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Original Article

Endovascular management of giant middle cerebral artery aneurysms

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Abstract: Background: This article reported the experience of endovascular treatment in giant middle cerebral artery (MCA) aneurysms with parent artery occlusion or stent-assisted coiling. Material and methods: Eleven consecutive patients with giant MCA aneurysms were included. The aneurysms predominantly involved the M1 segment in two cases, bifurcation in four cases, and M2 in five cases. Four M2 fusiform aneurysms were treated with parent artery sacrifice after balloon occlusion test. The seven unruptured aneurysms and one ruptured one were treated with stent-assisted coiling. The post-operation and long-term follow-up angiographic and clinical outcomes were analyzed. Results: Endovascular coiling was performed successfully in all 11 cases. All four M2 fusiform cases using parent artery occlusion strategy achieved complete occlusion of aneurysms. In the seven cases with stent-assisted coiling, four were completely occluded, two were partially occluded and one remained small residue. Mild perioperative complications occurred in six patients. The follow-up angiography taken at a mean of 13.5 months of eight patients showed that seven aneurysms remained stable or improved and one M1 aneurysms relapsed and needed further treatment. Conclusion: Stent-assisted coiling or parent artery occlusion of selected giant MCA aneurysms is an option to consider.

Keywords: Aneurysm, endovascular treatments, giant, middle cerebral artery

Introduction

Giant intracranial aneurysms have an extremely grave natural history. More than 50% of patients suffer from rupture of these aneurysms and mortality is >60% in two years [1-3]. The majority of giant aneurysms are located in the ICA and MCA regions (16%-32%) [4-8]. The MCA region is the common site for ruptured giant aneurysms [8, 9]. Giant MCA aneurysms have distinctive anatomic features such as significant size, fusiform morphology, intraluminal thrombus and branch corporation that present a number of technical challenges for both surgical and endovascular repair. Although MCA aneurysms have long been considered favorable for surgery, the combined surgical morbidity and mortality of giant intracranial aneurysms have remained in the 20% to 50% range in recent years [4-7, 10].

Endovascular therapy has emerged as an alternative to surgery for treatment of giant aneurysms in particular [11-13]. However, problems for this approach including incomplete obliteration, aneurysm recanalization, procedure-related complications, distal location and heavy adjunctive reliance remain stubborn. We therefore reviewed our experience on endovascular treatment of giant MCA aneurysms. The technique application on different MCA segments, the associated complications and the patients' long-term outcomes were retrospectively evaluated.

Materials and methods

We retrospectively reviewed a database of aneurysms with endovascular treatment at our institution between 2002 and 2013. Those with proximal giant MCA aneurysms (M1 and M2) were analyzed. Giant aneurysms were

Table 1. Clinical summary of patients undergoing endovascular treatment for giant MCA aneurysms

Patient ID	Gender/ age	Presenta- tions	Initial mRS	Loca- tion	Type	Methods	Post- angio	Discharge mRS	Discharge GOS	Follow- up time	Follow- up mRS	Follow- up GOS	Follow- up angio	Retreat
1	F/25	Headache	1	M1	Saccular	Single Stent + coilling, double microcatheter	Class I	0	5	10 m	0	5	Class I	
2	M/50	Incident	0	M1	Fusiform	Overlapping Stent + coilling	Class III	0	5	16 m	2	4	Class III	Bypass, PAO
3	F/69	Headache	1	Bifur	Saccular	Single Stent + coiliing	Class II	2	4	24 m	0	5	Class I	
4	F/67	Headache	1	Bifur	Saccular	Single Stent + coiliing	Class III	1	4	22 m	0	5	Class I	
5	M/75	Incident	2	Bifur	Saccular	Single Stent + coiliing	Class I	2	4	20 m	4	3	NA	
6	F/55	Dizziness	1	Bifur	Saccular	Stent + coiliing, double microcatheter	Class I	0	5	6 m	0	5	Class I	
7	F/78	SAH	5	M2	Fusiform	Overlapping Stent + coiliing	Class I	5	3	12 m	4	3	NA	
8	F/39	Headache	1	M2	Fusiform	BTO; PAO	Class I	0	5	11 m	0	5	Class I	
9	F/57	Dizziness	1	M2	Fusiform	BTO; PAO	Class I	2	4	7 m	0	5	Class I	
10	M/48	SAH	3	M2	Fusiform	BTO; PAO	Class I	0	5	20 m	0	5	Class I	
11	M/27	Headache	1	M2	Fusiform	BTO; PAO	Class I	0	5	8 m	0	5	NA	

