%) vs clipping, n=5 (83.3%); ruptured PAAs: coiling, n=8 (80%) vs clipping, n=6 (60%), p=0.63]. One patient in the coiling group exhibited recurrence. No patients experienced rebleeding during the follow-up period in either group.

CONCLUSION: In our study, both endovascular coiling and microsurgery were technically feasible and achieved favorable clinical outcomes in patients with PAAs. Longer radiological follow-up is necessary. Patients should be evaluated by a multidisciplinary team prior to determining the optimal treatment modality.

KEYWORDS: Intracranial aneurysm, Pericallosal artery aneurysm, Distal anterior cerebral artery aneurysm, Surgery, Treatment

ABBREVIATIONS: IAs: Intracranial aneurysms, **PAAs:** Pericallosal artery aneurysms, **DACA:** Distal anterior cerebral artery, **CTA:** Computerized tomography angiography, **DSA:** Digital subtraction angiography, **mRS:** Modified Rankin Scale, **GOS:** Glasgow Outcome Scale.

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INTRODUCTION

Pericallosal artery aneurysms (PAAs), also known as distal anterior cerebral artery (DACA) aneurysms, occur in the A2-A5 segment of the anterior cerebral artery (8,19). Although PAAs are rare, accounting for only 1 to 9% of all intracranial aneurysms (IAs), the management of PAAs has proven to be intractable (9,13,20,23).

Compared to aneurysms in other locations, PAAs are highly susceptible to rupture; therefore, active treatment is recommended in the clinical setting (13). Unfortunately, both microsurgical and endovascular treatments for PAAs are complicated (12,20). The distal location, narrow parent vessel and small size of the aneurysm result in a lack of stability and support, which are needed for microcatheter and coiling control during endovascular treatment (1,12,14,21). PAAs are embedded between the cerebral hemispheres; due to the narrow space, it is difficult to obtain a favorable degree of exposure, sufficient parent artery control and successful clip placement (2,20,24). Furthermore, PAAs are always associated with a high risk of recurrence and intraoperative rebleeding (1,22,24).

We aimed to summarize the clinical outcomes and follow-up results and to discuss the optimal therapeutic strategy for PAAs.

MATERIAL and METHODS

A retrospective review was performed with all PAA patients who underwent microsurgery or endovascular treatment in the Department of Neurosurgery at Xuanwu Hospital between January 2013 and May 2017. Patients with trauma, infections, and dissecting aneurysms were excluded. Eventually, 49 PAA patients, representing 2.43% of the total 2,018 consecutive patients with IAs, were evaluated. Based on an interdisciplinary consensus, PAAs were treated by endovascular or microsurgical occlusion. Of the 49 PAA patients, 42 patients were treated with either microsurgical clipping (n=18, 42.9%) or endovascular coiling (n=24, 57.1%), while 7 patients were not treated. We performed preoperative digital subtraction angiography (DSA) in 41 patients; one patient with a ruptured PAA underwent emergency microsurgery with preoperative computerized tomography angiography (CTA) rather than preoperative DSA. This study was reviewed and approved by the ethics committee of our institution.

The baseline characteristics, clinical data and radiological data of the patients were collected. The morphological parameters of the PAAs were measured, and all patients were followed after the procedure. The preoperative symptoms were evaluated by the Hunt-Hess classification system and the modified Rankin Scale (mRS). A good neurological outcome was defined as an mRS score of 2 or less or a Glasgow Outcome Scale (GOS) score between 4 and 5. Complete recovery was defined as an mRS score of 0.

Categorical variables were compared using the Pearson χ^2 test with continuity correction. Continuous variables were compared using the Mann-Whitney U test or Student's t test. P values <0.05 were considered statistically significant, and all analyses were performed with IBM SPSS Statistics 24.0.

RESULTS

The baseline characteristics of the patients are summarized in Table I; there were no significant differences between the clipping and coiling groups, except in terms of gender (p=0.04) and hospitalization duration (p=0.03). In total, 17 males and 25 females were included, with a mean age of 53.3 ± 10.6 years (range: 16-77 years). There was no significant difference in preoperative mRS scores between the two groups. The aneurysms in the coiling group were larger than those in the clipping groups, but the difference was not significant (Table. II). In total, 81.8% of the ruptured PAAs (n=18) had irregular domes, while only 52.2% of the unruptured PAAs had irregular domes (Table III).

