ORIGINAL ARTICLE

Single flow diverter to manage multiple intracranial aneurysms in a parent artery

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Abstract

Background: Endovascular coil embolization has become an important method in the management of intracranial aneurysm. However, simultaneously coiling multiple intracranial aneurysms (MIAs) in unilateral parent artery in one-stage may fail or insufficient in geographic difficult aneurysm. Flow diverter (FD) has the potential to manage MIAs with nonamenable to coiling. Herein, we report periprocedural morphologic change and outcomes using single FD to manage unruptured MIAs in a parent artery.

Methods: Over a 3-year period, a total of 63 patients with 126 MIAs successful managed by single FD with complete angiographic follow-up. There were 49 women and 14 men, with ages ranging from 42 to 77 years (mean: 59 years). We retrospectively assessed the clinical data, aneurysm characteristic, angiographic and clinical outcomes of all patients and compared with 171 patients with single aneurysm managed by FD.

Results: Sixty-one patients with 118 aneurysms (94%) located in internal carotid artery or middle cerebral artery (n = 4, 3%), two patients with four aneurysms (4%) were found in the basilar artery. The mean aneurysm size was 5.6 mm (range from 1.8 to 38 mm). Mean angiographic follow-up was 14 months. Complete obliteration of aneurysm was achieved in 102 aneurysms (83%), subtotal or partial aneurysm obliteration was demonstrated in 18 aneurysms (15%), unchanged aneurysm morphology in three (2%). Aneurysm morphology synchronized alteration in 55 patients (87%), other eight patients (13%) with 16 aneurysms showed different morphologic alteration in angiographic follow-up. Four patients (6.3%) had intraprocedural ischemic complication. During the follow-up period, 61 patients (97%) were neurologic stable; there was no hemorrhagic or ischemic event.

Conclusion: Single FD was feasible to treat MIAs in a parent artery with both effective and safe in one-stage management. Most aneurysms synchronized alteration of morphology in a mid-term follow-up. The procedure was almost the same with FD managing single aneurysm, but longer FD is needed in MIAs.

Keywords: Embolization; Flow-diverter; Multiple intracranial aneurysms; Outcome

1.INTRODUCTION

Endovascular detachable coil embolization of intracranial aneurysms has become an important minimally invasive procedure of management of single or multiple aneurysms in different territories with promising results.[1–4] Despite the increase in clinical experiences, innovation of technology and the advertent of new devices, one-stage simultaneously coiling multiple intracranial aneurysms (MIAs) in a segmental parent artery remain challenge and risky in some geographic difficult aneurysms.

Flow diverter (FD) was designed as a single-stent treatment solution for intracranial aneurysm by endoluminal reconstruction instead of aneurysm coiling. Because of better metallic surface coverage than tradition stent with low porosity density, FD had advantage of changing the hemodynamic of parent artery/aneurysm sac, to promote subsequent aneurysm thrombosis.[5–11] Complete obliteration (CO) of aneurysms occurred gradually after FD deployment. FD is particularly useful for large (13–24 mm) and giant (>25 mm) broad-neck aneurysms and had the capability of providing the durable angiographic outcomes.

Application of single FD in MIAs has not been well report. The purpose of this study was to report our experiences, hemodynamic and morphologic alteration of using single FD, one-stage managed MIAs in a unilateral parent artery and compared with those patients with single aneurysm treated by FD.

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Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

Journal of Chinese Medical Association. (2023) 86: 289-294.

Received June 14, 2022; accepted November 25, 2022.

doi: 10.1097/JCMA.0000000000000868.