Table 2. Patient, aneurysms, and treatment characteristics

	N = 11
Male	36.4% (4/11)
Age (Median, range), yr	54 (25-78)
Presentation	
Headache	45.5% (5/11)
Dizziness	18.2% (2/11)
Subarachnoid hemorrhage	18.2% (2/11)
None	18.2% (2/11)
Location	
M1	18.2% (2/11)
M2	45.5% (5/11)
Bifurcation	27.3% (3/11)
Aneurysm type	
Saccular	45.5% (5/11)
Fusiform	54.5% (6/11)
Method	
Stenting + coiling	63.6% (7/11)
PAO	36.4% (4/11)
BTO	36.4% (4/11)

defined as those with a diameter greater than 2.5 cm as measured by digital subtraction angiography (DSA). We reviewed the size, type of aneurysm, symptoms at presentation, treatment modalities used, complications and outcomes of each patient. The patients' clinical examinations and imaging studies, and angiographic reports and in- and outpatient records were reviewed.

The initial evaluation included assignment on the modified Rankin's Scale (mRS) for all patients regardless of presentation. Vascular imaging was performed using conventional angiography. Aneurysm occlusion was classified by Raymond classification. Short-term outcome was the postoperative complications. Clinical functional outcomes were assessed using mRS and Glasgow Outcome Scale (GOS) scores. The decision to treat aneurysm with endovascular therapy was based on patient preferences, aneurysm morphology, aneurysm-parent artery relationship, and the clinical characteristic of the patient.

Parent artery occlusion (PAO) was preferred for fusiform M2 aneurysms. The preliminary balloon occlusion test (BOT) combined with hypotension test was performed for 30 minutes by using an inflated non-detachable balloon (Magic B1; Balt, Montmorency, France; or HyperForm/HyperGlide; Covidien, Irvine, California; or Gateway; Boston Scientific, Natick, Mass) at the distal M2 branch. We performed the hypotension test with intravenous injection of nimodipine to decrease the mean arterial pressure 20 mmHg compared with baseline. BOT was judged by clinical neurologic evaluation and angiography of collateral vessels. The definitive occlusion of the aneurysm and the parent artery was performed using detachable platinum coils.

Stent-assisted coiling (SAC) was performed on the cases not amenable for BOT including all M1 or bifurcation aneurysms, and one M2 aneurysm conceived with high rebleeding risk during BOT procedures.

Local anesthesia was administrated during BOT procedures and general anesthesia was used in all SAC and PAO cases. Systemic heparinization was administered and followed by a maintenance dose per hour. Postoperative systolic blood pressure was maintained over 120 mmHg. Dual antiplatelet therapy (aspirin, 100 mg/day, and clopidogrel, 75 mg/day) was introduced 3 days before treatment and continued for 6 months after.

Results

Between Jan 2002 and Dec 2013, we identified 11 patients (4 males, 7 females) with proximal MCA giant aneurysms (6 fusiform and 5 saccular) and treated them using endovascular techniques (**Tables 1** and **2**). The mean age was 54 year old with a range of 25-78 years. The aneurysms predominantly involved the M1 segment in 2 cases, M2 in 5 cases, and bifurcation of MCA in 4 cases. Three patients had multiple aneurysms including 1 aneurysm of the posterior communicating artery, 1 of the anterior communicating artery and 1 of the C1 segment of ICA.

One patient (case 7) presented acute subarachnoid hemorrhage (SAH) and basal ganglia infarction. One patient (case 10) had a history of SAH. In the other 9 cases, the aneurysms were identified incidentally or during evaluation of symptoms associated with mass effect.

