

Hemispheric divided coiling technique for coil embolization of middle- and large-sized intracranial aneurysms

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ABSTRACT

Despite major developments in treating intracranial aneurysms by endovascular coil embolization, complete occlusion of the entire aneurysmal neck remains a problem. We present a novel endovascular strategy for middle- and large sized aneurysms called the “hemispheric divided coiling technique” and compare the short-term follow-up results of this technique with those of conventional coil embolization. Ten patients (mean age, 69.7 ± 9.7 years) with middle- or large-sized ruptured or unruptured intracranial aneurysms (mean maximum aneurysmal diameter, 12.09 ± 3.6 mm) were treated by the hemispheric divided coiling technique, in combination with various adjunctive techniques. We compared the initial occlusion grade, volume embolization ratio, and recurrence rate in this group of patients (hemispheric group) with the results from 20 previous cases (conventional group: mean age, 62.8 ± 9.8 years; mean maximum aneurysmal diameter, 11.43 ± 3.5 mm). The mean volume embolization ratio of the hemispheric group was significantly higher than that of the conventional group (42.3% vs. 31.1%). The hemispheric divided coiling technique achieved a high volume embolization ratio for middle- and large sized intracranial aneurysms, with a low recurrence rate.

Keywords: coil embolization, endovascular treatment, intracranial aneurysms

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INTRODUCTION

A higher volume embolization ratio after coil embolization for intracranial aneurysms is a factor involved in the prevention of recanalization and re-enlargement.^{1,2)} To achieve a high embolization rate, various techniques have been developed, such as bioactive coils and stent-assist technique.^{3,4)} However, large and giant aneurysms remain difficult to treat with a single procedure. We recently developed a “hemispheric divided coiling technique” to obliterate aneurysms by achieving a high volume embolization ratio. Here, we report the technical details of this procedure and compare the clinical outcomes and recurrence rates between aneurysm cases treated by the hemispheric divided coiling technique and matched cases treated by conventional coil embolization.

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MATERIALS AND METHODS

Subjects

This study was a retrospective analysis of 30 patients with middle- or large-sized aneurysms who received endovascular treatment at our hospital between January 2015 and May 2016. Middle- or large-sized aneurysms were defined as those with a maximum diameter between 7.0 and 25.0 mm. After January 2016, 10 of these 30 patients were treated with the hemispheric divided coiling technique (the hemispheric group). Before January 2016, 20 patients were treated by the conventional method, in which coils were inserted like an onion skin, with or without adjunctive techniques (the conventional group). Nine of the 30 patients (four in the hemispheric group and five in the conventional group) had ruptured aneurysms. Clinical outcomes, including initial occlusion grade, volume embolization ratio, and recurrence rate, were compared between the hemispheric and conventional groups.

Aneurysmal evaluation

Aneurysmal size was measured in three directions (height, length, and width) by 3D rotation cerebral angiography with a biplane angiograph (GE Healthcare, CT, USA). The degree of embolism was evaluated by the Raymond scale (RS)⁵: RS1, complete occlusion; RS2, aneurysmal neck remnant; and RS3, intra-aneurysmal contrast enhancement remnant (RS2 and RS3, incomplete occlusion). Aneurysmal volume and volume embolization ratio were calculated by the following formulae:

$$\text{Aneurysmal volume (mm}^3\text{)} = 4/3\pi \times (\text{length}/2) \times (\text{width}/2) \times (\text{height}/2)$$

$$\text{Volume embolization ratio (\%)} = \frac{\sum \{ \pi \times (\text{coil diameter}/2)^2 \times \text{coil length} \}}{\text{aneurysmal volume} \times 100}$$

For posttreatment assessment, 1.5T MRI and plain X-rays of the head were performed. The former was performed immediately after treatment and after 1 and 6 months. The latter was performed immediately after treatment, 1 week after treatment, and after 1 and 6 months. In patients with incomplete embolization, MRI was also performed 3 months after treatment. Patients with an increase in high intensity in the aneurysm on MR angiogram in comparison with that immediately after treatment or deformity of the coil mass on plain X-ray of the head were regarded as having recurrent aneurysms. In patients with suspected recurrence, cerebral catheter angiography was performed, and when there was a marked increase in intra-aneurysmal blood flow in comparison with that immediately after previous treatment, additional treatment was performed.

