INTRODUCTION

During the past decade there has been a significant evolution in the nature of endovascular treatment for intracranial aneurysms. Indeed, both endovascular coil embolization and microsurgical clipping are now firmly established as treatment options for the management of cerebral aneurysms. Moreover, they are sometimes used as complementary approaches to each other. This study retrospectively analyzed our experience with endovascular and microsurgical procedures as complementary approaches in treating a single aneurysm.

MATERIALS AND METHODS

We retrospectively reviewed information on consecutive patients with aneurysms treated with microsurgical clipping and/or endovascular treatment at our institution between March 2001 and December 2006. A total of 365 coil embolization procedures and 616 surgical clipings were performed in treating 981 aneurysms in 836 patients during this time period.

All patients who were treated with combined therapy involving microsurgical clipping and endovascular coil embolization for a single aneurysm were evaluated in this study. We excluded patients who were treated with attempted endovascular coiling and failed microsurgical clipping. These criteria lead to the inclusion of 19 aneurysms (1.94%) in 19 patients (2.27%). There were 10 males and 9 females ranging in age from 37 to 70 years (mean, 51.53 years).
Eighteen patients presented with ruptured aneurysms. The clinical grade of the ruptured aneurysms included Hunt and Hess grade II in 6 cases, grade III in 7 cases, grade IV in 4 cases, and grade V in 1 case. Clinical summaries of their information are provided in Table 1 and 2.

All aneurysms were located in the anterior circulation. The most common aneurysm locations were the anterior (n=6) and posterior communicating arteries (n=6). The remaining seven aneurysms were located in the paraclinoid segment of the ICA (n=2), the MCA (n=2), the anterior choroidal artery (n=2), and the ICA bifurcation (n=1).

Fourteen aneurysms had diameters of less than 10 mm, and five had diameters of 10 to 25 mm. The patients were followed for 10 to 78 months (mean, 29 months).

RESULTS

Clipping after coil embolization

Thirteen patients were initially treated with endovascular coil embolization and followed by microsurgical management (Table 1). The aneurysm sites were the posterior communicating artery (n=5), the anterior communicating artery (n=4), the anterior choroidal artery (n=1), the MCA (n=2), and the ICA bifurcation (n=1).

Six of these 13 patients had experienced aneurysm rupture during coil embolization. To make matters worse, during the insertion of further coils into the aneurysmal sac, 4 patients of them had additional procedure-related complications such as coil stretching, coil mass protrusion or prolapse into parent artery (cases 1, 2, 6, 8, 9) (Fig. 1).

In four patients, there were protrusions or prolapses of the placed coil and occlusions of the parent artery (cases 2, 3, 7, 8). In cases 2, 3 with a small and saccular aneurysm, there were occlusions of the MCA by the placed coil. In case 7, in which the aneurysm was saccular in shape and superior-posterior in direction, there was protrusion of the coil into the ICA bifurcation and evidence of thromboembolism in the MCA. In case 8, there

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<th>Size (mm)</th>
<th>H&amp;H grade</th>
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Paracrin. indicates Paracrinoid

Fig. 1. Case 6. A 39-year-old man after subarachnoid hemorrhage from a right posterior communicating artery aneurysm. A : Right internal carotid artery angiogram demonstrating a 4 × 2 mm posterior communicating artery aneurysm. B : Angiographic image obtained with an injection through the guiding catheter in the right internal carotid artery demonstrating filling of the aneurysm neck and extravasation of contrast material. C : During further insertion of an additional coil, a stretched coil extending from the coil pack into the more distal internal carotid artery and extravasation of contrast material can be seen. D : Postoperative right internal carotid angiogram : the stretched coil was removed, and the aneurysm was clipped beneath the coil mass.
was evidence of partial occlusion of the A2 segment of the ACA with breakage of the coil and protrusion. These patients underwent emergency craniotomy and the aneurysms were opened, and the coils were removed before direct clipping.

In one patient (case 10), coil migration occurred during the endovascular procedure. The aneurysm was a small anterior communicating artery aneurysm (3 × 2 mm) and superior-posterior in direction. The coil mass migrated into the callosomarginal branch of the ACA, but the patient was neurologically intact. The patient underwent surgical exploration with direct clipping of the aneurysm neck without removal of the migrated coil (Fig. 2).

In three cases, aneurysm regrowth and coil compaction after coil embolization were found in routine follow-up angiography (case 4, 5, 12). These patients underwent microsurgical retreatment after a signed consent form was obtained from patient and legal guardians.

In case 11, this patient had multiple aneurysms; anterior communicating artery and paracloinal ICA aneurysms. The patient attempted coil embolization for all the aneurysms. Coil embolization was technically difficult, because of broad-necked, bi-directed pointing, anterior communicating artery aneurysm. The patient was initially treated with partial aneurysm coil packing. Staged microsurgical clipping was then performed.

Coil embolization after microsurgical clipping

Six patients who had undergone microsurgical clipping were followed by coil embolization (Table 2). Aneurysm locations were the anterior communicating artery (n=2), the paracloinal ICA (n=2), the posterior communicating artery (n=1), and the anterior choroidal artery (n=1).

Four of these aneurysms had residual sac. The aneurysms were located in the anterior communicating artery (n=2), and the posterior communicating artery (n=1), and the anterior choroidal artery (n=1). The two anterior communicating artery aneurysms and the anterior choroidal artery aneurysm had multi-lobulated, and multiple point direction. They could not be clipped completely because of complex aneurysmal morphology and severe brain swelling. These residual aneurysms were treated successfully with endovascular coiling. One patient (case 15) had a posterior communicating artery aneurysm clipped 14 years previously before presenting with a recurrent aneurysm. This patient underwent reclipping, but the aneurysm was incompletely clipped due to broad neck, and a remnant neck was identified on immediate postoperative angiography. The aneurysm was then completely occluded by endovascular coiling (Fig. 3).

