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Original Article

Double-catheter technique for the embolization of recurrent cerebral aneurysms: A single-center experience

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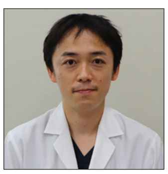

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ABSTRACT

Background: Recurrent cerebral aneurysms have complex shapes and are often technically challenging to treat with a single microcatheter. This study evaluates the clinical characteristics and treatment outcomes of patients who received double-catheter coil embolization for recurrent cerebral aneurysms.

Methods: Patients who underwent double-catheter coil embolization at our institution between April 2011 and March 2022 for recurrent aneurysms were included in the study. Baseline characteristics, course to recurrence, details of the procedures, and outcomes after endovascular treatment were retrospectively analyzed based on past medical records.

Results: Eight patients with recurrent aneurysms were treated with the double-catheter technique. One patient had a subarachnoid hemorrhage due to a rupture of a recurrent aneurysm and the others had radiological recurrence during follow-up. The initial treatment for the aneurysm was clipping in one case and coiling in seven cases. All the aneurysms were located at bifurcation sites. During retreatment, balloon remodeling technique was used in five cases. Angiographic features immediately after the treatment included complete occlusion in one case, neck remnant in three cases, and dome filling in four cases. There were no procedure-related severe complications, besides preexisting oculomotor nerve palsy due to the mass effect of the aneurysm worsened in one patient. The mean follow-up period after retreatment was 4.3 years. There was one case of recurrence after retreatment in which additional endovascular coiling was necessary.

Conclusion: This study demonstrated that the double-catheter technique could be a safe and useful treatment option for patients with recurrent aneurysms at bifurcation sites.

Keywords: Aneurysm recurrence, Coiling, Endovascular treatment, Intracranial aneurysm

INTRODUCTION

Rebleeding of a target aneurysm after treatment causes severe outcomes.[2,12] The rebleeding rate after a treatment of ruptured aneurysms has been reported to be higher in a coiling group than in a clipping group,[2,13] and the retreatment rate is significantly higher in the coiling group.[21] A treatment for recurrent cerebral aneurysms includes both clipping and coiling. In clipping, it is often difficult to reach the aneurysm because of strong adhesion to the surrounding tissues. The difficulty depends on the interval between initial treatment and reoperation, the presence of clips and coating agents, and the complexity of the lesion.[7] On the other hand, in performing coil embolization which is the other treatment method, preexisting material including coils or clips makes it difficult to separate the parent artery and recurrent aneurysm in fluoroscopic views. Due to the complex shapes, morphological diversity, and wide necks of recurrent aneurysms, it is often difficult to achieve complete embolization with a single microcatheter alone, requiring an adjunctive technique.[5,8-10] However, few studies have investigated the effectiveness of a particular embolization technique for recurrent aneurysms, probably due to the relative rarity of aneurysm recurrence after initial treatment. Recently in those recurrent aneurysms, we have attempted the double microcatheter technique, in which two microcatheters were inserted in an aneurysm and coils were inserted alternately through these catheters.[1,8,9]

The purpose of this study is to investigate the baseline characteristics, endovascular procedure, and long-term results of coil embolization for recurrent cerebral aneurysms using the double-catheter technique, presenting radiological images and an intraoperative video of a representative case, and to evaluate its efficacy and safety.

MATERIALS AND METHODS

Subjects

This study was approved by the Institutional Review Board of our hospital (#2231). The subjects of this study were patients with recurrent cerebral aneurysms who underwent coil embolization using the double-catheter technique at our institution between 2011 and 2022. The criteria for the treatment of recurrent cerebral aneurysms at our institution are as follows: (1) subarachnoid hemorrhage or (2) increased size on radiological follow-up with magnetic resonance angiography (MRA) or digital subtraction angiography (DSA). Cases of recurrent cerebral aneurysms treated with endovascular therapy were screened. The patients in which coil embolization was performed using the double-catheter technique were extracted. Medical records, operative courses, and radiological data were retrospectively analyzed.

