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Clinical Article

Clinical and Radiogical Outcomes of Endovascular Detachable Coil Embolization in Paraclinoid Aneurysms : A 10-Year Experience

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Objective : Direct surgical clipping of paraclinoid aneurysms poses technical challenges to even very experienced neurosurgeons, making endovascular treatment an alternative treatment modality in many centers. We have therefore retrospectively evaluated the safety and efficacy of endovascular detachable coil embolization of paraclinoid aneurysms.

Methods : From June 1997 to June 2007, 65 patients underwent endovascular detachable coiling for 67 paraclinoid aneurysms (of which 9 were ruptured and 58 were unruptured) in our institute. Their medical records, radiological images and readings, and operation records were reviewed retrospectively.

Results : After the initial embolization procedure, complete occlusion was achieved in 29 (43.3%) of the aneurysms treated by endovascular detachable coiling. Six aneurysms required retreatment, with two each requiring one, two, or three additional endovascular procedures. Fifty-five (82.1%) aneurysms were measured by three-dimensional time of flight (TOF) magnetic resonance images (MRI) or transfemoral cerebral angiography (TFCA) at a mean follow-up of 29.7 months (range from 4 to 94 months), with 39 aneurysms (70.9%) showing complete occlusion. Thromboembolic events (3.8%) were the most frequent complication. Rupture did not occur during or after any of the procedures. According to the Glasgow Outcome Scale (GOS), 98.4% of the patients treated by coil embolization had a score of 4 or 5.

Conclusion : Our results indicate that endovascular detachable coiling is a safe and effective treatment modality in paraclinoid aneurysms.

KEY WORDS : Paraclinoid · Aneurysms · Endovascular.

INTRODUCTION

Paraclinoid aneurysms can be defined as intracranial aneurysms that arise from the internal carotid artery distal to the roof of the cavernous sinus but proximal to the posterior communicating artery[1,5,27]. Direct surgical clipping of paraclinoid aneurysms, however, poses technical challenges to even very experienced neurosurgeons. Microsurgical treatment has been associated with high morbidity and mortality rates owing to the difficulty of proximal control and of safe intracranial exposure.[15,24,25,31,35,47] During the past several decades, however, the development of microsurgical techniques and further advancement of anatomical knowledge have facilitated surgical approaches and greatly improved microsurgical outcomes in patients with paraclinoid aneurysms[13,17,20,25,27,34,50,53,54] although successful treatment of paraclinoid aneurysms continuously presents neurosurgical challenges. Endovascular treatment, an alternative treatment modality for paraclinoid aneurysms, has been performed in many centers. We have therefore retrospectively evaluated the safety and efficacy of endovascular detachable coil embolization in paraclinoid aneurysms at our center.

MATERIALS AND METHODS

This study included all saccular aneurysms arising from the internal cerebral artery (ICA) between the roof of the cavernous sinus and the origin of the posterior communicating artery that were treated by detachable coil emboliza-

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tion between June 1997 and June 2007 at our institution. A total of 159 consecutive patients with paraclinoid aneurysms were treated by either endovascular or microsurgical treatment. Selection of the treatment modality for each patient was discussed by neurosurgeons (B.K., J.A.) and neurointerventionists (C.C., D.K.). Of the 71 consecutive patients with paraclinoid aneurysms treated by endovascular procedures, 6 were excluded as they had been treated by parent artery trapping with balloon or coil. The remaining 65 patients underwent endovascular procedures with detachable coils for 67 paraclinoid aneurysms (of which 9 were ruptured and 58 were unruptured). Indications for endovascular detachable coiling for paraclinoid aneurysms included : 1) small aneurysms with narrow neck (n=26); 2) aneurysms reasonable to embolization (1 < dome to neck ratio < 2)(n=28); 3) poor clinical status unprofitable for surgery due to brain swelling (n=1); 5) trial for endovascular detachable coiling (dome to neck ratio < 1) (n=12). Paraclinoid aneurysms were defined as lesions arising from the clinoid (C5) and ophthalmic (C6) segments of the ICA[7]. Clinoid segment aneurysm variants were differentiated into anterolateral and medial variants according to their site of origin and direction of projection[11]. Ophthalmic segment subtypes were divided into ophthalmic artery, superior hypophyseal artery and dorsal wall aneurysms[11,13,14].