2.METHODS

2.1. Patient demography

From February 2018 to January 2021, a series of 281 patients with 362 unruptured intracranial aneurysms were managed by FD in three institutions by one major operator. Of these patients, 76 patients (29%) had MIAs in a segmental parent artery managed by deployment of single FD; 71 patients had two aneurysms and five patients had three aneurysms. Deployment of FD to treat all aneurysms was achieved in 73 of 76 patients, resulting in a deployment success rate of 96%. From these database, 10 patients were excluded because of lacking follow-up conventional angiography, there were 63 patients with 126 aneurysms were successfully managed by single FD with more than 6-month digital subtraction angiography (DSA) follow-up. There were 49 women (78%) and 14 men (22%) with age between the 42 and 77 years (mean: 59 years). Before initiation of this study, it was approved by IRB of our institute; all patient's informed consents were obtained from patients and/or patient's family. Information including sex, age distribution, and characteristics of aneurysms are summarized in Table 1. Seven patients (11%) were symptomatic because of giant aneurysms (n = 6), or large aneurysms (n = 1) compression of nearby cranial nerve or brain stem, leading to decreasing visual acuity or limb weakness. The sizes of the aneurysms varied from 1.8 to 38 mm in their maximal dimension (mean: 5.6 mm) and most (n = 92; 73%) aneurysms were less than 7 mm. The locations of aneurysms were internal carotid artery (ICA, n = 118; 94%), basilar artery (n = 4; 3%), middle cerebral artery (n = 4; 3%). Regarding pharmacological therapy, clopidogrel 75 mg and aspirin 200 mg per day were given for 6 days before embolization.

2.2. Endovascular treatment

With patients under general anesthesia, the femoral arteries were catheterized by means of a percutaneous technique. DSA of parent artery, rotational and three-dimensional reconstruction DSA were routinely obtained to evaluate the angioarchitecture of aneurysm and parent artery. A bolus of intravenous heparin of 3000 units was routinely administered after the guiding catheter was placed into parent artery and we maintained an activated clotting time to two times baseline throughout the whole procedure. The 8F femoral sheath and guiding catheter were introduced and navigated into parent artery, then a 6F intermediate catheter was coaxially placed to parent artery as close as possible to aneurysms. The a 2.7F microcatheter was navigated to distal parent artery or its branch, then a proper size and length self-expandable Pipeline flex (n = 16, Medtronic, Irvine, CA, USA) or FRED (n = 47, MicroVention, Tustin, CA, USA) was negotiated and deployed into the parent artery to bridge the aneurysm necks. The stent length was chosen to provide at least a 4 to 5 mm landing zone beyond the aneurysm neck on the proximal and distal parent artery. The stent was sized to equal or 0.2 mm greater than the caliber of the parent vessel at the targeted landing zone. Adjunctive aneurysm coiling was performed to enhance the CO of aneurysms in giant (n = 6), large (n = 9). For adjunctive aneurysm coiling, we accessed to the parent artery and aneurysm sac by puncture of contralateral femoral artery to avoid interfering the microcatheters for FD and coiling, followed by navigation of a 6F guiding catheter to parent artery, the microcatheter was navigated into the aneurysm sac before the stent was deployed (stent-jail catheter technique). After the FD was successfully deployed into target site with the tip of the microcatheter was stabilized in the aneurismal sac, those aneurysms were partially coiling by using the proper size and length of detachable coils.

Postembolization DSA, Dyna-computed tomography (CT) of brain were routinely used to assess hemodynamic alteration of aneurysm sac, patency of the parent artery, and its intracranial branches. CT vessel-wall images were obtained in most patients (n = 56) to evaluate the apposition of FD. We gave clopidogrel 75 mg and 200 mg aspirin daily for 6 months, followed by clopidogrel 75 mg and aspirin 100 mg daily for next 6 months.

Table 1

Demography and characteristics of 63 patients with 126 MIAs managed by single FD

	Value (%)
No of patients with MIAs treated by FD	63
No. of aneurysms	126
Mean age (y)	59 (range 42-77)
Gender	
Female	49 (78%)
Male	14 (22%)
Number of symptomatic patients	7 (11%)
Location and number of aneurysms	
ICA	118 (94%)
MCA	4 (3%)
BA	4 (3%)
Size and number of aneurysms	
>25 mm	6 (5%)
13-24 mm	9 (7%)
7-12 mm	19 (15%)
<7 mm	92 (73%)
Mean size of aneurysms (mm)	5.6 (range 1.8-38)
Adjunctive aneurysm coiling	15 (12%)

BA = basilar artery; FD = flow diverter; ICA = internal carotid artery; MIA = multiple intracranial aneurysms; VA = vertebral artery.