No technical failures were observed in the clipping group, while one patient treated with endovascular coiling suffered from rebleeding during the operation, resulting in a poor prognosis. Two patients died of severe complications, namely, cerebral herniation and neurogenic shock, despite undergoing microsurgical clipping or endovascular treatment. The mean follow-up period was 31.3 ± 13.8 months, and only one patient was lost to follow-up. All patients in the clipping group and most patients in the coiling group (n=22/24, 95.7%) achieved favorable outcomes (mRS score 0-2 or GOS score 4-5) (Table IV). Although the difference was not significant, compared with the clipping groups, the coiling group had a better complete recovery rate [overall: coiling, n=20 (87.0%) vs clipping, n=11 (68.8%), p=0.33; unruptured PAAs: coiling, n=12 (92.3%) vs clipping, n=5 (83.3%); ruptured PAAs: coiling, n=8 (80%) vs clipping, n=6 (60%), p=0.63] (Figure 1). There were no instances of rebleeding during the follow-up period in either group.

Postoperative DSA was available for 28 patients (coiling n=14, clipping n=14), with a mean follow-up period of 14.39 ± 15.69 months; complete occlusion was shown for all 14 clipping patients. One patient in the coiling group experienced a recurrence 3 years after endovascular treatment. Representative cases are shown in Figures 2A-F and 3A-F.

DISCUSSION

It is recognized that, compared to aneurysms in other locations, PAAs have a high rupture rate (9,13,14,23). For example, Gross et al. (9) reported that PAAs account for the highest percentage of all ruptured aneurysms (59%, OR 3.07, 95% CI 1.30- 7.27, p=0.011). Therefore, when PAAs are encountered in clinical practice, appropriate treatment should be actively applied.

Unfortunately, previous studies indicated that PAAs are intractable and difficult to manage, with the foremost cause being specific anatomical characteristics (11,12, 20,22). These lesions are embedded between the cerebral hemispheres, making it difficult to obtain a favorable degree of exposure, sufficient parent artery control and successful clip placement (2,10,11,22). Moreover, the distal location results in a lack of stability and support, both of which are needed for microcatheter and coiling control (6,10,18). Once the aneurysm ruptures, hematoma, brain edema and dense

Table I: Baseline Characteristics of Patients with PAAs

Factors		Clipping Group (patients: n=18)	Coiling Group (n=24)	p
Unruptured		6 (33.6%)	13 (54.2%)	0.18
Ruptured		12 (66.7%)	11 (45.8%)	
Gender (Male)	unruptured	2 (33.3%)	8 (61.5%)	0.52
	ruptured	2 (16.7%)	5 (45.5%)	0.29
	overall	4 (22.2%)	13 (54.2%)	0.04*
Age ($\bar{x}$ ± s, years)	unruptured	50.00 ± 8.60	53.38 ± 13.68	0.59
	ruptured	53.00 ± 7.19	55.36 ± 11.39	0.56
	overall	52.00 ± 7.58	54.29 ± 12.45	0.49
Hypertension	unruptured	4 (66.7%)	7 (53.8%)	0.98
	ruptured	5 (41.7%)	6 (54.5%)	0.54
	overall	9 (50%)	13 (54.2%)	0.79
Prior CVD	unruptured	3 (50.0%)	6 (46.2%)	NS
	ruptured	5 (41.7%)	5 (45.5%)	NS
	overall	8 (44.4%)	11 (45.8%)	0.93
mRS [M (P25, 25)]	unruptured	1 (1, 1)	2 (1, 2)	0.29
	ruptured	2 (1, 3)	1 (1, 2)	0.48
	overall	1 (1, 2.25)	1 (1, 2)	0.89
Hospitalization duration	unruptured	14.67 ± 3.56	7.0 ± 3.37	< 0.001**
	ruptured	13.50 ± 7.22	12.18 ± 8.32	0.69
	overall	13.89 ± 6.14	9.38 ± 6.55	0.03
Heart disease		0	3 (12.5%)	0.25
Hunt-Hess [M (P25, P75)]		1.5 (0, 2)	0 (0, 2)	0.56

CVD: *cerebrovascular disease;* ***"NS":*** *no significance;* ***Statistically significant:*** ** p<0.05, ** p<0.001.*