Technical details of the hemispheric divided coiling technique

This technique uses a single microcatheter with or without a stent. After the conventional frame with the first coil is made, the second coil is selected with half the diameter of the first coil. Then, it is deployed into the part of the aneurysmal fundus (Fig. 1). Next, the distal hemisphere is embolized by the conventional procedure. When the distal hemisphere is occluded, the proximal part is embolized with the conventional technique. The hemispheric divided coiling technique is aimed preventing early kick-out of the microcatheter and leaving a substantial coil-free dead space. In particular, when the microcatheter is unstable in the aneurysm, this technique allows it to stay in position until at least the distal hemisphere is occluded. In cases of stent-assist embolization, the jailed microcatheter should be retained as long as possible. Moreover, if the framing coil is vulnerable, this technique ensures that it is not broken by the following coils. Tightening of the unstable frame at the fundus with the second and third coils makes the frame rigid. Finally, a higher volume embolization can be achieved than with the conventional onion

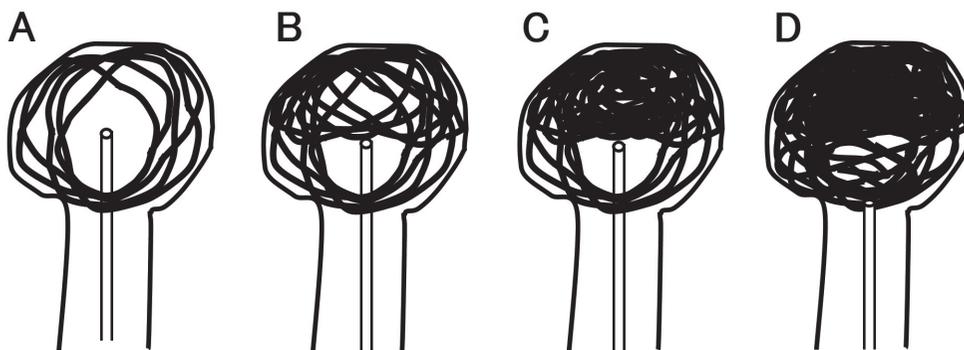


Fig. 1 Schematic drawing of the hemispheric divided coiling technique.

- (A) After a frame has been made by the usual technique, the microcatheter is set around the center of the aneurysm.
 (B) A second coil is selected with half the diameter of the first coil.
 (C) The distal hemisphere is embolized by the conventional procedure before the proximal hemisphere.
 (D) When the distal hemisphere is occluded, the proximal part is embolized by the conventional technique.

skin insertion technique.

Statistical analysis

The details of patient characteristics and clinical results are presented as means \pm standard deviation for continuous variables and numbers (percentage) for categorical variables. Bivariate comparisons between the conventional and the hemispheric group used the unpaired *t*-test for continuous data, and Fisher's exact test for categorical data. For all statistical analyses, $P < 0.05$ was considered to indicate statistical significance.

RESULTS

The mean age of the patients was 65.1 ± 9.7 years, and 67% were women. A detailed summary of patient demographic and clinical characteristics is presented in Table 1. There were no significant differences between the two groups in age ($P = 0.17$), sex ratio ($P = 0.58$), proportion of ruptured aneurysms ($P = 0.39$), dome/neck ratio ($P = 0.59$), or maximum aneurysmal diameter ($P = 0.72$). In both groups, the most common location of the aneurysm was the internal carotid artery.