The medical records, radiological images and readings, and procedural reports of all patients were retrospectively reviewed. Initial patient clinical status was assessed using the Hunt and Hess scale, and clinical outcomes were assessed using the Glasgow Outcome Scale (GOS). Aneurysm fundus and neck sizes were taken at the point of maximum width or length. A fundus was classified into tiny if <5 mm in size, small if 5 to 10 mm, and large if ≥10 mm. Neck size was divided to narrow if <4 mm and broad if ≥4 mm arbitrarily. Outcomes in each aneurysm were assessed as : class 1, complete obliteration; class 2, residual neck; or class 3, residual aneurysm[43,45,46]. Routine follow-up evaluation by three dimensional time of flight (TOF) magnetic resonance image (MRI) was performed after 6 months if the aneurysms were completely obliterated, but after 3 months if the aneurysms were incompletely occluded, and every year thereafter. Conventional digital subtraction angiography (DSA) was also performed to confirm coil compaction or recurrence of the aneurysm.

RESULTS

The 65 patients evaluated were 13 (20.0%) men and 52 (80.0%) women, of mean age 52.3 years (range, 32 to 73 years). Their clinical presentations are shown in Table 1. Nine patients (13.8%) presented with subarachnoid hemorrhage from a ruptured paraclinoid aneurysm; of these, five were classified as Hunt and Hess Grade II, three as Grade III, and one as Grade IV. Twenty-three patients (35.4%) presented with non-specific headache, and 33 (40.8%) with incidental paraclinoid aneurysms; of the latter, 5 suffered from prior subarachnoid hemorrhage (SAH) caused by other ruptured aneurysm and 6 presented with unrelated transient ischemic attack (TIA) or ischemic stroke.

The 67 aneurysms were classified into five anatomic subgroups (Table 2). Fifteen (22.4%) were clinoid medial or anterolateral aneurysms, 10 (14.9%) were ophthalmic aneurysms, 27 (40.3%) were superior hypophyseal aneurysms, and 8 (11.9%) were dorsal wall aneurysms. The fundus and neck sizes of these paraclinoid aneurysms are shown in Table 3. There were 17 tiny aneurysms with narrow necks, 8 tiny aneurysms with wide necks, 11 small aneurysms with narrow necks, 17 small aneurysms with wide necks, 4 large aneurysms with narrow necks, and 10 large aneurysms with wide necks.

Immediate post-procedural angiograms showed complete occlusion in 29 aneurysms (43.3%), residual neck in 26 aneurysms (38.8%), and residual sac in 12 aneurysms (18.9%). Six aneurysms (9.0%) required retreatment, with two each requiring one, two, or three additional endovas-

Table 1. Clinical presentation of 65 patients with paraclinoid aneurysms

Clinical presentations	No. of patients (%)
SAH	9 (13.8)
Headache	23 (35.4)
Incidental finding	22 (33.8)
Previous other ruptured aneurysm	5 (7.8)
TIA or ischemic stroke	6 (9.2)

SAH : subarachnoid hemorrhage, TIA : transient ischemic attack

Table 2. Subtypes of the 67 paraclinoid aneurysms

Subtype of aneurysm	Total (%)
Clinoid-medial	14 (20.9)
Clinoid-anterolateral	1 (1.5)
Ophthalmic	10 (14.9)
Superior hypophyseal	27 (40.3)
Dorsal wall	8 (11.9)
Multiple paraclinoid	7 (10.4)

Table 3. Fundus and neck sizes of the 67 paraclinoid aneurysms

Fundus size	Neck size (%)		Total (%)
	Narrow (<4 mm)	Wide (≥4 mm)	
Tiny (<5 mm)	17 (25.4)	8 (11.9)	25 (37.3)
Small (≥5 mm, <10 mm)	11 (16.4)	17 (25.4)	28 (41.8)
Large (≥10 mm)	4 (6.0)	10 (14.9)	14 (20.9)