BOT was performed in 4 fusiform M2 aneurysms (case 8, 9, 10, and 11). All 4 patients achieved negative results of BOT, so PAO was then performed. Single stent-assisted coiling (SSAC) was attempted in 5 aneurysms (case 1,

Table 3. Intraoperative complications

Patients ID	Complications	Presentations	Location	Reason
3	Infarct	Heimplegia	Lateral frontal and parietal lobe	Coil herniation into the anterior cerebral artery during the embolization of combined anterior communication artery aneurysm
4	Infarct	Asymptomatic	Temporal lobe	Coil herniation into the inferior trunk arising from the aneurysm
5	Infarct	Asymptomatic	Temporal lobe	Thrombosis of the inferior trunk
7	Infarct	Asymptomatic	Basal ganglia	Occlusion of the LAs arising from the aneurysm
9	Infarct	Hemiplegia	Basal ganglia	Thrombosis of lateral LAs
11	Infarct	Hemiplegia	Frontal lobe and basal ganglia	Thrombosis of M1

Footnotes: LAs: lenticulostriate arteries.

Table 4. Length of follow-up (months), outcome scores, and complications

	N = 11
Death	0
Intracranial hemorrhage	0
Perioperative ischemic event	54.5% (6/11)
Follow-up months (median, range)	14.2 (6, 24)
Postoperative Angiographic outcome	
Class I	72.7% (8/11)
Class II	9.1% (1/11)
Class III	18.2% (2/11)
Follow-up angiographic outcome	
Class I	87.5% (7/8)
Class II	0% (0/8)
Class III	12.5% (1/8)
Follow-up outcome	
good recovery (GOS 5 or 4)	81.8% (9/11)
mobility (GOS < 4)	27.3% (3/11)

3, 4, 5 and 6). Of those, 2 aneurysms (case 1 and 6) were treated combined with double microcatheter technique. Overlapping SAC was performed in 2 fusiform aneurysms (case 2 and 7).

Perioperative mortality was 0% and morbidity was documented in 54.5% (6/11) of the patients, which were all ischemic events confirmed by postoperative CT/MRI (**Table 3**). Considering the basal ganglia infarction before the treatment in case 7, the lenticulostriate arteries arising from the aneurysm were sacrificed and postoperatively the patient presented no aggravated symptoms. One patient (case 11) received Tirofiban for M1 thrombosis and achieved the recanalization of M1. All 6 patients achieved good outcomes (GOS 5 or 4, mRS 0-2) including 3 with symptomatic infarctions after medical therapy.

Patients' outcomes are summarized in **Table 4**. Postoperatively, 8 of 11 aneurysms (72.7%) were completely occluded. One aneurysm had neck remnants and 2 were incompletely occluded (9.1% and 18.2% respectively). In 8 cases having follow-up angiography, two bifurcation cases (case 3 and 4) with incompletely occlusion achieved complete occlusion, whereas recurrence was noted in a M1 fusiform aneurysm (case 2) and the patient received combined surgery bypass and endovascular PAO. No perioperative morbidity or mortality was associated with retreatment.

Clinical follow-up was available in all 11 patients. The mean length of follow-up was 14.2 months with a range of 6-24. Good outcomes (GOS 5 or 4) were seen in 81.8% (9/11) of patients. The mean GOS were 4.5 (range, 3-5; median, 5) and mRS scores 1.0 (range, 0-4; median, 0).

Case reports

Case 1 (Patient 1)

A 25-year-old woman presented recurrent headache for half a year. Angiography demonstrates a giant irregular M1 aneurysm (**Figure 1A**). Double microcatheters technique was applied for better occlusion result before the stent implantation (**Figure 1B**, **1C**). The aneurysm was further densely packed after the stent deployment (**Figure 1D**, **1E**). The patient remained neurologically intact after the embolization. The 11-month follow up angiography demonstrates no relapse of the aneurysm and the intact of the M1 segment (**Figure 1F**).