2.3. Angiographic analyses

These DSA findings and treatment outcomes of 63 patients of MIAs and 171 patients with single aneurysm were evaluated by two experienced interventional neuroradiologists with 29 and 24 years independently using the same workstation to evaluate the angioarchitectures and treatment outcomes with emphasizing location, number of aneurysms, periprocedural complication, and CO of aneurysm sac. Any discrepancy in the DSA findings of these two interventional neuroradiologists was resolved through reassessment and discussion to make the agreement.

2.4. Statistical analysis

The SPSS statistical software package (version 20) was used for all statistical analysis. Correlations of groups of MIAs and single aneurysm between the age, gender, aneurysm size, working length of FD, CO of aneurysm, adjunctive aneurysm coiling and alteration of periprocedural aneurysm hemodynamic were analyzed using Chi-square test for categorical variables. A two-sided p value <0.05 was considered to be statistically significant. No adjustment of multiple testing (multiplicity) was made in this study.

3. RESULTS

A summary of the data on immediate, follow-up DSA and procedure-related complications, as well as neurologic outcomes are presented in Table 2. Regarding to postembolization hemodynamic alteration of aneurysm sac, immediate CO of aneurysm sac was observed in two (2%), delayed washout of contrast material in the aneurysm sac were found in 90 (71%), unchanged aneurysm hemodynamic in 34 (27%). Four patients (6.3%) had thromboembolic complication because of in-stent thrombosis (n = 3, 4.7%) or distal embolic (n = 1, 1.6%). Patients underwent microcatheter/microguide wire message FD (n = 2) to improve FD apposition and managed by intra-arterial administration of glycoprotein (GP) IIb/III inhibitor to lysis the blood clots (n = 4); the dose of GP was depended on patient's body weight. The final DSA demonstrated almost total revascularization of partially occlusive parent artery or branches. Clinical follow-up extending longer than 3 months was available in all 63 patients, ranging from 6 to 23 months (mean: 14 months), two patients (3.2%) associated with mild permanent neurologic deficit (mRS = 1). During the follow-up period, no event of late hemorrhage was observed. Follow-up DSA in 63 patients are listed on Table 2, CO

Table 2

Angiographic and clinical outcomes of 63 patients of 126 aneurysms successfully managed by single FD

	Number (%)
Immediately DSA outcomes	
CO of aneurysm	2 (2%)
Delayed washout of contrast in the aneurysm	90 (71%)
Unchanged of hemodynamic of aneurysm	34 (27%)
Follow-up DSA (mean 14 mo)	
Obliteration of aneurysm	
Raymond class I	104 (83%)
Raymond class II	8 (6%)
Raymond class III	10 (8%)
Unchanged	4 (3%)
Patients with synchronize morphology change of aneurysms	53/63(84%)
Procedural-related complication (n = 4, 6.3%)	
In-stent thrombosis	3 (4.7%)
Distal thrombosis	1 (1.6%)
Neurologic outcomes of 63 patients (mean follow-up time)	14 mo
mRS 0	61 (97%)
mRS 1	2 (3%)

CO = complete obliteration; DSA = digital subtraction angiography; FD = flow diverter; mRS = modified Rankin scale (>3 mo after discharge).