The results of treatment are shown in Table 2. In all patients, the procedures were successfully performed. The mean volume embolization ratio in the conventional and hemispheric groups was $31.1\% \pm 3.6\%$ and $42.3\% \pm 7.4\%$, respectively, with a significant difference between groups ($P = 0.00013$). There was no significant difference between the groups in the proportion of patients treated with stents ($P = 0.78$). The complete occlusion rates (RS1) immediately after treatment were 20% and 60%, showing a significant difference ($P = 0.029$). There were no perioperative complications in either group. In the conventional group, there were three cases of recurrence at the 6-month follow-up.

Table 1 Baseline characteristics of aneurysms.

	Conventional group	Hemispheric group	P value
Number of aneurysm	20	10	
Age (years)	62.8 ± 9.8	69.7 ± 9.3	0.17
Female	14 (70%)	6 (60%)	0.58
Ruptured	5	4	0.39
mean dome/neck ratio	1.87 ± 0.3	1.95 ± 0.5	0.59
Mean maximum aneurysmal diameter (mm)	11.43 ± 3.5	12.09 ± 3.6	0.72
Location: number			
ACoA	3	0	0.20
ICA	9	5	0.80
PCoA	3	2	0.73
MCA	1	1	0.61
BA	2	2	0.45
Others	1	0	0.47

ACoA, anterior communicating artery; BA, basilar artery; ICA, internal carotid artery; MCA, middle cerebral artery; PCoA, posterior communicating artery.

Table 2 Comparison of relevant results between the conventional and hemispheric groups.

	Conventional group n = 20	Hemispheric group n = 10	P value
Mean packing ratio (VER) (%)	31.1 ± 3.6	42.3 ± 7.4	0.00013
Stent assist	7	3	0.78
Balloon assist	4	0	0.12
Double catheter	9	0	0.010
Initial occlusion grade			
RS 1	4 (20%)	6 (60%)	0.029
RS 2	8 (40%)	2 (20%)	0.27
RS 3	8 (40%)	2 (20%)	0.27
Perioperative complication	0	0	1.00
Number of recurrence at 6-month	3	0	0.20

RS, Raymond score (RS 1 indicates complete obliteration; RS 2 indicates neck remnant without contrast filling of the aneurysmal sac; RS 3 indicates contrast filling of the aneurysmal sac);
VER, volume embolization ratio.

Representative case

A 64-year-old woman was incidentally found to have a basilar apex aneurysm on brain MRI, and was referred to our hospital. Cerebral angiography showed an aneurysm (height 8.6 mm, length 8.3 mm, width 7.0 mm) at the apex of the basilar artery (Fig. 2A). Clopidogrel 75 mg and aspirin 100 mg were administered from 2 weeks before coil embolization. Under local anesthesia, a 6Fr Cerulean catheter DD6 115 cm (Medikit, Tokyo, Japan) was inserted as a guiding catheter into the right vertebral artery through the right radial artery. A Prowler SP microcatheter was navigated into the left posterior cerebral artery for stent delivery using a