Table II: Morphological Parameters of PAAs

Factors		Clipping Group (aneurysms: n=17)	Coiling Group (n=28)	p
Unruptured		6 (35.3%)	17 (60.7%)	0.10
Ruptured		11 (64.7%)	11 (39.3%)	
Neck ($\bar{x}$ ± s, mm)	unruptured	3.07 ± 1.12	3.05 ± 1.42	0.99
	ruptured	2.87 ± 1.27	2.49 ± 0.89	0.44
	overall	2.94 ± 1.19	2.84 ± 1.25	0.79
Diameter ($\bar{x}$ ± s, mm)	unruptured	3.56 ± 2.12	4.81 ± 3.96	0.47
	ruptured	3.89 ± 2.54	5.42 ± 1.52	0.10
	overall	3.78 ± 2.34	5.05 ± 3.20	0.16
Width ($\bar{x}$ ± s, mm)	unruptured	3.65 ± 1.73	4.85 ± 3.82	0.47
	ruptured	3.32 ± 1.47	4.06 ± 1.19	0.21
	overall	3.43 ± 1.52	4.54 ± 3.06	0.17
Height ($\bar{x}$ ± s, mm)	unruptured	3.52 ± 2.13	4.54 ± 3.42	0.50
	ruptured	3.57 ± 2.56	5.19 ± 1.49	0.09
	overall	3.55 ± 2.35	4.79 ± 2.80	0.13

arachnoid adhesions between the cingulate gyri significantly increase the difficulty of treatment (1,8,20,22). In addition, Nguyen et al. (16) discovered a higher rate of intraprocedural rupture for coiled PAA lesions than for aneurysms in other locations (3/25 vs 8/476, 95% CI 2.1-22.5, p=0.03). Even when successful occlusions are performed, PAAs have a high recurrence rate (3,9,16,20,22,23).

Above all, because PAAs are rare in clinical practice, the optimal therapeutic strategy for PAAs is still under debate (1,20). In earlier studies, endovascular treatment for PAAs was reported to have high morbidity and mortality rates, low technical success rates and a high degree of technical difficulty, and microsurgical clipping has been the preferred option

Table III: Baseline Characteristics of the Ruptured and Unruptured Groups

Factors		**Ruptured (patients: n=23, aneurysms: n=22)**	**Unruptured (n=19, 23)**	**p**
Gender	Male	7 (30.4%)	10 (52.6%)	0.15
	Female	16 (69.6%)	9 (47.4%)	
Age ($\bar{x}$ ± s, years)		52.32 ± 12.16	54.13 ± 9.29	0.59
Multiple aneurysms		6 (26.1%)	4 (21.1%)	0.99
Morphological	Regular	4 (18.2%)	11 (47.8%)	0.04*
	Irregular	18 (81.8%)	12 (52.2%)	
Neck ($\bar{x}$ ± s, mm)		2.68 ± 1.08	3.06 ± 1.32	0.31
Diameter ($\bar{x}$ ± s, mm)		4.66 ± 2.19	4.48 ± 3.57	0.84
Height ($\bar{x}$ ± s, mm)		4.38 ± 2.21	4.27 ± 3.12	0.89
Width ($\bar{x}$ ± s, mm)		3.81 ± 1.61	4.49 ± 3.45	0.28
Hypertension		11 (47.8%)	11 (57.9%)	0.52
Heart disease		1 (4.3%)	2 (10.5%)	0.86
Prior CVD		10 (43.5%)	9 (47.4%)	0.80
mRS=0		14 (70%)	17 (89.5%)	0.27
Hospitalization duration		12.87 ± 7.61	9.42 ± 4.95	0.09
mRS [M(P25, P75)]		2 (1, 3)	1 (1, 1)	<0.001**
Hunt-Hess [M(P25, P75)]		2 (2, 3)	0 (0, 0)	<0.001**
Post-OP mRS [M(P25, P75)]		0 (0, 0)	0 (0, 0)	0.08
Post-OP GOS [M(P25, P75)]		5 (5, 5)	5 (5, 5)	NS

***Post-OP:** post-operation.*

Table IV: Clinical Outcomes of Patients with PAAs

Factors		**Clipping Group (patients: n=18)**	**Coiling Group (n=24)**	**p**
mRS [M,(P25, P75)]		0 (0, 1)	0 (0, 0)	0.11
GOS [M,(P25, P75)]		5 (5, 5)	5 (5, 5)	0.75
mRS= 0-2		16 (100%)	22 (95.7%)	NS
GOS= 4-5		16 (100%)	22 (95.7%)	NS
mRS= 0	unruptured	5 (83.3%)	12 (92.3%)	NS
	ruptured	6 (60.0%)	8 (80.0%)	0.63
	overall	11 (68.8%)	20 (87.0%)	0.33