of aneurysm (Raymond class I) was observed in 104 aneurysms (83%, Figs. 1–3), subtotal or partial obliteration of aneurysms (class II-III) with residual sac in 18 (14%, Fig. 4), unchanged aneurysm morphology occurred in 4 (3%). In 10 patients with 20 aneurysms, the aneurysms did not synchronize showing morphologic alteration with CO in one, the other one was partial obliteration (Fig. 4). Neurologic outcomes more than 3 months after discharge showed stable in 61 patients; two patients had mRS1 because of sequela of in-stent thrombosis. In comparison with those 171 patients with single aneurysm (Table 3), there is no statistical significance in terms of mid-term of CO of aneurysm, adjunctive aneurysm coiling and immediate alter aneurysm hemodynamic after FD. Longer FD in managing MIAs was found with statistical significance (p = 0.041). The complication and permanent neurologic deficit or death for single FD managed MIAs in our series were 6.3% with 3.2%, these are comparable, but slightly higher than those of single aneurysm of 4% and 2.4% in our series, but no statistical significance.

4. DISCUSSION

The reported incidence of MIAs was found in 15% to 35% of patients who presented with SAH.[11] The prognosis of patients with MIAs is less favorable outcome than single aneurysm cases after SAH.[12] Most series of MIAs have reported a women preponderance (51.5%) than men (31.7%) and higher in patient older than 40 years of age.[13] The ruptured risk of MIAs is usually higher than single aneurysm, therefore it is reasonable to treat MIAs in the same session, particularly in those patients with aneurysmal subarachnoid hemorrhage and uncertain of which one is rupture.[14]

Aneurysm coiling is currently accepted as a standard treatment for ruptured or unruptured intracranial aneurysms and has been increasingly used, regardless of the morphology, location of the intracranial aneurysm. One-stage coiling MIAs distributed in different arterial territories or bilaterally had been reported with promising results.[15–17] Coiling each aneurysm in MIAs was considered as combination of single aneurysm embolization. The principle of aneurysm embolization is coiling high-risk aneurysm first or start coiling from distal to proximal aneurysm. These procedures can be performed in a single session using same guiding catheter, microcatheter, and guidewire. The advantages of coiling MIAs in different territories as compare with surgical clipping were well document and included less invasive, cost effective, to avoid repeated general anesthesia and craniotomy. However, if MIAs were in vicinity or located in unilateral parent artery, the treatment strategy may become diverse. The advantage of aneurysm coiling was less and may be ignored because one-stage surgical clipping of these MIAs is feasible.[18] On the contrary, coiling MIAs may become more complex and difficult, particularly in those wide-neck MIAs needed stent-assisted technique. To achieve coiling MIAs in this setting by stent-jail technique, the larger-bore guiding catheter is necessary to allow two more microcatheters for coiling and one for stent. Interfering of these microcatheters are common during stent deployment and may lead to dislodge of microcatheter from aneurysm sac into parent artery. The alternative is selection of trans-stent mesh aneurysm catheterization and coiling. Another option is simple coiling or balloon-assisted coiling aneurysms, followed by deployment of stent to eliminate the interfering multiple microcatheter in guiding catheter and parent artery.

FD was first approved for the large or giant wide-neck aneurysms in the ICA to provide the durable angiographic outcomes or for those geographic difficult aneurysms with not amenable to catheterization and aneurysm coiling. The major advantage of FD to aneurysm treatment is not necessary to do aneurysm catheterization and coiling. therefore, the application of single FD to manage MIAs in one segmental parent artery has two major advantages. The first is FD has the potential to save procedure time by abbreviating the time frame of aneurysm catheterization and coiling, also to avoid intraprocedure aneurysm rupture or coil migration/protruding into parent artery causing by these devices.[19] The second benefit is that the FD can simultaneously treat two or more aneurysms in one segmental parent artery by deployment single FD, the procedure was almost the same with management of single aneurysm; as in our series, we had treated 29% patients with MIAs in one segmental unilateral parent artery. However, there are some limitations of using single FD to manage MIAs in a parent artery. (1) The maximal working length of current commercially available FD is less than 5 cm, and the working length of FDs were usually less than 4 cm, therefore the distributions of MIAs in the parent artery should within this length. Furthermore, the longer FD with longer foreign body in the parent artery, hence increased the risk or aggravation of thromboembolic complication; also, successful deployment of longer FD may become challenge and difficult due to several curvature has to be overcome such in carotid siphon; (2) the selection of proper diameter and length FD is depended on the diameter of proximal parent artery and aneurysm neck. To minimal the risk of stent migration, the FD should equal or a litter larger diameter than corresponding parent artery to achieve better stent apposition, and to avoid endoleak as well as risk of in-stent thrombosis. However, single FD to manage MIAs is not feasible if the diameter of distal to proximal landing zone of parent artery is larger than 2 mm.[20] To achieve better angiographic outcomes, it is better to select two or more proper FDs using telescoped technique to manage MIAs. The landing zone of working length of FD is better greater than 4 mm to ensure the full coverage of aneurysm neck during FD deployment. The other limitation of single FD to manage MIAs is all these aneurysms is nonruptured one, this is because thromboembolic complication may occur in patients lacking of pretherapeutic dual antiplatelet treatment due to aneurysm subarachnoid hemorrhage.