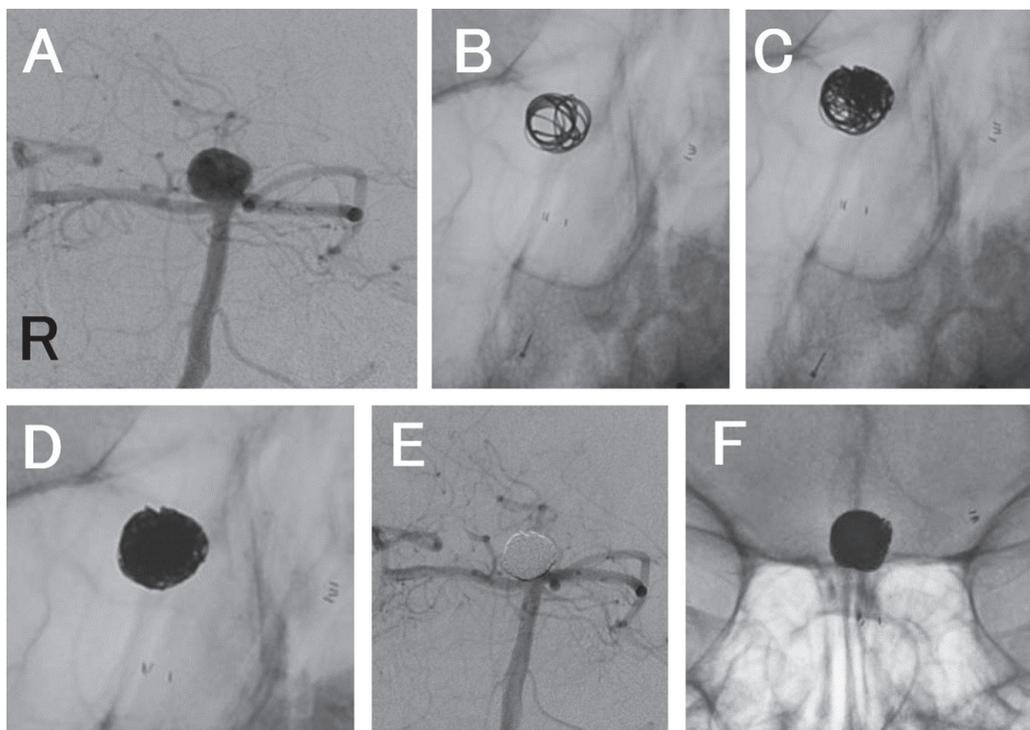


Fig. 2

- (A) Preoperative digital subtraction angiography showing a basilar apex aneurysm.
 (B) X-ray image showing deployed stent and a frame.
 (C) The distal hemisphere is embolized before the proximal hemisphere.
 (D) X-ray image showing the final configuration of the embolized aneurysm.
 (E) Postoperative digital subtraction angiography showing complete occlusion.
 (F) Skull X-ray image at 12-month follow-up reveals no coil compaction.

CHIKAI 14 microguidewire (Asahi Intecc, Aichi, Japan). A Headway 17 straight microcatheter (Terumo, Tokyo, Japan) was guided into the aneurysm using the CHIKAI 14 microguidewire. After a frame was made using Cashmere 8 × 200 mm (Cordis, Johnson & Johnson, Fremont, CA, USA), an Enterprise 2 VRD 4.0 × 23 mm (Cordis) was deployed from the left posterior cerebral artery to the basilar artery (Fig. 2B). A Cashmere 4 × 80 mm was inserted into the aneurysm as the second coil. Then, the upper hemisphere of the aneurysm was embolized using four Target 360 coils (Stryker Neurovascular, Kalamazoo, MI, USA) and two Deltaplus coils (Cordis) (Fig. 2C). As the Headway microcatheter was kicked down into the lower hemisphere, a Cashmere 3 × 60 mm was deployed. In succession, three VFC coils (Terumo), two Deltapaq coils (Cordis), and four Deltaplus coils were inserted (Fig. 2D). Complete occlusion was achieved (Fig. 2E). The volume embolization ratio was calculated as 44.4%. The postoperative course was favorable, and the patient was discharged 5 days after coil embolization. Administration of aspirin was discontinued 1 month after treatment, and clopidogrel was continued. There has been no recurrence during the 12-month postoperative follow-up.

DISCUSSION

The hemispheric divided coiling technique enabled a higher coil-packing attenuation in middle- and large-sized aneurysms than that achieved by conventional techniques, possibly accounting for the significantly lower angiographic recurrence rate.