Case 2 (Patient 6)

A 55-year-old woman presented dizziness for a month. Angiography demonstrated a giant bifurcation MCA aneurysm with both the main trunks and the lenticulostriate arteries originating from the side wall of the aneurysm (**Figure 2A**). This was treated with SSAC combined with

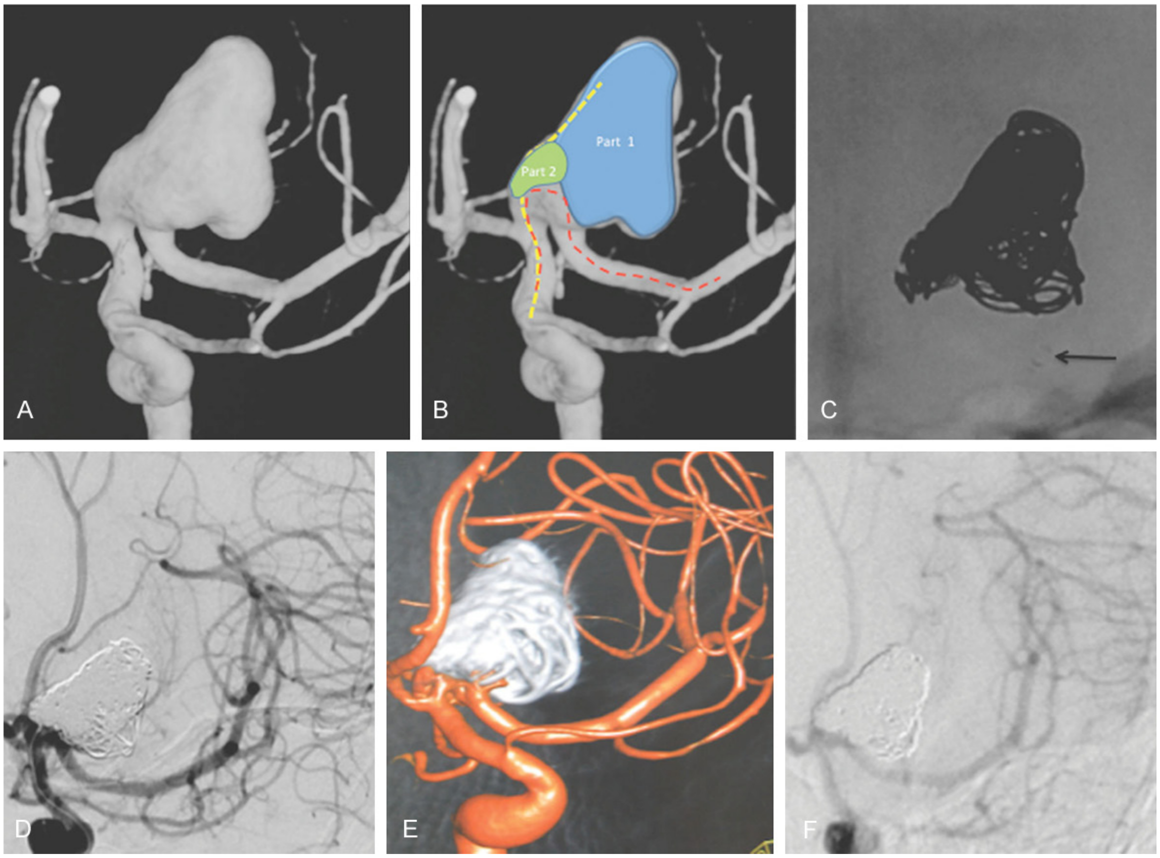

Figure 1. Patient 1. 3-dimensional reconstruction demonstrates a giant M1 MCA aneurysm (A). After partial embolization (Part 1) of the aneurysm by double microcatheter technique, the stent was deployed to ensure parent-vessel patency (red line) and the residue aneurysm (Part 2) was further embolized (B, C). Working position angiogram (D) and 3-dimensional reconstruction (E) demonstrates the complete occlusion of the aneurysm and the patency of M1 segment. Angiography at 11 months follow up examination (F) demonstrates complete occlusion of the aneurysm. Arrow in C indicates stent markers.