Two aneurysms had early regrowth of aneurysmal sac (case 14, 16). These patients had the paracloinal ICA aneurysm, rebleeding occurred 2 weeks (case 14), and 1 month (case 16) after clipping. Early regrowth of aneurysmal sac was identified on angiography. Obliteration of the aneurysms was achieved by coil embolization.

Clinical outcomes

According to the Glasgow Outcome Scale, a ‘good’ recovery was achieved in 14 of the 19 patients, but two patients who
underwent microsurgical clipping after an endovascular procedure experienced moderate and severe disabilities caused by symptomatic vasospasm and severe brain swelling. In three of the 6 patients who underwent an endovascular procedure after microsurgical clipping, moderate and severe disabilities occurred as a result of symptomatic vasospasm after rebleeding and thromboembolism during the endovascular procedure.

**DISCUSSION**

In 1995, endovascular treatment of surgically high-risk intracranial aneurysms using Guglielmi detachable coils (GDCs) was approved by the United States Food and Drug Administration (FDA). Since then, there has been a significant evolution in the nature of endovascular treatment for intracranial aneurysms. Endovascular coil embolization was established as treatment option for the management of cerebral aneurysms, especially since the completion of the International Subarachnoid Aneurysm Trial (ISAT)22).

Endovascular coil embolization and microsurgical clipping are now both firmly established as treatment options for the management of intracranial aneurysms. Moreover, they are sometimes best used together in a complementary approach to complex intracranial aneurysms, especially those with periprocedural endovascular complications and/or failed microsurgical clipping.

**Microsurgical solutions to periprocedural problems of coil embolization**

Complications associated with intraprocedural coil embolization of intracranial aneurysms have been reported in many retrospective studies2,4,6,8-15,19,21,23,24,26,27,29). The common procedural complications are aneurysm rupture, coil protrusion or migration, thromboembolic events, and vessel dissection.

Periprocedural aneurysm rupture is a well-described event and may cause to death from an increase of ICP20,26,29). Several factors and mechanisms have been proposed, including smaller aneurysms, tortuosity of the arteries, and operator experience. The perforation of an aneurysm may occur by microcatheter perforation, guide wire perforation, coil penetration, and high-pressure contrast dye injection20,26,29). Following a perforation, it has been generally proposed that there be immediate reversal of anticoagulation, that the perforating device not be pulled out, and that further coils be inserted into the aneurysmal sac by placing a second microcatheter to complete the embolization34). However, the consequences of complex intraprocedural rupture, failed further coil insertion, or coil stretching or breakage have not been extensively described. Microsurgical management of the unsuccessful obliteration of aneurysms with endovascular maneuver has been reported5,13,27).

Coil mass protrusion and migration into the parent artery are one of the most dreadful complications3,24,25). These complications can occur during treatment of wide-neck aneurysms, small aneurysms with size mismatch8,25).

Following a protrusion of coils, it has been proposed several rescue endovascular procedures that the retrieval of protruded coils after snaring of the prolapsed strand7), the inflation of a nondetachable microballoon in front of the aneurysm orifice20), and the stent deployment in the protruded portion of the parent artery1). Despite these endovascular maneuvers, when the coil protrusion still occurs or the coil retrieval is failed, microsurgical management is required5,33).

Our cases required microsurgical solutions had complex problems such as inaccessible rescue endovascular treatment (a second microcatheter could not be achieved to ruptured aneurysm), additional complications occurred such as coil protrusion and stretching. With intraprocedural aneurysmal rupture with coil protrusion and/or parent artery occlusion with prolapsed coil, the aneurysm was clipped with removal of coil mass (Fig. 1).

**Endovascular retreatment after microsurgical clipping**

A residual aneurysm after clipping is usually the result of technical or anatomical difficulties (e.g., inadequate access, fusiform morphology, branch arteries at the base of the aneurysm), clip slippage, or regrowth of an aneurysmal sac9,12,17). The overall incidence of residual aneurysm after microsurgical clipping has been reported to be approximately 4 to 7%, and the regrowth rate of incompletely clipped aneurysms is approximately 7%10,28,32). Furthermore, some patients present with repeated subarachnoid hemorrhage or mass effect in the long-term follow up. Repeating the angiography after clipping has been recommended to confirm the complete obliteration of the aneurysm.

Owing to possible scar adhesions and a compromised aneurysm neck position from a previous operation and clipping, recapping of a residual aneurysm can present a higher risk and greater technical difficulty than the initial operation9,12). Consequently, endovascular management has been used in dealing with a residual aneurysm after a previous clipping9,11,29,31). We have experienced four cases of residual aneurysm and two cases of regrowth after clipping, and we have achieved aneurysm obliteration using complementary endovascular coil embolization.

**CONCLUSION**

We describe our experiences in patients who underwent combined treatment with endovascular coiling or incomplete
15. Lavine SD, Larsen DW, Giannotta SL, Teitelbaum GP: Parent vessel
11. Fraser KW, Halbach VV, Teitelbaum GP, Smith TP, Higashida
10. Feuerberg I, Lindquist C, Lindqvist M, Steiner L: Natural history
19. Marks MP, Steinberg GK, Lane B: Combined use of endovascular
18. Lot G, Houdart E, Cophignon J, Casasco A, George B: Combined
15. Leber KA, Klein GE, Trummer M, Eder HG: Intracranial aneurysms: a
11. Drake CG, Friedman AH, Peerless SJ: Failed aneurysm surgery: