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Original Article

A coil placement technique to treat intracranial aneurysm with incorporated artery

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Abstract

Background: Endovascular coil embolization is an accepted treatment option for intracranial aneurysms. However, the coiling of aneurysms with an incorporated artery (IA) poses a high risk of IA occlusion. Here we report our experience of endovascular coil placement using a technique that avoids IA occlusion in aneurysms with IAs.
Methods: Over a 6-year period, 185 patients harboring 206 intracranial aneurysms underwent endosaccular coiling. Forty-two of these patients with 45 aneurysms were treated by coil placement to avoid IAs occlusion. We assessed the anatomy of the aneurysms and IAs, technical feasibility of the procedure, and degree of aneurysm occlusion. Clinical and angiographic outcomes were assessed as well.
Results: Aneurysms were located in the supra-clinoid intracranial internal carotid artery (n = 24), anterior cerebral artery (n = 6), middle cerebral artery (n = 7), and vertebrobasilar artery (n = 8). The IA was at the aneurysm neck in 34 patients, body in 10, and dome in 1. Immediate post-coiling angiogram showed preservation of blood flow through the IA in all aneurysms. Coil compaction with aneurysmal regrowth was found in 7 of 36 patients having follow-up conventional angiography. One patient had an IA territory infarction after embolization. All 42 patients were followed up (mean: 21 months) and showed no re-bleeding.
Conclusion: This technique is effective and safe in managing intracranial aneurysms with IAs. Although aneurysmal recurrence may occur in some aneurysms because of insufficient coiling, this technique is simpler to perform and requires less skill than other techniques. It can be an alternative option for treating some selected intracranial aneurysms with IAs.

Keywords: Aneurysm; Coil; Embolization; Incorporated artery

1. Introduction

Endovascular detachable coil embolization of intracranial aneurysms has increasingly become a selective treatment modality to manage intracranial aneurysm with promising results.[11−13] Despite increased clinical experience with this technique, and improvements in endovascular skills, access devices, and embolic materials, endovascular coiling of aneurysms still has inherent limitations when applied to some geographically difficult intracranial aneurysms such as those with an incorporated artery (IA). The most common complication of the endovascular coiling of aneurysms with an IA is ischemic stroke due to inadvertent occlusion of the vital IA. Because of this concern, aneurysms with IAs have been regarded as a major contraindication to endovascular coiling. To preserve the patency of IA and to minimize the risk of vascular occlusion, some device-assisted techniques have been

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sporadically described,[1−5,10] however, these techniques may fail because anatomical sites of the parent artery, aneurysm, and IA are too difficult to access.

The purpose of this study was to report our experience by using a technique of coil compartmentalization to manage complex intracranial aneurysms with preservation of IA blood flow.

2. Methods

2.1. Patients and clinical presentations

From January 2010 to December 2015, a series of 185 consecutive patients harboring 206 intracranial aneurysms underwent endovascular coil embolization in our institute. Forty-two of these patients (18 men and 24 women; aged 42−86 years [mean, 67 years]) had 45 aneurysms with IAs and received coil placement to preserve blood flow through the IAs. Twenty-six patients had asymptomatic aneurysms, seven presented with acute ischemic strokes, five had aneurysmal subarachnoid hemorrhages, and four presented with third cranial nerve palsy. The aneurysms were located in the supraclinoid intracranial internal carotid artery (n = 24), anterior cerebral artery (n = 6), middle cerebral artery (n = 7), vertebral artery (n = 6), and basilar artery (n = 2). The IA was located at the aneurysm neck in 34 patients (76%, Fig. 1), body in 10 (22%, Fig. 2) and dome in 1 (2%). The aneurysm size varied from 3.5 to 18 mm at their maximal dimension (mean: 7.6 mm); aneurysms were wide-necked in 36 patients (neck-to-dome ratio greater than 0.5 and/or aneurysm neck diameter greater than 4 mm). Information including patient's age and sex, clinical manifestations, anatomy of the aneurysm and IA, and aneurysm size is summarized in Table 1.

2.2. Techniques of aneurysm coiling

All embolizations were performed under general anesthesia using a femoral approach. A 6- or 7-F guiding catheter was placed into the parent artery via a 6- or 7-F femoral sheath. Digital subtraction angiography (DSA) and rotational angiography were performed, with reconstruction of their images to evaluate the angioarchitecture of the parent artery, aneurysm, and IA. A microcatheter was advanced into the aneurysm using roadmap guidance: a 2-tip 0.017-inch microcatheter (Headway, MicroVention, Inc. CA, USA or Echelon, Ev3, Inc, Irvine, CA, USA) and a 0.014-inch microguidewire (Traxcess, MicroVention, Inc. CA, USA) were used to access the aneurysm sac. One (n = 29) or two (n = 16) microcatheters were navigated into the aneurysm sacs depending on the size of the aneurysm (e.g., larger than 7 mm) to enhance the effect of aneurysm packing density. When feasible, the tip of the microcatheter(s) was placed into the distal part of aneurysm sac and/or away from the opening of the IA to avoid IA occlusion during coiling. Aneurysm coiling was commenced by selecting the proper detachable coils (Microplex, MicroVention, Inc. CA, USA). Typically, the first coil was selected to create a basket to support the aneurysm sac and bridge the aneurysm neck. A bolus of intravenous heparin was routinely administered after the first coil was detached into the aneurysm sac, and an activated clotting time of 1.5-times that of the baseline was maintained throughout the procedure. Smaller sized coils (two-thirds to three-fourths the maximal dimension of the aneurysm body) were selected to fill the aneurysm sac; if the coil loop extended into the aneurysm sac near the opening of the IA, the coil was repositioned or its shape and/or size was adjusted to avoid blockage of IA flow. The main principles of aneurysm coiling are loose packing of coils in the aneurysm sac near the opening of the IA and dense packing in other portions and/or the inflow zone of the aneurysm sac; in addition, any weakness of the aneurysm sac (e.g., pseudoaneurysms) should be totally obliterated by coiling and blood flow through the aneurysm should be totally blocked at the end of procedure. The endpoint of the endovascular procedure is re-insertion of microcatheter(s) back into the parent artery. The patency and hemodynamic blood flow of the IA and the effect of aneurysm coiling were checked intermittently by DSAs. In 5 patients with IA originating from a dome (n = 1), body (n = 5), or neck (n = 2), IA protection was improved by adjuvant use of stent-assisted (n = 4) and/or microcatheter-assisted techniques (n = 4). Immediate post-embolization DSA was routinely obtained to assess the aneurysm occlusion and patency of the IA. The angiographic outcomes were assessed as: total obliteration, neck remnant, or partial occlusion with contrast media flow into the aneurysm body/dome. The post-treatment antiplatelet therapy with lifelong aspirin 100 mg daily was given to prevent or delay IA occlusive events.

3. Results

A summary of the data on angiographic and clinical outcomes is presented in Table 2. Immediate post-embolization DSA demonstrated no instance of total aneurysm occlusion, residual neck remnant in 35 (78%, Fig. 1), and partial aneurysm occlusion with aneurysm body/dome opacification in 10 (22%, Fig. 2); the blood flow through all IAs was preserved without significant flow compromise. Two patients suffered from immediate thromboembolic complications in the M3 branch of the MCA after aneurysm coiling; affected arteries were recanalized by intra-arterial infusion of IIb/IIIa platelet inhibitor. No peri-procedural aneurysm rupture occurred. Follow-up DSA was available in 36 patients (mean: 15 months) and revealed free flow through the IA without occlusion. The morphology of the coiling aneurysm was stable in 29 patients (81%); coil compaction with aneurysm recurrence was observed in 7 (19%) of 36 patients; retreatment was not initiated owing to the small size of the recurrent aneurysm sac. No aneurysm bled or rebled in the clinical follow-up period (mean: 21 months). One IA arising from the dome of a posterior communicating artery aneurysm had a delayed territorial infarction, although a magnetic resonance angiogram showed the patency of the IA. The total clinical follow-up time ranged from 6 to 36 months (mean: 21 months) and exceeded 1 year post-treatment in 36 patients (86%).

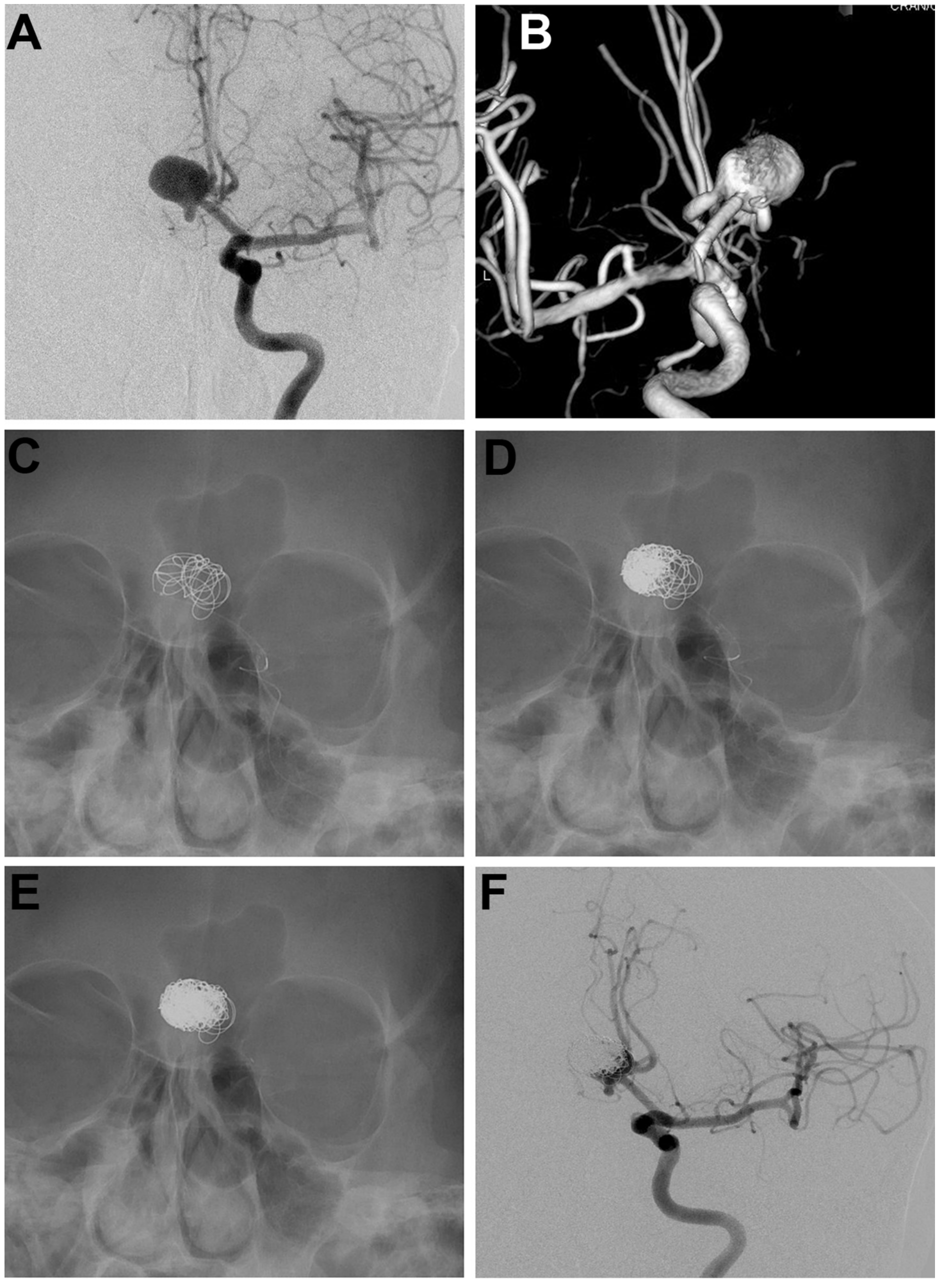

Fig. 1. A 78-year-old man presented with a large unruptured aneurysm of the anterior communicating artery. **A**, **B)** Conventional and reconstruction carotid angiograms demonstrated bilateral A2 anterior cerebral arteries (ACAs) incorporated into the neck of the aneurysm sac. **C−E)** The patient underwent aneurysm coiling. A large, long first coil was selected to frame the aneurysm sac, then the sac was packed with coils from dome to body and neck. **F)** Post-embolization angiograms revealed subtotal occlusion of the aneurysm sac with dense packing of the aneurysm dome and body and loose packing of aneurysm neck to keep the patency of the A2 bilateral ACAs.

4. Discussion

A common cause of intracranial aneurysms is vessel degeneration at the bifurcation where there is turbulent flow and change in hemodynamic forces. All intracranial aneurysms can expand and grow over time. With aneurysm growth, the arterial branch may be incorporated into the aneurysm neck, body, or dome. Aneurysms with IAs are not uncommon. Kim et al. reported 79 of 350 (23%) intracranial aneurysms had IAs.[4] Based on their location in the aneurysm sac, IAs may arise from aneurysm neck, body, or dome. Most IAs arise from the aneurysm neck, followed by the aneurysm body; few arise from the aneurysm dome. The greatest challenge to endovascular restoration of IA flow is coiling of the aneurysmal sac when the IA arises from the aneurysm dome. This procedure without device assistance has a high risk of coil compaction or protrusion into the vital IA leading to brain ischemia.

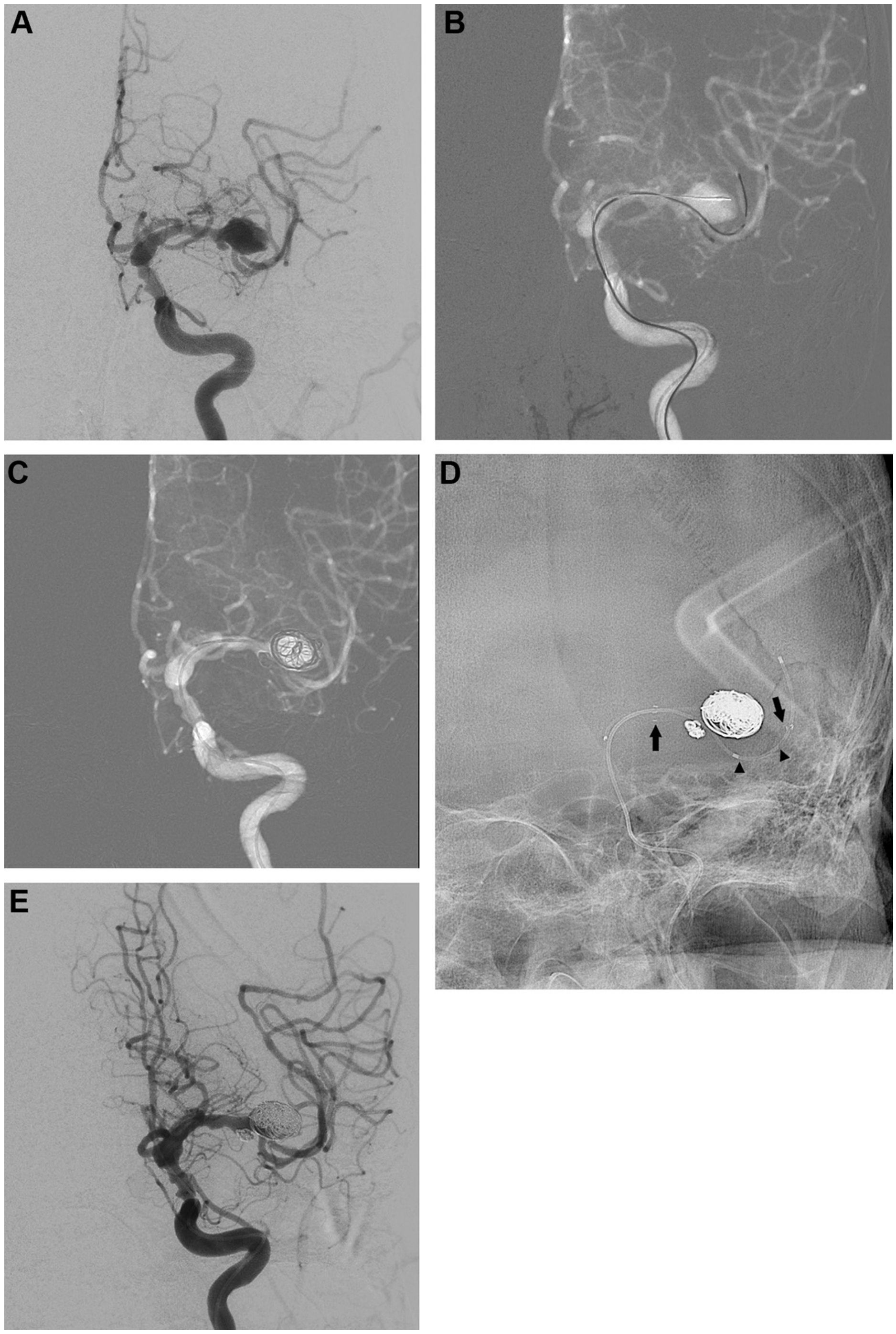

Fig. 2. A 63-year-old man suffered from right limb weakness because of acute infarction of the left lentiform nucleus. **A)** A left carotid angiogram revealed a big saccular aneurysm at the distal M1 segment of the left middle cerebral artery (MCA), incorporation of two major branches of the M1 into the inferior body of the aneurysm sac; and a small saccular aneurysm at the distal M1 segment of the left MCA located proximal to the bigger one. **B–D**). The patient underwent coil placement to avoid occlusion of the M2 branches. To preserve blood flow of the incorporated branches, a stent was deployed into the superior branch of M2 (arrows), and a catheter was used to protect the inferior branch (arrowheads). A longer first coil was selected to frame the aneurysm sac, followed by aneurysm sac coiling using a coil placement technique. Note the loose packing at the ostia of the incorporated branches and the dense packing in other parts of the aneurysm sac. The smaller aneurysm was coiled during the same embolization session. **E)** Post-embolization angiography demonstrated partial endosaccular coiling with preservation of blood flow through the incorporated branches.

It is considered technically challenging to protect an IA arising from the aneurysm sac via the endovascular route. Most intracranial aneurysms are regarded as candidates for open surgery[6] or management by a combination of endovascular and open surgery.[16] Endovascular management of aneurysms with IAs includes intentional occlusion of the arterial branch in patients without or with adequate collateral blood flow after bypass surgery. In a 2006 study by Lubicz

Table 1
Demographic and aneurysm anatomy of 42 patients with 45 aneurysms with IA managed by the technique of coil compartment.

Demographic and aneurysm anatomy	No (percentage)
Gender (n = 42)	
Male	18 (43%)
Female	24 (57%)
Mean age (age range, years)	67 (42−86)
Clinical presentation (n = 42)	
Aneurysm rupture	5 (12%)
Acute ischemic stroke	7 (17%)
CN palsy	4 (9%)
Asymptomatic	26 (62%)
Mean of maximal aneurysm dimension (mm)	7.6
Range of maximal aneurysm dimension (mm)	3.5−18
Aneurysm location (n = 45)	
ICA	24 (53%)
MCA	7 (16%)
ACA	6 (13%)
VA	6 (13%)
BA	2 (5%)
IA location in aneurysm sac (n = 45)	
Neck	34 (76%)
Body	10 (22%)
Dome	1 (2%)
Microcatheter (s) for aneurysm coiling (n = 45)	
Single catheter	29 (64%)
Two catheters	16 (36%)
Adjuvant device	8 (18%)
Stent	4 (9%)
Balloon	0 (0%)
Microcatheter	4 (9%)

IA = incorporated artery; CN = cranial nerve palsy; ICA = internal carotid artery; MCA = middle cerebral artery; ACA = anterior cerebral artery; VA = vertebral artery.

Table 2
Angiographic and clinical outcomes of 42 patients with 45 aneurysms with IA managed by the technique of coil compartment.