Endovascular procedures

In patients with unruptured aneurysms, in principle, a single antiplatelet agent (aspirin 100 mg or clopidogrel 75 mg) was initiated 3 weeks before surgery, and administration of the agent was adjusted according to each case. In patients with subarachnoid hemorrhage, a loading dose of aspirin (200 mg) was applied through a nasogastric tube after arterial sheath insertion. Endovascular procedures were performed under general anesthesia. After placing a sheath through the right femoral artery, heparin was injected systemically to maintain an activated clotting time of 1.5–2.5 times the initial value. The double-microcatheter technique was mainly used for wide-neck, bifurcation-type aneurysms, where it was difficult to achieve sufficient coil embolization with a single microcatheter. This method was applied in cases where the diameter of the parent artery was sufficiently large (approximately >2 mm) and the arteriosclerosis was not severe enough to interfere with the guidance of the microcatheter. The aneurysm size was measured in three directions using three-dimensional rotational angiography (3DRA). The sizes of the first and second coils were investigated retrospectively. In the results section, these values are expressed as mean ± standard deviation, unless otherwise stated. In cases where the coil protruded into the parent vessel during coil insertion, the balloon remodeling technique was used selectively.[15,20] In DSA immediately after the treatment, complete occlusion was defined as no inflow into the aneurysm, neck remnant as inflow of contrast medium into the neck of the aneurysm, and dome filling as a uniformly enhanced aneurysm.[19]

Management after coil embolization

Postoperative neurological status was assessed immediately after the treatment in the intensive care unit and at a discharge. Head computed tomography (CT) and magnetic resonance imaging/angiography were performed on postoperative day 1 to check hemorrhage and cerebral infarction. To prevent ischemic complications, a single antiplatelet drug (aspirin 100 mg daily or clopidogrel 75 mg daily) was continued for 1 month after the treatment. Follow-up after an endovascular treatment was performed at the outpatient clinic at 3 months, 6 months, and 1 year. In CT angiography and MRA, accurate evaluation of the recurrence is difficult due to coil artifacts; therefore, we checked the recurrence by DSA as long as the patient's condition permitted.

RESULTS

Of 281 endovascular treatments for cerebral aneurysms performed during the study period, 19 (6.8%) were for recurrent aneurysms. The double-catheter technique was used in eight of the 19 patients treated (42%), which were evaluated in the following analyses. Of the remaining 11 patients, six were treated with a simple technique, two with a neck-bridging stent, and two with a flow diverter (FD). In one patient, a catheter was difficult to navigate, and the treatment was unsuccessful. The patients' baseline characteristics are described in Table 1. There were two male and six female patients; the median age at recurrence was 61 years (range 43–75). The initial treatment for the aneurysm was clipping in one case and coiling in seven cases. One patient who was initially treated endovascularly

Table 1: Baseline characteristics of the study cohort.

S. No.	Age/ Gender	Location/ Initial size (mm)	Initial treatment/ VER	Second presentation/ Time to recurrence (years)	Maximum diameter (mm)	Neck size (mm)	Number of coils/ coil length (cm)	First coil size (mm×cm)	Second coil size (mm×cm)	Balloon usage	Results	Procedure-related complications	Postop deficits	Second recurrence/ f/u period (years)	mRS at final f/u
1.	75/F	PCom/17.7	Coiling/14%	Follow-up/0.2	7.2	NA	16/134	4×8	4×8	Yes	NR	No	No	No/10.6	0
2.	77/F	PCom/12.3	Coiling/16%	SAH/2.9	8.0	NA	15/188	7×30	7×20	Yes	DF	No	No	No/1.1	6
3.	67/F	PCom/6.5	Coiling/15%	Follow-up/1.1	4.3	3.8	6/42	3×8	3.5×7.5	Yes	NR	No	No	No/3.7	6
4.	63/F	MC/4.6	Coiling/28%	Follow-up/0.4	3.2	2.6	2/5	1.5×3	1×2	No	NR	No	No	No/7.0	0
5.	59/F	PCom/6.7	Coiling/22%	Follow-up/4.0	6.5	4.9	6/23	3×10	1.5×3	Yes	CO	No	Diplopia	No/7.4	2
6.	57/M	ACom/NA	Clipping	Follow-up/10.0	3.4	2.2	3/10	2.5×4	2×4	No	DF	No	No	Yes/2.2	0
7.	46/F	PCom/3.7	Coiling/NA	Follow-up/0.5	3.4	2.2	3/7	1.5×3	1.5×2	Yes	DF	No	No	No/1.6	0
8.	43/M	ACom/3.7	Coiling/33%	Follow-up/1.2	3.2	2.4	5/13	2×4	1.5×3	No	DF	No	No	No/0.6	0