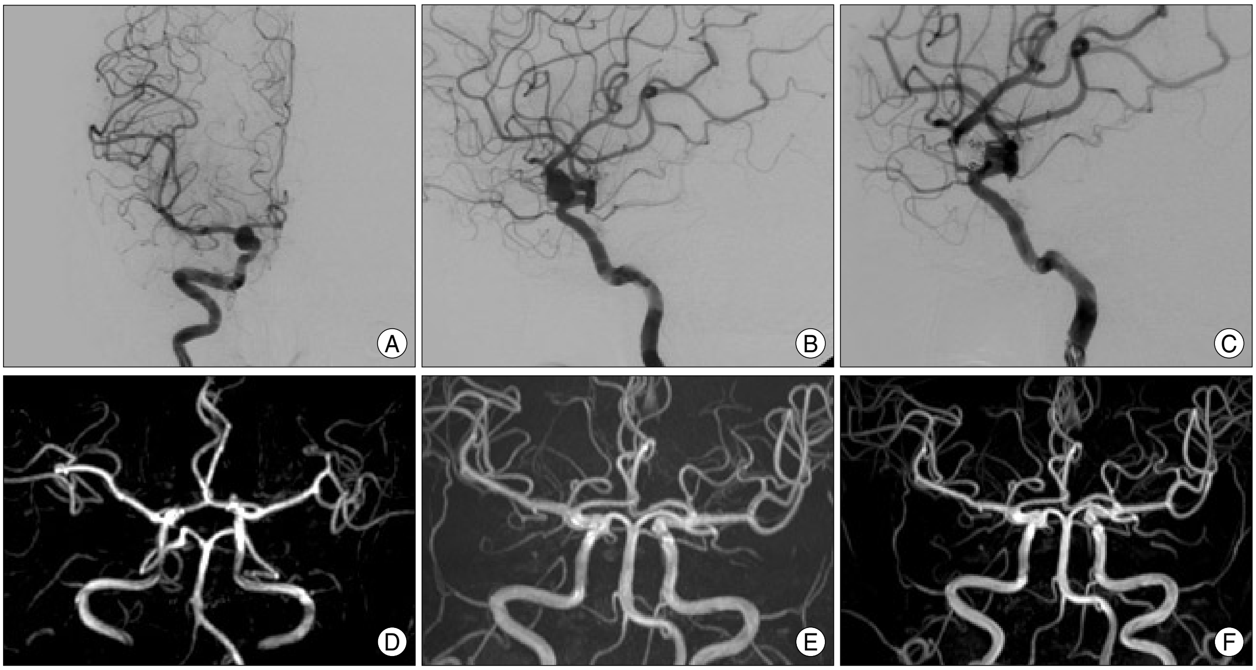

Fig. 1. Preoperative anteroposterior (A) and lateral (B) right carotid artery (CA) angiogram, revealing a dorsal wall aneurysm arising from the distal portion of the ophthalmic artery. Final lateral angiogram (C) after detachable coil embolization confirmed a small residual neck of the aneurysm. About 6 months later, follow-up 3D time of flight (TOF) magnetic resonance images (MRI) (D) shows that the small residual neck of the dorsal wall aneurysm is suspicious. Post-embolization 3D TOF MRI (E) taken one-and-half year later shows no definite residual sac. Post-embolization magnetic resonance angiography (F) performed at two-and-half year later confirms no definite residual sac or neck.

cular procedures.

Radiological follow-up was performed for 55 aneurysms, with mean follow-up of 29.7 months; 3D-TOF MRI was performed for 44 aneurysms; 3D-TOF MRI with conventional angiography was performed for 9 aneurysms; conventional DSA was performed for 1 aneurysm as a mean of radiological follow-up. Routine follow-up evaluation by 3D TOF MRI or conventional DSA was generally performed after 6 months if the aneurysms were completely obliterated, but after 3 months if the aneurysms were incompletely occluded, and every year thereafter. Conventional digital subtraction angiography (DSA) was also performed to confirm coil compaction or recurrence of the aneurysm.