In our series, three patients with three aneurysms failed to coverage by single FD, these led to successful stent deployment to idea position in 96% aneurysm treatment. The success rate of FD deployment in our series was comparable with previously

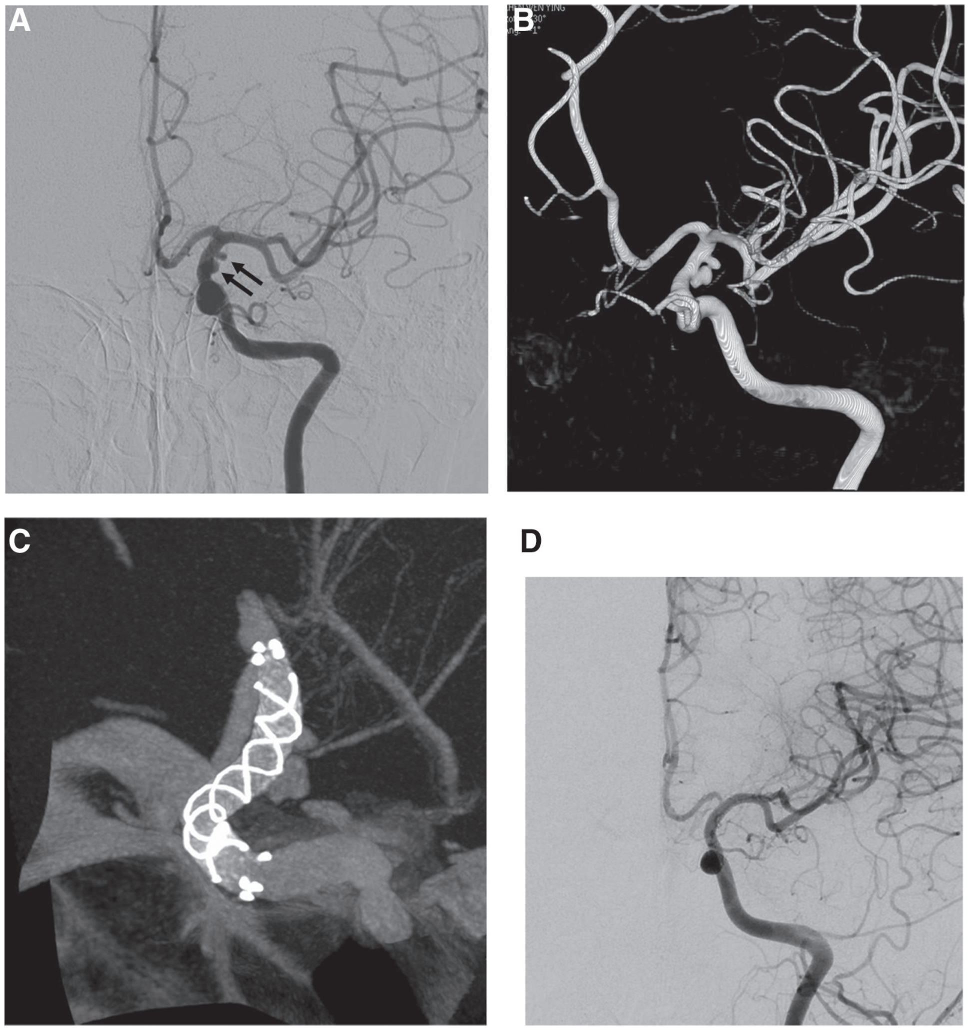

Fig. 1 Patient was a 56-y-old woman, she suffered from headache. A and B, Left internal carotid artery (ICA) conventional and reconstruction digital subtraction angiography (DSA) demonstrated two small aneurysm saccular aneurysms at the left supra-clinoid ICA (arrows). C, Patient underwent flow diverter (FD) to manage these aneurysms. D, Complete obliteration (CO) of aneurysms were demonstrated on 12-mo DSA.

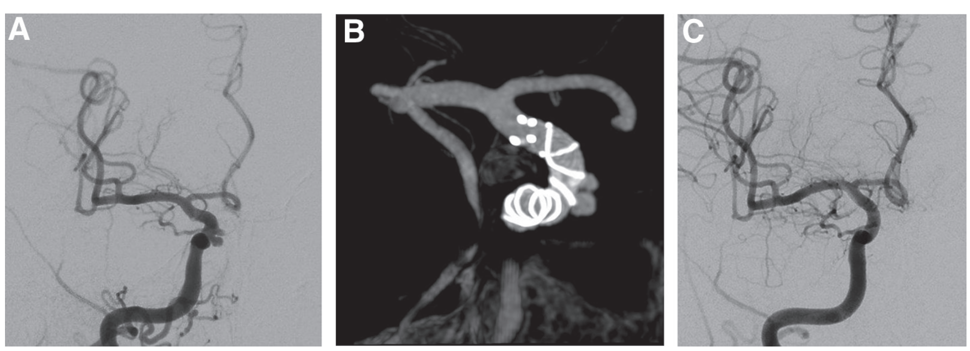

Fig. 2 Patient was a 61-y-old woman, she had two small asymptomatic aneurysms at the right medial para-clinoid internal carotid artery (ICA). A, Right carotid angiogram confirmed two small wide-neck aneurysms at the right ICA. B and C, Patient underwent flow diverter (FD) to treat these aneurysms and demonstrated complete obliteration of aneurysms on 12-mo postembolization follow-up.

published series, which ranged from 95% to 99%.[9] The rate of CO of aneurysm varied from 76% to 81.5% depended on the aneurysm size, location, aneurysm incorporating branch, and follow-up time frame.[21–23] One report demonstrated 95% of CO in 5-year follow-up.[22] In our series, CO of aneurysms were achieved in 83% of aneurysms in 14-month DSA, this midterm morphologic outcome was comparable with previous published data of FD.[14] In this series, simultaneous morphologic change of aneurysm in midterm follow-up DSA in 53 patients and included CO of MIAs of 47 patients with 94 aneurysms (82%), partial obliteration aneurysm in five patients of 10 aneurysms, and unchanged aneurysm morphology in one patient with two