ACom: Anterior communicating artery, CC: Coil compaction, CO: Complete occlusion, DF: Dome filling, F: Female, f/u: follow-up, M: Male; MC: Middle cerebral artery, mRS: Modified Rankin Scale; NA: Not available, NR: Neck remnant, PCom: Posterior communicating artery, RC: Recanalization, SAH: Subarachnoid hemorrhage, uAn: Unruptured aneurysm, VER: Volume-embolization ratio, WFNS: World Federation of Neurosurgical Societies. The maximum diameter indicates the largest diameter of the recanalized segment, not the diameter of the entire aneurysm.

developed subarachnoid hemorrhage and radiographical recurrence was confirmed in the other seven cases during imaging follow-up by MRA or DSA. Rerupture occurred 2.9 years after the initial coil embolization. In addition, the median duration of time from initial treatment to recurrence was 1.1 years (range, 0.2–10.0) in cases detected by imaging follow-up. The aneurysms were located at the bifurcation of the internal carotid artery (ICA) and posterior communicating artery in five cases, anterior communicating artery (ACoA) in two cases, and middle cerebral artery in one case. The size of the recurrent aneurysm was 4.9 ± 2.0 mm, and that of the neck was 3.0 ± 1.2 mm. The dome-to-neck ratio was 1.35 ± 0.16, and <2 in all cases. Regarding treatment, the balloon remodeling technique was used in five cases. Regarding coil selection, the diameter of the first coil was 3.06 ± 1.80 mm, which was 61 ± 15% of the maximal length of the recanalized aneurysm. In the single catheter group, the first coil was 3.30 ± 0.97 mm, which was 70 ± 32% of the maximal length of the recanalized aneurysm. The second coil diameter was 2.75 ± 2.02 mm, which was 86 ± 22% of the first coil diameter. On the other hand, the second coil diameter in the single catheter group was 75 ± 16% of the first coil diameter ($P = 0.37$, unpaired t-test), which was smaller than in the double catheter group. In total, a median of 7 (range, 2–16) coils was inserted. Postoperative aneurysm status was complete occlusion in one case, residual neck in three cases, and dome filling in four cases. No treatment-related deaths or postoperative symptomatic cerebral infarctions occurred. With regard to postoperative neurological symptoms, no new deficit appeared in seven patients, but oculomotor nerve palsy due to mass effect worsened in one case (Case 5). The median follow-up period was 3.0 years (range, 0.6–10.6), and all but one patient had no recurrence. In one patient, additional coil embolization was performed due to regrowth 26 months after coiling of the ACoA aneurysm. In the second treatment, stent-assisted coiling was performed and no recurrence was observed for 60 months after the treatment.