Post-treatment outcomes	No (percentage)
Immediate angiographic outcome (n = 45)	
Total occlusion (RROC I)	0 (0%)
Neck remnant (RROC II)	35 (78%)
Residual aneurysm (RROC III b)	10 (22%)
Procedural-related complication	
Aneurysm rupture	0 (0%)
Thromboembolic complication	2 (4%)
IA occlusion	0 (0%)
Angiographic follow-up (n = 36, mean: 15 months)	
Stable	30 (83%)
Coil compaction with aneurysm recurrence	6 (17%)
Re-treatment	0 (0%)
Delayed IA occlusion	0 (0%)
Clinical follow-up (n = 42, mean: 21 months)	
Aneurysm rupture	0 (0%)
Delayed thromboembolic event	1 (2%)

IA = incorporated artery; RROC = Raymond−Roy occlusion classification.

et al.[10] about the endovascular management of complex aneurysms with IAs, six IAs were successfully managed by balloon-assisted techniques with preservation of IA flow, two IAs were intentionally sacrificed, and one aneurysm was treated with partial coiling to avoid IA occlusion. In 2010, Kim et al.[4] reported using various device-assisted techniques to successfully coil 77 of 78 aneurysms with IAs and preserve their blood flow.

The most common device-assisted techniques used to preserve IAs include catheter-, balloon-, or stent-assisted techniques. In the catheter-assisted technique, a microcatheter and/or coil is navigated into the IA to protect blood flow and then another microcatheter is advanced into the aneurysm sac for subsequent aneurysm coiling. The protective microcatheter and/or coils in the IA are removed at the end of coiling.[1−3,5] This technique is selected when the IA is too small for the balloon- or stent-assisted technique. If the aneurysm is larger, multiple microcatheters can be placed into aneurysm sac to enhance the protective effect and the coil packing density in the aneurysm sac can be increased.[7] This technique can be applied to IAs that arise from the neck, body, or dome but not when the unfavorable angle of the parent artery/aneurysm/IA limits the surgeon's ability to navigate the microcatheter into the IA. Another concern is ischemic stroke due to the delayed occlusion of the IA after the microcatheter is removed and the coil mass migrates into the IA opening, particularly IAs that arise from the body and dome of the aneurysm sac.

Balloon-assisted coil embolization has been utilized to treat wide-neck and complex aneurysms with acceptable angiographic and clinical outcomes.[9,14] One such technique for coiling aneurysms with IAs uses a compliant non-detachable balloon (HyperForm balloon, ev3, Irvine, California[2]). The balloon should be positioned at the mouth of the IA and overinflated to create a bulge within the aneurysm that can protect the IA. Balloon-assisted techniques usually require repeated balloon-inflation and deflation, which may carry risks of thromboembolic complications, aneurysm rupture, or IA dissection and/or occlusion. This technique is only useful in IAs arising from the aneurysm neck or proximal aneurysm body. However, the balloon's position during inflation and deflation may be unstable. Also, IA preservation is not guaranteed because of possible coil instability caused by balloon removal.

The development of a self-expandable stent is another promising aneurysm neck reconstruction device that can be used to protect the parent artery during endosaccular coiling[17] and protect the IA if the IA diameter is larger than 2 mm and can be accessed by microcatheter and stent placement. Stent-assisted coiling is the most useful and effective technique available to protect the IAs,[15] particularly IAs that arise from the aneurysm dome. Following dense packing of the aneurysm sac with multiple coils, a stent is deployed in the IA to reconstruct its lumen and restore its flow. The keys to the success of this technique are that the angle of the aneurysm neck must allow catheterization of the IA and the IA diameter must be large enough to accomodate the deployed stent for prevention of IA occlusion. Deployment of the stent into the aneurysm using the waffle-cone technique also has been utilized to preserve the IAs.[8] The stent has to be precisely maneuvered into the aneurysm sac beyond the ostium of the IA. The major drawback of this technique is partial re-direction of blood flow from the parent artery into aneurysm sac leading to coil compaction with aneurysm recurrence.