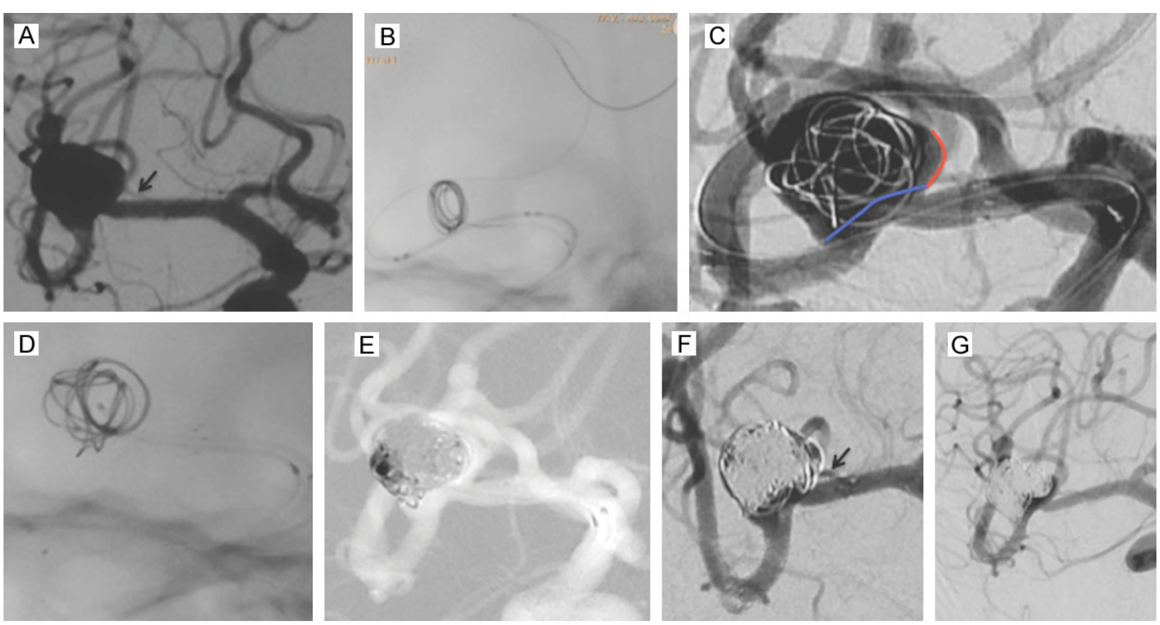

Figure 2. Patient 6. Right carotid angiogram (A) shows a giant bifurcation aneurysm involving two main trunks and a trunk of lenticulostriate arteries (black arrow). The stent was deployed after inserting the coil by the microcatheter

(B). (C) The stent reshaped the aneurysm neck to be a relatively narrow one. The part of the neck (blue line) was covered by the stent and the residue neck (red line) was protected by double microcatheter technique during embolization (D, E). The angiography after the embolization demonstrates the completely occlusion of the aneurysm with the preservation of the two main trunk of MCA and the lenticulostriate arteries (black arrow) (F). The occlusion result kept stable in 6-month follow-up angiography (G).