The follow-up evaluation showed that 12 aneurysms initially demonstrating residual neck (class II) and 5 demonstrating residual sac (class III) showed complete occlusion (Fig. 1). Of these, two aneurysms with incomplete occlusion after coil embolization were treated for coil compaction or recurrence of aneurysms. The other 15 aneurysms with incomplete occlusion after initial treatment occluded spontaneously. At the last necessary radiological follow-up, of the 55 evaluable aneurysms, 39 (70.9%) showed complete occlusion (class I), 11 (20%) showed residual neck (class II), and 5 (9.1%) showed residual sac (class III) (Table 4).

There were 6 procedural related complications (7.6%) among the 79 procedures (Table 5). The patient with middle cerebral artery territory infarction after embolization suffered from dense left upper extremity weakness (motor grade I/V) but recovered with slight motor deficit (motor grade IV+/V). Other complications except this did not affect morbidity directly. There was no permanent neurological morbidity. Rupture of aneurysms did not occur during any of the procedures.

Table 4. Radiological outcomes of initial embolization and final radiological follow-up in 55 paraclinoid aneurysms

Initial degree of occlusion	Final follow-up degree of occlusion			Total (%)
	Complete	Residual neck	Residual sac	
Complete	22	0	0	22 (40.0)
Residual neck	12	8	2	22 (40.0)
Residual sac	5	3	3	11 (20.0)
Total (%)	39 (70.9)	11 (20.0)	5 (9.1)	55 (100)

Table 5. Procedure-related complications in the embolization of paraclinoid aneurysms

Complications	Total (%)
ICA dissection	1 (1.3)
Puncture site hematoma	1 (1.3)
Thromboembolic	3 (3.8)
Major infarction	1 (1.3)

Table 6. Clinical outcomes of paraclinoid aneurysms with respect to clinical status at presentation

GOS	Clinical status (No. of patients)			Total (%)
	Unruptured	H-H gr 1-2	H-H gr 3-4	
Good recovery	56	5	2	63 (96.8)
Moderate disabilty	0	0	1	1 (1.6)
Severe disability	0	0	0	0
Vegetative state	0	0	0	0
Death	0	0	1	1 (1.6)

GOS : Glasgow Outcome Scale, H-H : Hunt&Hess, gr : grade

According to the Glasgow Outcome Scale (GOS), 64 patients (98.4%) treated by coil embolization had good recovery or moderate disability (Table 6). One patient died from diffuse brain swelling originating from dense SAH.

DISCUSSION

Paraclinoid aneurysms, which account for approximately 1.5-8% of all intracranial aneurysms[15,25,35,37)], occur more frequently in women than in men[5,18,27,28)]. Patients with paraclinoid aneurysms are likely to have multiple lesions, particularly at sites such as the posterior communicating artery, the contralateral paraclinoid artery, and the cavernous ICA segment[3,13,15,25,52,54)]. A significant number of paraclinoid aneurysms are found incidentally[13,27,51)], and they frequently present with large size[4,27,32)]. Similar to previous reports, we found that 52 out of our 65 patients (80%) were women, and paraclinoid aneurysms were found incidentally in 35 (53.8%) patients.

There have been many definitions and classifications of aneurysms arising in proximity to the anterior clinoid process, with some classifications according to their anatomic relationship to the carotid artery, optic nerves, and chiasm[2,3,5,13,20,27,33,42,52,54)]. We included all aneurysms arising from the ICA between the roof of the cavernous sinus and the origin of the posterior communicating artery. According to the recent anatomical segmentation of the ICA[7)], this portion of the ICA corresponds to the clinoid (C5) and ophthalmic (C6) segments. Aneurysms arising on the distal cavernous ICA were excluded because no definite methods could differentiate these aneurysms intradurally or extradurally.