Representative case (Case 8)

A 43-year-old man, who underwent endovascular coiling using the balloon remodeling technique for subarachnoid hemorrhage (World Federation of Neurosurgical Societies grade 2) due to a rupture of an ACoA aneurysm with a diameter of 3.7 mm, was found to have a recurrent aneurysm on DSA 1 year after the initial treatment [Figure 1a]. Endovascular procedures were performed in a hybrid operating room under general anesthesia with the patient on dual antiplatelet therapy (aspirin 100 mg and clopidogrel 75 mg). An 8Fr sheath was placed in the right femoral artery and systemic heparinization was performed to maintain an activated clotting time of over 250 seconds(s) during embolization. After an 8Fr FUBUKI guiding catheter

(ASAHI INTECC, Japan) was navigated to the proximal portion of the left ICA, a Cerulean DD6 intermediate catheter (Medikit, Japan) was advanced to the petrous portion of the ICA. Angiography, including 3DRA, was performed using an injector. Measured using the 3DRA model, the aneurysm had a wide neck with a maximum diameter of 3.2 mm and a neck of 2.4 mm [Figure 1b]. In addition to the small size of the aneurysm, in the superior view, the aneurysm protruded posteriorly and deviated from the axis of the left anterior cerebral artery A1, making coil embolization difficult anatomically [Figure 1c]. To accommodate the misalignment of A1 and the long axis of the aneurysm, we planned to shape the microcatheter such that the anterior wall of A1 served as a fulcrum. The 5-mm tip of the Headway 17 microcatheter (Terumo, Japan) was formed into a double angle [Figure 1d] using a heat gun and navigated in the aneurysm. As expected, the Headway 17 microcatheter was easily placed in the posteroinferior part of the aneurysm. To form a stable frame, we executed a double catheter technique. An additional Excelsior SL-10 pre-shapeJ microcatheter (Boston Scientific, USA) was navigated into the aneurysm and placed at the center of the aneurysm. Coil insertion was initiated with a Target 360 ULTRA (2 mm × 4 cm, Stryker, USA) using the SL-10 microcatheter. Since the initial coil was relatively soft, short, and unstable compared to the framing coil used in the coiling for the primary aneurysm, an iED coil (COMPLEX SilkySoft, 1.5 mm × 3 cm, KANEKA Medix, Japan) was inserted from the Headway microcatheter [Figure 1e] before detaching the initial coil inserted through the SL-10 microcatheter, to make the inserted coil mass more stable. In addition, we added two coils to the same microcatheter. After detaching the first coil, the COMPLEX SilkySoft iED coil (1 mm × 2 cm, KANEKA Medix, Japan) was added through the SL-10 microcatheter to complete the procedure. Five coils with diameters of 13 cm were used in the treatment. DSA revealed slight body filling [Figure 1f]. Postoperative CT showed no hemorrhage and the final activated clotting time was 234 s. Postoperative neurological examination revealed no new deficits and the patient returned to the intensive care unit. The patient was discharged on foot and there was no