(11,15). In particular, a meta-analysis of thirty studies involving 1329 patients with PAAs published in 2017 indicated that microsurgery remains a more effective treatment. Regardless of whether a PAA ruptures, compared with endovascular treatment, microsurgery has a higher success rate (99.0% vs 96.0%, p=0.001) and a significantly higher complete aneurysm occlusion rate (97.0% vs 69.0%, p<0.0001) (20). In addition, compared with endovascular treatment, microsurgery is associated with a significantly lower recurrence rate (2.0% vs. 18.0%, p<0.0001) and rebleeding rate (0.0% vs. 2.0%,

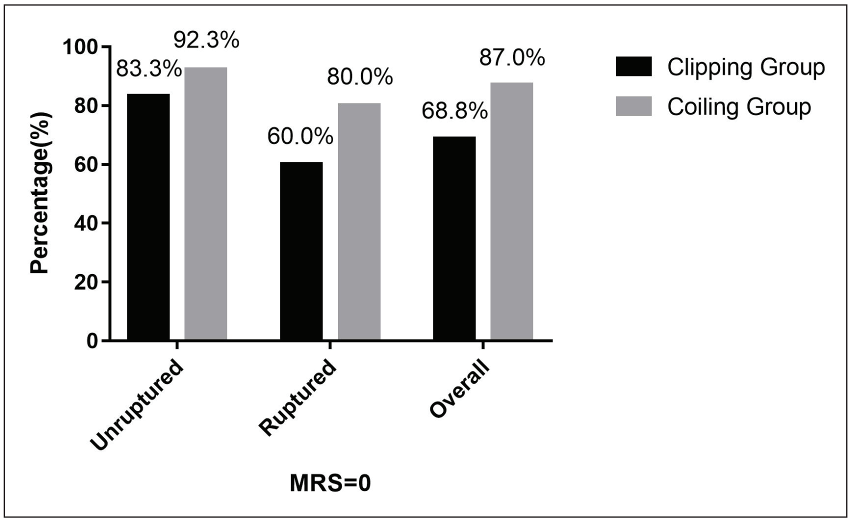

Figure 1: The neurological complete recovery (mRS=0) rates of patients with PAAs were compared between the clipping and coiling groups.