Advantages of the hemispheric divided coiling technique

The main advantages of this technique compared with the conventional onion skin or Russian doll-like coil insertion are the following: (1) The intra-aneurysmal microcatheter does not tend to be kicked back unexpectedly during coil insertion in the distal hemisphere. When we embolize ruptured aneurysms with a bleb, complete hemostasis can be achieved immediately with stable behavior of the microcatheter. (2) The framing coil can be stabilized with the distal hemispheric coils. In the conventional technique, the second or third coil tends to break the framing coil around the aneurysmal neck (Fig. 3). Our technique prevents the herniation of the framing coil into the parent artery. (3) Because the embolization begins from the aneurysmal fundus with relatively small-sized coils, coil-free dead space is not likely to remain. (4) Because the aneurysmal neck is not so dense with coils until the final stage, the positioning of the microcatheter can change easily. In particular, the trans-cell approach during the stent assist coiling is very effective (Fig. 4). We can navigate the microcatheter into the residual coil-free space wherever we want. Former hemispheric coils can prevent to penetrate the microcatheter which is likely to jump-in through the stent strut into the aneurysm. (5) As a result of these advantages, a higher volume embolization ratio can be achieved.

Comparison with other adjunctive and innovative techniques

A flow-diverting stent is one of the optional treatments for challenging intracranial aneurysms, including large and giant aneurysms. However, the rates of permanent morbidity and mortality with this treatment were reported to be 5.6% to 10.8%.^{6, 7} Moreover, placement of flow-diverting stents for posterior circulation aneurysms resulted in a higher rate of ischemia in patients due

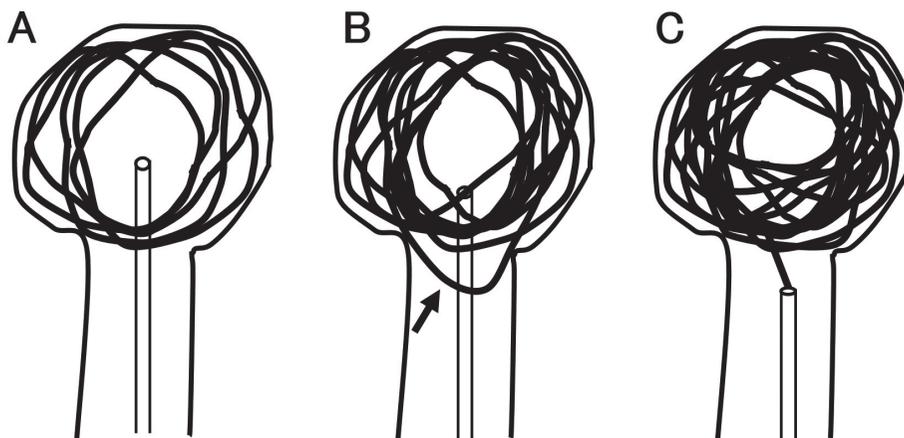


Fig. 3 Schematic drawing of the conventional coiling technique.

(A) After a frame has been made by the usual technique, the microcatheter is set around the center of the aneurysm. (B) When the second coil is inserted, one loop of the first coil unexpectedly protrudes towards the parent artery (arrow). (C) Because the movement of the tip of the microcatheter is large, it often kicks out. It is hard to navigate into the aneurysm again, because the coil density around the aneurysmal neck is already high.