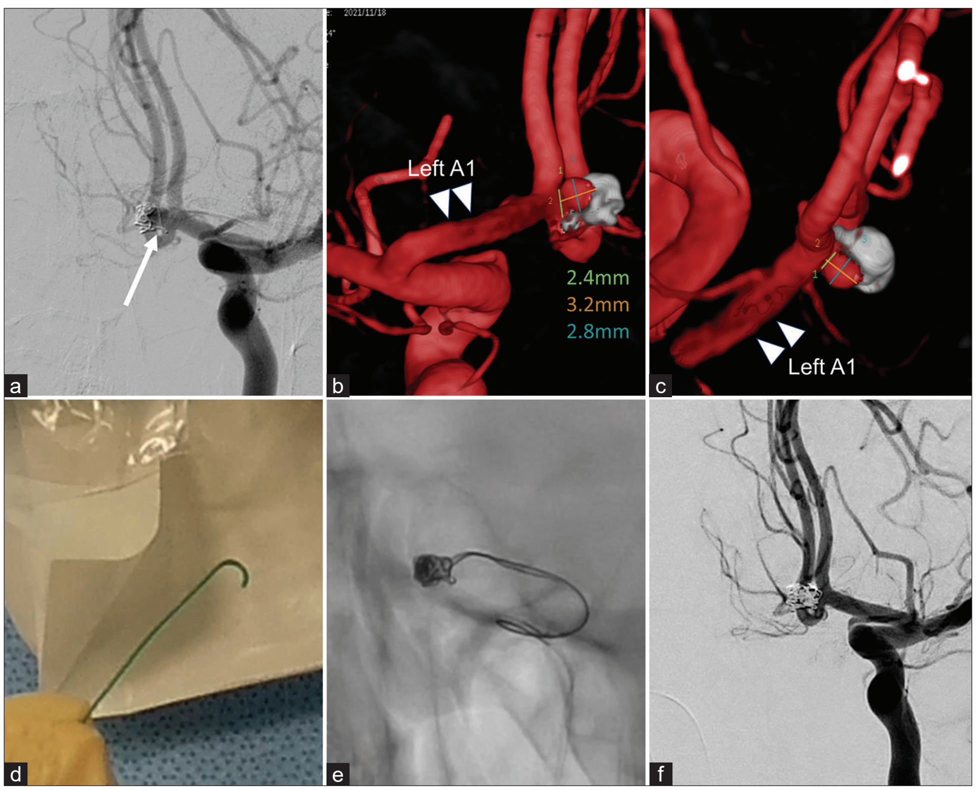
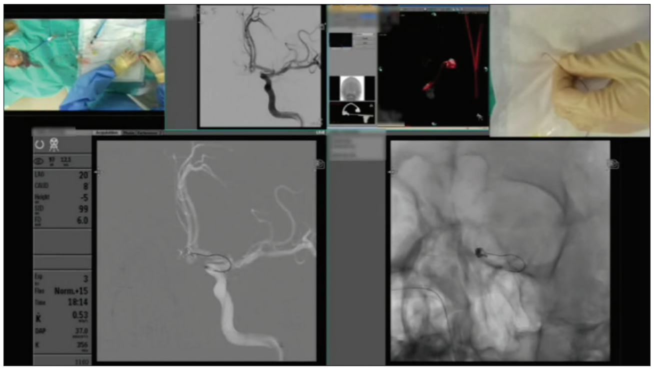


Figure 1: Pre and postoperative images of a representative case (Case 8) (a) Left internal carotid angiography shows a recurrent aneurysm located in the anterior communicating artery. One loop of the preexisting coil (arrow) protrudes at the neck. (b,c) Three-Dimensional rotational angiography shows the direction of protrusion of the aneurysm relative to the anterior cerebral artery A1 (double arrowhead) from the posterior (b) and superior (c) view. (d) The tip of the Headway 17 microcatheter is formed at a double angle. (e) The initial coil inserted from Headway17 was unstable, and the second coil was added from the other SL-10 preshape J microcatheter before detaching the first coil. (f) Postoperative digital subtraction angiography (DSA) shows slight body filling without interfering with the parent vessel.



Video 1: Detailed treatment course of a representative case (Case 8).

recurrence of the aneurysm at 7-month postoperatively. The detailed treatment course is presented in Video 1.

DISCUSSION

This study focused on endovascular treatment using the double microcatheter technique for recurrent aneurysms. There were no cases of intraoperative rupture, while postoperative exacerbation of oculomotor nerve palsy was observed in one patient, but no new neurological deficits were identified in the other cases. With a median follow-up of 3.0 years, 7 of 8 cases (87.5%) were recurrence-free.