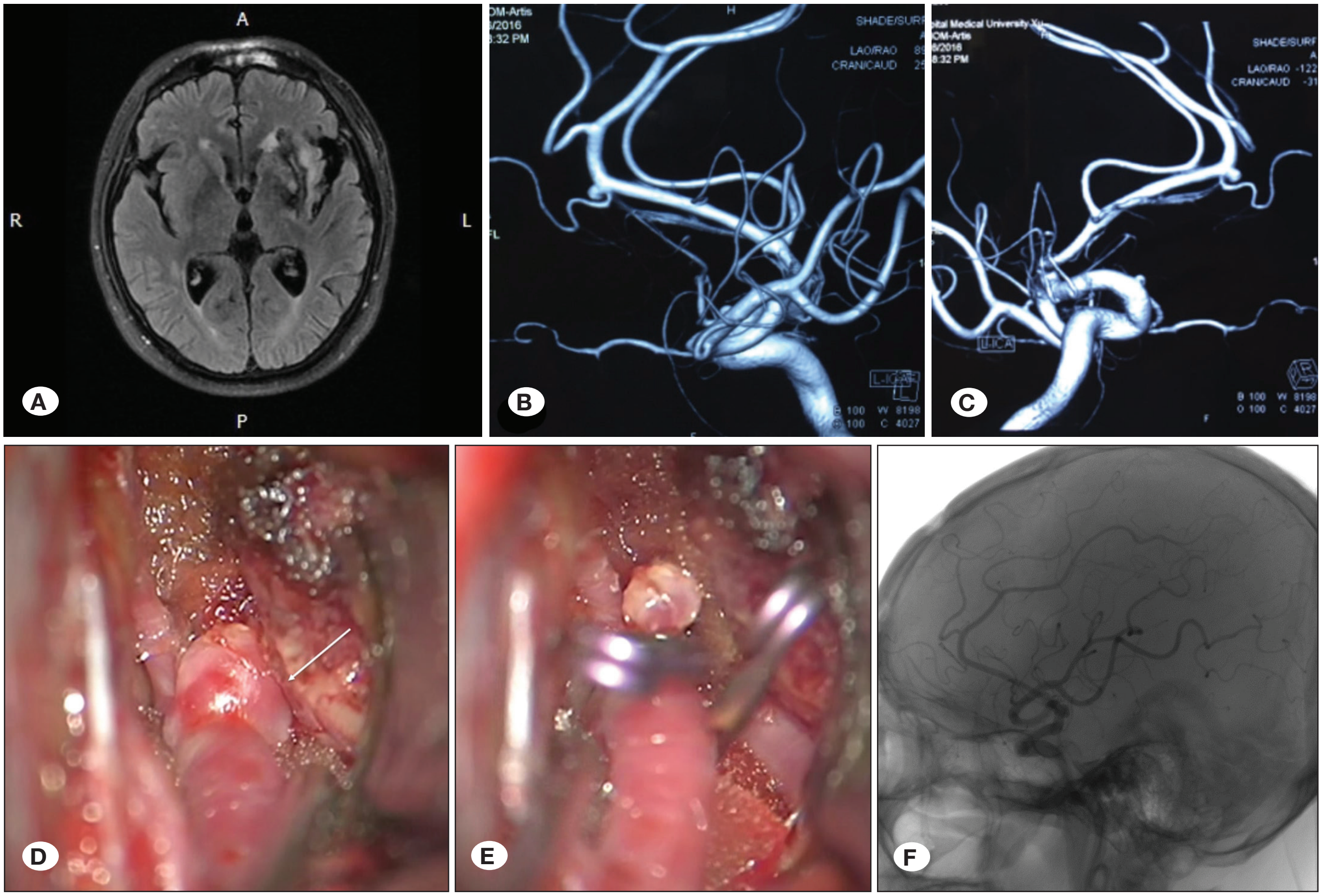

Figure 2: Ruptured PAA as seen on **(A)** preoperative MRI and **(B, C)** preoperative DSA. **D)** Intraoperative exposure of the PAA; the aneurysm is shown by the arrow. **E)** Aneurysm clipping. **F)** DSA at 14 months after microsurgery.