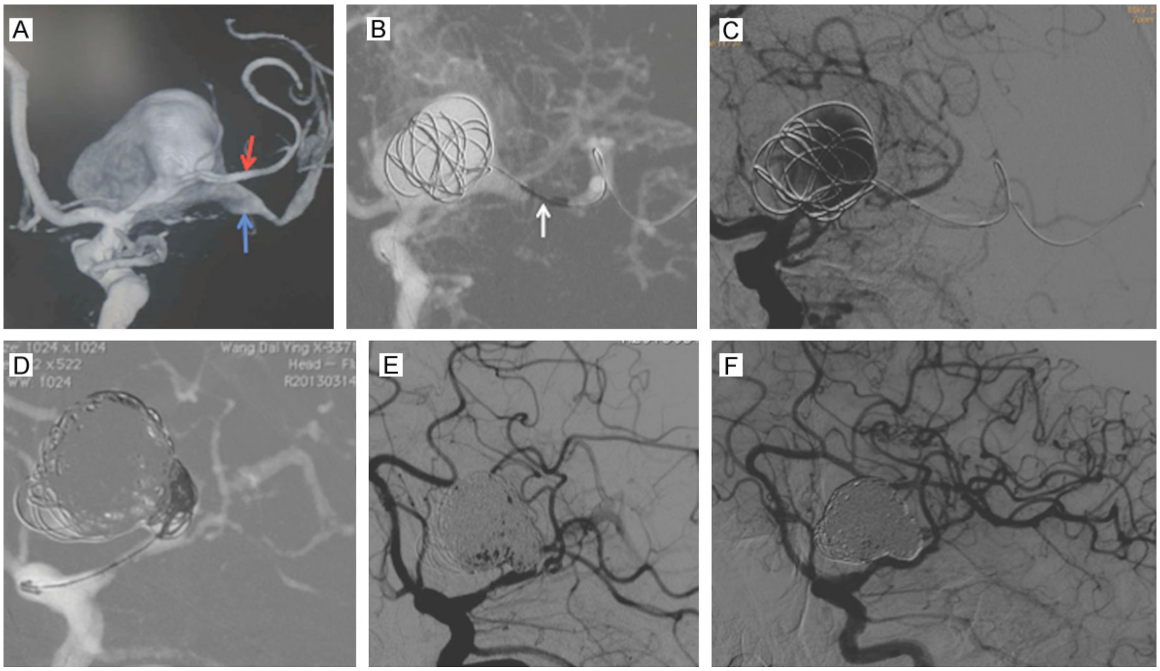

Figure 3. Patient 8. 3-dimensional reconstruction (A) shows a giant fusiform M2 aneurysm with the superior trunk (red arrow) arising from the aneurysm neck and the inferior trunk (blue arrow) arising from the aneurysm dome. The Gateway balloon was exchanged to the distal normal part of the inferior trunk, which was completely occluded after balloon inflation (B, C). The residue neck was coiled under the good observation of the superior trunk (D). Postoperative (E) and 11-month follow-up (F) angiography reveals the completely occlusion of the aneurysm and the inferior trunk with the preservation of the superior trunk.

double microcatheter technique (**Figure 2B-E**). The aneurysm neck was reshaped to the relatively narrow after the deployment of the Neuroform stent (Boston Scientific) to the dominant inferior trunk. Afterward the aneurysm was further embolized with double microcatheter technique for the more reliable preservation of the superior trunk and the lenticulostriate arteries (**Figure 2F**). The patient remained symptom free at 6-month follow-up and angiography demonstrated completely aneurysm obliteration, with the preservation of two main trunk and the lenticulostriate arteries (**Figure 2G**).

Case 3 (Patient 8)

A 39-year-old woman presented for treatment at our institution with headache for three months. Angiography revealed a giant fusiform MCA (M2 segment) aneurysm. The irregular fusiform enlarged inferior trunk arose from the side wall of the aneurysm and the superior trunk arose from the neck of the aneurysm (**Figure 3A**). BOT of the inferior trunk was performed. Gateway balloon (Boston Scientific) was exchanged to the inferior trunk with the guide of Floppy 300 (Boston Scientific). At first, the balloon could not be fixed in the fusiform enlarged part of the inferior trunk when deployed. After placed in the distal normal part passing the fusiform enlarged segment of inferior trunk, the balloon was successfully deployed (**Figure 3B**, **3C**). The result of BOT was negative. The aneurysm and the inferior trunk were occluded with the preservation of the superior trunk (**Figure 3D**, **3E**). The 11-month follow-up angiography revealed completely occlusion of the aneurysm with the patency of the superior trunk (**Figure 3F**).

Discussion

With the rapidly advancing technology, endovascular treatment will evolve to address giant and fusiform aneurysms in more distal arterial segments, including the MCA. Endovascular series included giant aneurysms were historically reported significant morbidity and mortality (20-48%) [4, 11, 12, 14, 15]. The current rate of complications has been reported of a 10.5% morbidity rate and an 8% mortality rate in recent series of large and giant aneurysms treated with endovascular coiling, in which favorable outcomes were achieved in 92% of patients. However, that study also demonstrates high rates of recurrence (52%) and retreatment (47%) for aneurysms >25 mm [13]. Thus, the treatment of giant MCA aneurysms poses a significant challenge for endovascular strategies.

In the present study, 72.7% (8/11) of patients achieved complete occlusion with a 0% preoperative mortality rate and a 54.5% morbidity rate. 81.8% (9/11) of patients achieved favorable outcome over 14 months of clinical follow-up and only one patient (12.5%, 1/8) showed recurrence and need retreatment. No long-term procedure-associated morbidity. Those results indicate a more favorable outcome in our patient series than previous studies.