Aneurysms have a high risk of developing subarachnoid hemorrhage due to re-enlargement[11] and bleeding from the target aneurysm after treatment can be fatal.[12] For wide-neck bifurcation-type aneurysms, as in this cohort, sufficient coil embolization using a simple technique is difficult, and an adjunctive technique is often required.[5,8-10] Aneurysms with incomplete occlusion have been reported to have a higher postoperative recurrence and rerupture rate.[2,4,17,18]

The rates of complete occlusion immediately after surgery and long-term occlusion are higher when adjunct with neck-bridging stents or FDs than simple coiling for both primary and recurrent cerebral aneurysms.[6,10,14,16] During the study period, we actually treated four cases of recurrent side-wall-type aneurysm without complication. However, the use of stents has several disadvantages. First, treating bifurcation-type aneurysms with stents and FDs is technically difficult and may result in complications. Although combination stents are sometimes used for intracranial bifurcation-type aneurysms, the risk of ischemic complications cannot be overlooked.[3] Second, it is technically challenging to retreat the aneurysm through the stent in case of recurrence. The double-microcatheter technique was first reported in 1998[1] and has since proven its efficacy and safety in embolizing wide-neck aneurysms.[8,9] Using the double-catheter method for recurrent aneurysms has an advantage over using stents because it makes the approach easier if the aneurysm recurs again.

The recanalized cavity inside preexisting coils or clips has an irregular shape, making endovascular embolization of recurrent aneurysms technically challenging, and it is generally difficult to form a stable frame in the initial stage of coiling. As shown in the representative case, it is sometimes necessary to use short and soft coils initially to hold them inside the aneurysm. However, these coils are unstable and there is a risk of coil protrusion into the parent artery when inserting subsequent coils. Considering the geometric nature of recurrent aneurysms, the advantage of the double-microcatheter method is the formation of a more stable frame before detaching the first coil. Technically, it is important to place the two microcatheters at different positions inside the target aneurysm. Usually, the first microcatheter is placed near the neck and the other is placed in the center. Regarding the selection of the first and second coil in our strategy, it is important to choose the small-diameter coil according to the maximal length of the recanalized aneurysm as the first coil, and not to decrease the diameter of the second coil too much compared to the first one. Consequently, a stable frame within the recanalized cavity can be safely created using the first two coils.

The disadvantages of this technique include the complexity of the procedure and the potential difficulty in removing the microcatheter. The technical tips are as follows. In the beginning, the 1st and 2nd coils are stabilized by alternately moving them in and out and entangling them with each other. If knots of microcatheters are formed at this time, the two microcatheters were pulled out with their coils. This allows the coil embolization to be performed again from the beginning. It is important to insert two microcatheters from the same guiding or distal access catheter to achieve this bailout. On the other hand, the third and subsequent coils should not be forcibly intertwined with the previous coils. We simply pushed the coils through the microcatheter and repeated detaching them as soon as they settled within the aneurysm. This rarely caused knots in the each microcatheter, making it difficult to remove. In addition, it is sometimes difficult to distinguish between the markers of the two microcatheters, which can be overcome by frequently changing the angle of the flat panels.

This study has some limitations. First, this was a retrospective study with a small sample size. Second, all recurrent aneurysms coiled with the double-catheter technique were included in the study. Because the morphological characteristics of recurrent aneurysm after coiling and clipping may not be strictly the same, future analyses should be classified according to the method of initial treatment. Third, we did not compare patient backgrounds and treatment outcomes between the double microcatheter technique and other techniques used. Fourth, endovascular procedures and criteria for adoption of treatment methods have not been standardized because multiple operators have performed endovascular treatment during the target period. Thus, there are no strict criteria to distinguish between simple catheter and double catheter techniques in this study period. Fifth, novel remodeling devices for bifurcation aneurysms, such as WEB (Microvention, USA) and PulseRider (Cerenovus, USA), were not used at our center during the study period.

Despite these limitations, our study demonstrated the efficacy of the double-catheter technique in treating recurrent aneurysms. Our technique can be a reasonable option to simultaneously minimize invasiveness and reduce the recurrence rate. The future studies are warranted to investigate appropriate management strategies for recurrent cerebral aneurysms.

CONCLUSION

The double-catheter technique is a safe and useful treatment option for patients with recurrent cerebral aneurysms at bifurcation sites. The technique can assure the long-term occlusion of the target aneurysm with relatively low perioperative complication rate.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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