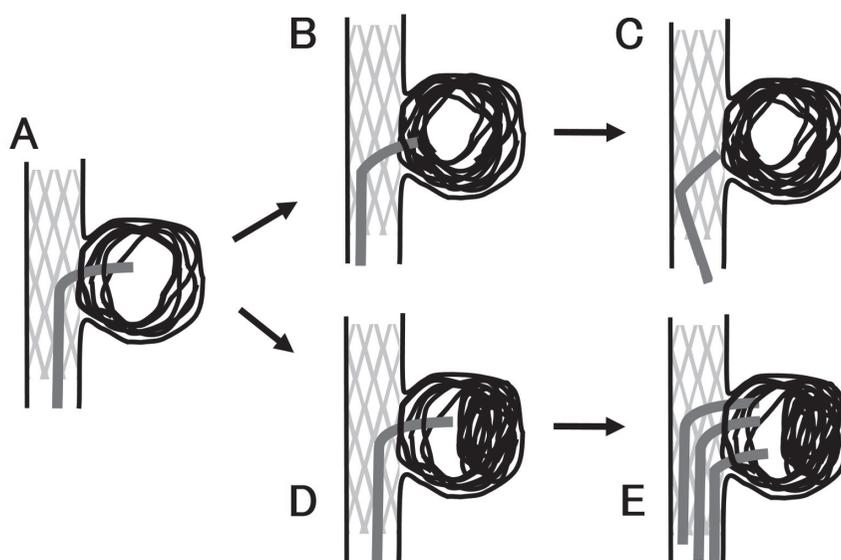


Fig. 4 Schematic drawing of stent-assisted coil embolization with the conventional and hemispheric dividing techniques.

(A) After a frame has been prepared by the usual technique, the microcatheter is set around the center of the aneurysm. (B) With the conventional technique, the tip of the microcatheter is likely to move the entire aneurysm during the second or third coil insertion. (C) Once the microcatheter is kicked out, it is difficult to navigate into the aneurysm again. (D) With the hemispheric dividing technique, the tip of the microcatheter remains. (E) The trans-cell approach can be accepted wherever appropriate.

to perforator occlusion.⁸⁾ Therefore, a more effective strategy is required, particularly for large and giant posterior circulation aneurysms.

Miyachi et al. reported the effectiveness of the one and a half round microcatheterization technique for stent-assisted coil embolization of large and giant intracranial aneurysms.⁹⁾ In this technique, a microcatheter is deeply inserted along the aneurysmal wall and withdrawn stepwise to result in homogeneous coil packing. We used this technique for several patients in our conventional group. In our experience, unexpected catheter kick-out often occurred when the loop of the microcatheter suddenly became small during coil insertion. We struggled to insert the microcatheter into the aneurysm again with the trans-cell approach, because the area around the aneurysmal neck was densely packed with coils. In the hemispheric group, the aneurysmal neck was not so dense with coils until the final stage; therefore, the microcatheter could be delivered easily with the trans-cell approach. Moreover, the straight microcatheter is more controllable and enables better visualization of the second marker than the extremely curved microcatheter.

Ohta et al. reported a maze-making and solving technique that can achieve high coil-packing attenuation.¹⁰⁾ This technique is relatively complicated because it requires two microcatheters for coil delivery, one balloon catheter, and one microcatheter for stent placement. After the aneurysms are filled with larger-diameter coils, the coil dead spaces are filled in a stepwise fashion. This technique also uses the one and a half round microcatheterization technique. Although it is similar to our technique at the point of the piece-meal coil filling, we believe that simple manipulation with a straight microcatheter is more effective for dense packing than a complicated procedure. When unexpected catheter kick-out occurs, a large coil-free space may remain and result in insufficient embolization. With our technique, the course of a microcatheter that is kicked out

can be predicted. Therefore, we can select the most suitable length and thickness of the coil for each stage of coil embolization. Our technique requires fewer coils and thus has a lower cost than the maze technique.

Limitations

The small number of patients enrolled in this case series may not yield sufficient conclusions for estimation of long-term results. However, the homogeneous and higher coil-packing attenuation with the hemispheric divided coiling technique may help surgeons to avoid delayed recanalization of aneurysms. In this case series, there were no giant intracranial aneurysms. Giant aneurysms may require to be divided into three or more sections depending on the individual size and shape.

CONCLUSIONS

The hemispheric divided coiling technique achieved a high volume embolization ratio for middle- and large-sized intracranial aneurysms, with a low recurrence rate. With our technique, complicated aneurysms can be altered to the most preferred shape of aneurysm, which we are confident about, step by step. Studies of larger numbers of cases will be needed to confirm these initial findings and assess the efficacy of the technique.

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