PAO has long been considered the reference treatment for giant or fusiform aneurysms of the carotid siphon. However, this technique is not well suited for MCA aneurysms for the absent compensation from the circle of Willis. PAO with bypass has been used in the treatment of the unclippable MCA aneurysms for its reliable effect and the ability to preserve perfusion. However, this method is associated with unavoidable operation injure and the failure of bypass.

The vessel anatomy of giant M2 aneurysms is different from those located in other MCA segment such as M1 and bifurcation. The recent study on the distal aneurysms indicated the adequate collateral circulation can prevent infarction in the territory of the occluded vessel in most patients [16]. Distal occlusion of the parent artery seems feasible in cases of adequate collateral arterial supply. In our series, four M2 giant aneurysms were performed PAO with preliminary BOT of sacrificed distal M2 segment to determine patient collateral reactivity. All four cases presented the well tolerance and received immediate complete occlusion. No procedure-related ischemic event was observed except one patient (Case 9) experienced mild stroke after the occlusion of lateral lenticulostriate arteries arising from M1 segment. There was no recurrence observed in 3 of those patients who received follow-up angiography (7-20 M).

The main challenge of BOT at the distal M2 segment was to deliver the balloon in the distal parent artery and keep the balloon stable during the inflation. Each balloon system used in our series has pros and cons respectively. Gateway balloon can be exchanged to the distal parent artery across the aneurysm neck with the guide of microwire. The risk of wire-related hemorrhage events is low for Magic balloon system without the guidewire.

As endovascular PAO is not suitable for giant intracranial aneurysms, SAC is a commonly used endovascular technique for improving the occlusion and recanalization rates with acceptable mortality and morbidity [13, 17-19]. SAC may also contribute to progressive occlusion in nearly incompletely treated aneurysms. We performed SAC in 7 patients including SSAC in 5 patients with saccular aneurysms and overlapping SAC in 2 patients with fusiform aneurysms. 3 patients had initial incomplete occlusion. 2 saccular bifurcation aneurysms achieved complete occlusion at the time of last angiographic follow-up. 1 fusiform M1 aneurysm showed relapsed and finally achieved complete occlusion after the bypass and PAO.

The MCA aneurysms in SAC presented high procedural complications rate [20]. In our series, complication occurred in 54.5% (6/11) of patients and all were ischemic events. There was no death or permanent morbidity. Coil herniation and perforating infarction are the two major reasons in our series. Immediate observation and medical therapy improved clinical outcomes. Half were asymptomatic and half achieved good clinical outcome in follow up.

SSAC combined with double microcatheter is the technique we used in recent two saccular aneurysms. Both two cases achieved immediate complete occlusion without any complications. Conversely, the other three cases performed SSAC without double microcatheter technique experienced ischemic complications and only one case achieved initial complete occlusion. From our limited experience, SSAC combined with double microcatheter technique might increase the occlusion rate and decrease the ischemic complications for giant saccular M1 and bifurcation aneurysms. The single stent could only cover a part of aneurysm neck but it can reshape the broaden neck into a relatively narrow one. The following coiling with double microcatheter technique under the suitable working projection could increase the efficacy and safety of embolization.

Recently, the flow diversion have been designed to treat the aneurysms with unfavorable geometric configurations such as the giant fusiform M1 aneurysm in our series. However, the wire-braided design with very high metal attenuation and low porosity [21] make it difficult to maneuver especially for distal location. Early or delayed rupture or thrombosis, distal ipsilateral hemorrhage and the perforation infarctions related to flow diversion have been reported [22-25]. In addition, the device has not been formally available in our district.

The major limitations of this study are the retrospective design, the small number and the lack of long term follow up for aneurysmal recurrence. Though these techniques already been documented by previously published articles, the results, far from being generalizable, seem encouraging for appropriate use of these techniques in giant MCA aneurysms. Careful selection of techniques considering the heterogeneity of aneurysms regarding morphology, location and relationships with parent arteries or their branches seem crucial for successful treatment.

Conclusion

In this study, PAO by using coils to treat giant or fusiform aneurysm on M2 segment afforded the opportunity for a complete cure. SSAC with double microcatheter technique might be a feasible and effective technique for giant saccular MCA aneurysms. Further experience and long-term follow-up are required to evaluate the efficacy of the method.

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Disclosure of conflict of interest

None.

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