The usefulness of device-assisted techniques with a trans-aneurysmal approach to IA catheterization usually depends on the anatomy of the parent artery, aneurysm, and IA. If the angle between the aneurysm and IA is less than 90°, successful navigation of the catheter into the IA may be difficult, risky, or impossible. Over-manipulation of the microcatheter and guidewire in the aneurysm sac and IA may pose risks of aneurysm rupture, occlusion, or dissection of the IA.

The goal of endovascular coiling is to achieve angiographic total obliteration of the aneurysm by packing the coil mass densely and evenly into the aneurysm sac. Good packing density usually results in longer lasting aneurysm occlusion and fewer aneurysm recurrences. To achieve this angiographic goal, larger coils are usually selected to frame the aneurysm sac, and then large to small-sized coils are used for packing. However, occlusion may not be achieved because of difficult surgical access or inappropriate coil selection. One of disadvantages of coil embolization is the possibility of uneven distribution of the coil mass leading to partial aneurysm occlusion. This usually is the result of under-sized coils with dense packing of the aneurysm sac near the tip of microcatheter and loose packing elsewhere. In this study, we selected coils appropriate to the aneurysm sac anatomy and to ensure protection of blood flow through the IA. The guiding principle of aneurysm coiling is loose packing of aneurysm sac near the opening of the IA, to let blood flow to the IA, and dense packing in other parts of the aneurysm, particularly the inflow zone. In addition, angiographic obliteration of vascular complications such as pseudoaneurysms should be achieved, either by endosaccular coiling or blockage of the flow into the pseudoaneurysm at the end of the procedure to enhance the coil embolization effect, even in aneurysm sacs with insufficient coiling. To achieve this angiographic goal, attempts should be made to navigate the microcatheter into the aneurysm sac with catheter tip away from the opening of the IA and/or close to the pseudoaneurysm of the aneurysm sac. Then the aneurysm sac should be framed using coils to form a basket and packed with coils of the proper size/length (diameters, less than the average width of the aneurysm dome/ body) to reduce the risk of coil loops protruding from the aneurysm sac into the opening of the IA. Intermittent DSA check-ups to assess the effect of aneurysm coiling on patency and hemodynamics in the IA are mandatory, particularly before each coil is deployed by the delivery system into the aneurysm sac. In this study, a single conventional microcatheter was sufficient to treat 29 aneurysms (64%); in another 16 aneurysms with size larger than 7 mm, two microcatheters were placed into the aneurysm sac to increase packing density. Catheter- ($n = 4$) and/or stent-assisted ($n = 4$) coiling techniques were adjunctively used in 8 aneurysms with IAs arising in the aneurysm neck ($n = 3$), body ($n = 4$), and dome (1) to ensure durable patency of the IAs. Clinical outcomes were excellent in almost all cases and no immediate procedural complication related to IA occlusion was observed. One IA arising from the aneurysm dome had a territorial infarction at the 3-month magnetic resonance angiography follow-up, though the IA was patent. The delay in the thromboembolic event was attributed to clot formation in the aneurysm sac with migration into the branches of the IA. The major advantage of this technique is its greater simplicity and lesser skill requirement as compared with device-assisted techniques, which are more risky than simple coiling. Furthermore, there is no need for trans-catheter treatment of the IA, and hence less risk of intra-procedural rupture of the aneurysm, IA, or dissection/occlusion of the IA. The major disadvantage of this technique is the possibility of insufficient aneurysm coiling concomitant with lack of long-term aneurysm occlusion durability in some cases. Another potential risk is coil compaction by blood flow with coil mass migration into the opening of IAs resulting in delayed occlusion, particularly IAs originating from the body and dome of aneurysm sac. However, delayed IA occlusion was not observed in our series.

In conclusion, this technique is simple and requires less endovascular skill that other techniques for managing aneurysms with IAs. It is particularly useful for the management of aneurysms with IAs arising from the aneurysm neck and those that require trans-catheter treatment of the IAs. Our results also demonstrated the safety and effectiveness of this technique in managing some complex intracranial aneurysms with IAs. Despite coil compaction, insufficient coiling may occur and lead to aneurysmal recurrence. Nevertheless, this technique is a useful alternative in some aneurysms with IAs, when other techniques fail.

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