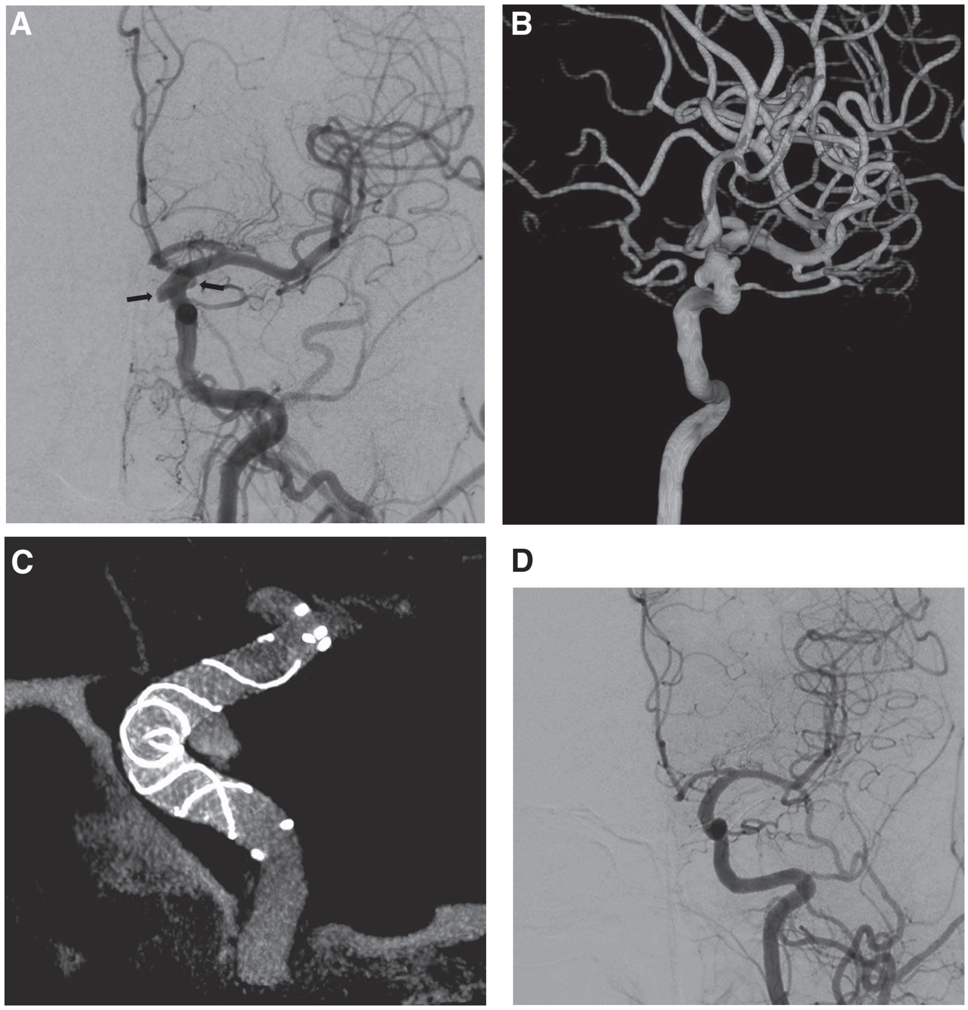

Fig. 3 Patient was a 50-y-old woman, she had two small asymptomatic aneurysms at the left supra-clinoid internal carotid artery (ICA). A and B, left ICA frontal and reconstruction digital subtraction angiography (DSA) demonstrated two small saccular aneurysms. C, Patient underwent single flow diverter (FD) to treat these two small aneurysms. D, 12-mo post-FD DSA depicted complete obliteration (CO) of aneurysms.