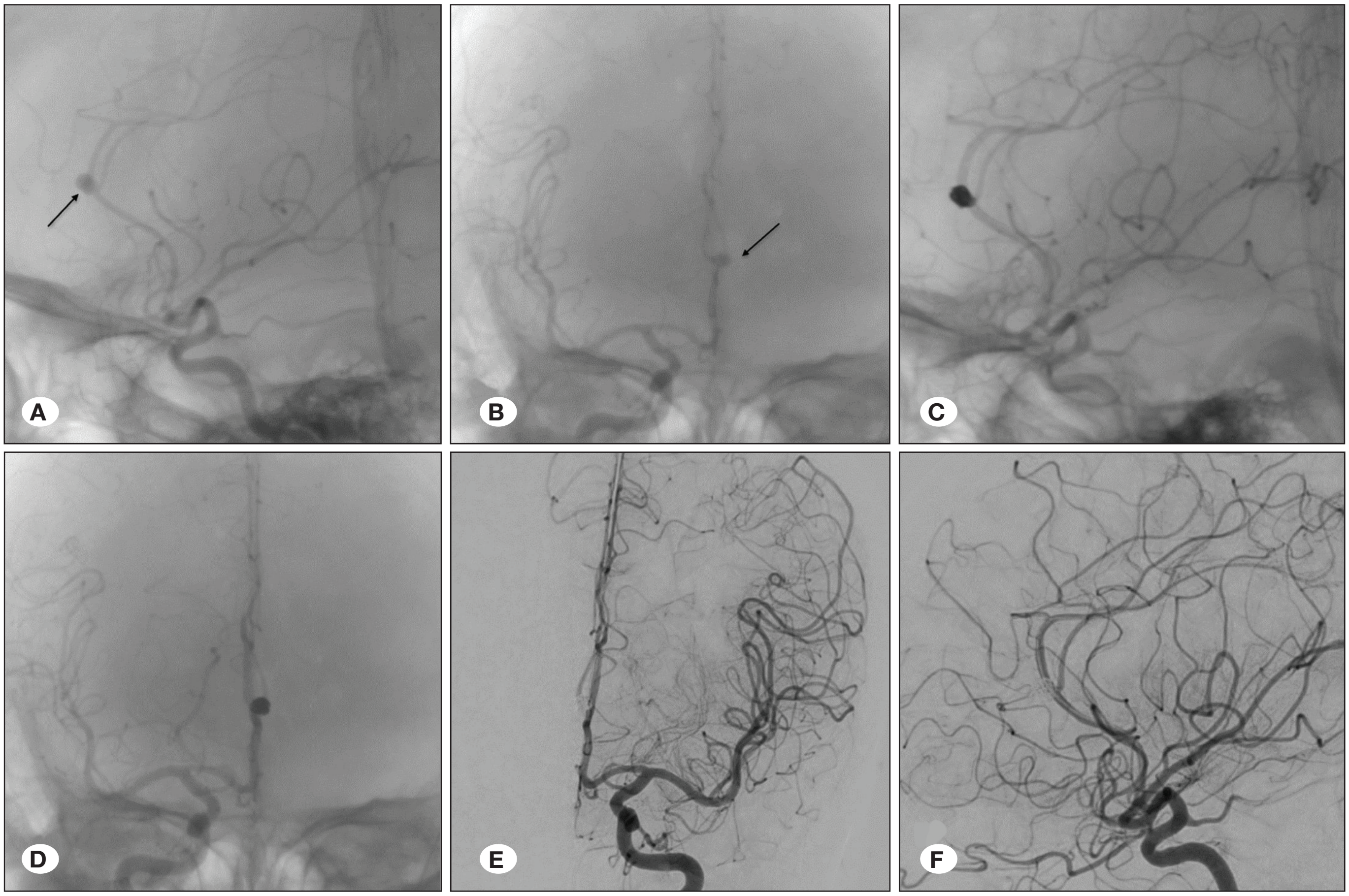

Figure 3: Preoperative DSA **(A, B)** shows the unruptured PAA (arrow). **C, D)** Postoperative DSA. **E, F)** DSA at 6 months after endovascular treatment.

p=0.029). Therefore, many researchers have suggested that compared with endovascular coiling, microsurgical clipping of PAAs is associated with superior clinical and radiological outcomes.

Is microsurgical clipping superior to endovascular treatment? Although the capacity of this meta-analysis to include large sample sizes makes the results seem reliable, half of the included studies were published more than 10 years ago, which is likely to lead to favorable results of microsurgical treatment. Hence, the continued validity of the conclusions drawn in these previous studies should be treated with skepticism due to the rapid development of endovascular techniques in recent years. With the advancement and refinement of endovascular techniques, recent studies have reported high rates of technical success and improved clinical and radiological outcomes (10,19,20,22). For example, Hui et al. (10) demonstrated that compared with the clipping group, the coiling group achieved better neurological outcomes (mRS 0-2 vs 3-6, p=0.028) and had higher complete recovery rates (mRS 0, p=0.017) and lower mortality rates (mRS 6, p=0.026). Furthermore, Park et al. (19) reported that procedure-related complications tended to occur more frequently in the clipping group than in the coiling group (p=0.121).

In our study, we retrospectively evaluated and compared the clinical outcomes of PAAs in patients who were treated with endovascular coiling or microsurgical clipping. Both treatment modalities appeared to be efficacious and safe. Although the difference was not significant, compared with the microsurgery group, the endovascular group achieved better clinical outcomes regardless of whether the aneurysm ruptured (Figure 1). In our study, within the endovascular group, 1 patient experienced rebleeding, and 1 patient had a recurrence; however, considering the poor outcomes reported in previous studies, substantial progress has been made in the endovascular treatment of PAAs. Moreover, with the emergence of new and more effective endovascular devices and the recent refinement of techniques for endovascular treatment (4,7), the high recanalization rate caused by the coiling procedure is expected to decrease. For example, De Macedo Rodrigues et al. (7) demonstrated the feasibility of using flow-diverter devices for the treatment of PAAs, and no thromboembolic or hemorrhagic complications were seen during the follow-up period. We have no doubt that the future of endovascular treatment for PAAs is promising.

Considering the significant technical challenges associated with both treatment strategies, a multidisciplinary analysis of each patient is needed to determine the optimal treatment.

Some studies have reported improved outcomes when endovascular treatment is used in patients with aneurysms with a dome/neck ratio > 1.5, in patients with parent arteries in good condition, and in older patients with multiple comorbidities (5,20). On the other hand, microsurgery is preferred for patients with aneurysms involving branch arteries or a large volume hematoma, aneurysms in the A3-A5 segment of the anterior cerebral artery, and intra-aneurysmal thrombi (1,5,17,19,20).

Limitation

The main limitation of this study is its small cohort and retrospective design, which restrict the power and generalizability of our conclusions. Because recanalization is often observed in PAAs after coiling, a longer radiological follow-up is necessary.

CONCLUSION

Despite the technical difficulties encountered during the treatment of PAAs, in our study, both endovascular coiling and microsurgery were technically feasible and achieved favorable clinical outcomes. A multidisciplinary evaluation is needed to optimize the clinical outcomes and management of PAA patients.

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