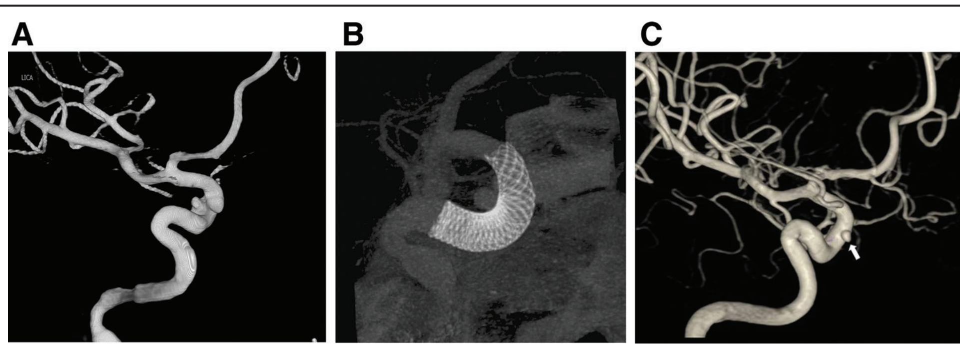

Fig. 4 Patient was a 53-y-old woman, she had two small asymptomatic aneurysms at the right posterior and medial para-clinoid internal carotid artery (ICA). A, Reconstruction digital subtraction angiography (DSA) demonstrated two small aneurysms at the posterior and medial para-clinoid ICA. B, Patient underwent single flow diverter (FD) to manage aneurysms. C, Reconstruction DSA of 12-mo post-FD demonstrated complete obliteration (CO) of aneurysms of medial para-clinoid ICA, partial obliteration of aneurysm posterior para-clinoid ICA (arrow).

aneurysms. In 10 patients (16%) with 20 aneurysms, the aneurysms did not synchronize showing morphologic alteration of aneurysm with one CO, the other one was partial obliteration. All these 20 aneurysms were smaller one with size less than 7 mm and no aneurysm incorporating arterial branch. Therefore, the only possible factor of affecting morphologic change of aneurysm was presumed as different porosity of FD in larger/smaller curvature of different side/location of parent artery. We believe CO may be achieved in longer time frame followed-up in these partial obliteration of aneurysm sacs. The complication and permanent neurologic deficit or death for single FD managed MIAs in our series were 6.3% with 3.2%, these are comparable, but

Table 3

Comparison of demography and outcomes of FD managing 63 patients with MIAs and 171 patients with single aneurysm

	MIA	Single aneurysm	Total	*p* of MIAs and single aneurysm
No. of patients	63	171	234	
Age (y) (mean)	59	55	54	0.778
No of aneurysms	126	171	297	
Gender				
Men	14 (22%)	46 (27%)	60 (26%)	0.580
Women	49 (78%)	125 (73%)	174 (74%)	0.580
Mean size of aneurysm (mm)	5.6	6.4	5.8	0.308
Mean working length of FD (mm)	25	17	21	0.041[a]
CO of aneurysm	104/126 (83%)	131/171 (77%)	235/297 (79%)	0.125
Periprocedural complications	4 (6.3%)	7 (4%)	11 (4.7%)	0.428
Mean DSA follow-up time (mo)	14	13	13	0.928
Adjunctive aneurysm coiling	15/126 (12%)	35/171 (20%)	50/297 (17%)	0.182
Alter aneurysm hemodynamic after FD	90/126 (71%)	131/171 (77%)	221/297 (75%)	0.504

CO = complete obliteration; DSA = digital subtraction angiography; FD = flow diverter; FU = follow-up; MIA = multiple intracranial aneurysm.

slightly higher than those of single aneurysm of 4% and 2.4% in our series, but no statistical significance. It was presumed as longer FD was selected in the groups of MIAs (25 vs 17mm), which may associate with higher risk of in-stent thrombosis and difficult to achieve better apposition of stent to arterial wall.

There had two limitations of our study: first, this is a retrospective study done by three institutes. A prospective study is warranted to confirm our observation; the second is the mean angiographic follow-up time is not long enough to justify the real morphologic change of aneurysm after FD.

In conclusion, single FD, one-stage treatment of MIAs in a parent artery was feasible and was proven to be both effective and safe. It can be selected in MIAs with difficult in one-stage coiling or clipping. Morphologic alteration of aneurysm sacs synchronized occurred in most MIAs in a midterm angiographic follow-up. Our results also demonstrated similar endovascular procedure, clinical angiographic and clinical outcomes as compare with those patients with single aneurysm managed by one FD, but longer FD is necessary to manage MIAs.

ACKNOWLEDGMENTS

This study was supported in part by NSC-108-2314-B-075-004-MY2, NSC-111-2314-B-075-023, TVGH-110C-066, and TVGH-108C-033.

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