Paraclinoid aneurysms were specifically classified as described previously[11,13,14)], with the two clinoid segment variants differentiated according to their site of origin and direction of fundus. The anterolateral variant arises from the anterolateral surface of the clinoid segment as it obliquely ascends toward the dural ring, whereas the medial variant extends from the medial surface of the clinoid segment and enlarges toward the sphenoid sinus and sella. Three aneurysm subtypes originate from the ophthalmic segment. Those showing a clear association with the ophthalmic artery were defined as ophthalmic artery aneurysms. Those arising from the inferior or inferomedial surface of the ICA in close association with origin of the superior hypophyseal artery were defined as superior hypophyseal artery aneurysm. Those arising along the dorsal surface of the ICA distinctly distal to the ophthalmic artery origin were defined as dorsal wall aneurysms. According to another specific subclassification of paraclinoid aneurysms[1)], those arising distal to the origin of the ophthalmic artery and proximal to the posterior communicating artery were defined as superior hypophyseal aneurysms projecting superiorly or ventral paraclinoid aneurysms projecting posteroinferiorly; those arising at the junction of the ophthalmic artery and the ICA were defined as true ophthalmic aneurysms. Medial infraophthalmic and supracavernous aneurysms are designated carotid cave aneurysms if they arise from the ICA in the clinoid space (carotid cave)[33)]. Superior hypophyseal aneurysms[13,14)] therefore include superior hypophyseal and ventral paraclinoid aneurysms[1)], and clinoid aneurysms[13,14)] include carotid cave and transitional aneurysms[1)]. Subclassification according to location, however, is not important for the endovascular treatment of paraclinoid aneurysms. Rather, it is important to preoperatively localize the lesion in relation to the distal dural ring (DDR), which will discriminate it intradurally or extradurally. Thus, for endovascular procedures, a new classification of paraclinoid aneurysms according to their relationship to the DDR and distinguishing intradural and extradural aneurysms, may be required for adequate treatment. High-resolution MRI or CT analysis may discriminate intradural from extradural paraclinoid aneurysms.

In general, direct surgical clipping of the aneurysm at the neck and preserving the circulation through the parent vessel have been the procedure of choice for the treatment of paraclinoid aneurysms. However, mortality rates range from 20% to 60%, with good outcomes reported from 40% to 71%[15,25,31,35,47)]. This led to the development of indirect techniques, including common carotid artery ligation, ICA occlusion with a balloon and with or without extracranial-intracranial bypass (EIAB), or aneurysm trapping with or without EIAB[19,27,31,37,50)]. These indirect techniques, however, are associated with increased risks of ischemic complications and do not always provide favorable outcomes[21,27,29,41,49)].

Advances in microcatheter technology, endovascular techniques, and embolization materials have increased the popularity of neurointerventional therapy for paraclinoid aneurysms[8]. The major advantage of endovascular occlusion of cerebral aneurysms is that it is less invasive and more economical compared with clipping. Additionally, a prospective, randomized, controlled trial, found that patients who underwent endovascular coiling of ruptured intracranial aneurysms had a 6.9% absolute reduction in the risk of dependency or death at 1 year, compared with those who underwent surgical clipping[39]. Nevertheless, direct surgical clipping is used for some specific paraclinoid aneurysms inappropriate for endovascular detachable coil embolization. In addition, the durability of direct surgical treatment may favor direct clipping for young patients with paraclinoid aneurysms.

The follow-up of the paraclinoid aneurysms that showed incomplete occlusion after detachable endovascular coiling revealed that some showed spontaneous complete occlusion, some showed no change from previous images, and some showed coil compaction or aneurysm recurrence. We found that the mean diameters of the fundus (5.89±2.738 mm vs 10.50±6.143 mm, p=0.076) and aneurysm neck (3.90±1.014 mm vs. 4.89±1.389 mm, p=0.064) were smaller in paraclinoid aneurysms with spontaneous complete occlusion than in those with coil compaction or aneurysm recurrence. However, there was no statistical significance. We found that age, sex, primary aneurysm origin, and initial occlusion status were not associated with spontaneous complete occlusion. Three-dimensional morphology of the residual portion (e.g., eccentric or concentric residual filling of contrast agent) and coil compaction density, which were not included as independent variables for spontaneous complete occlusion, may be associated with spontaneous complete occlusion of aneurysms treated incompletely by coiling.

Since the introduction of the Guglielmi Detachable Coil (GDC), endovascular treatment of intracranial aneurysms has been shown to be feasible for both ruptured and unruptured lesions, with complication rates of less than 10% and delayed re-bleeding rates of 1-2%[6,9,10,12,16,22,23,30,36,38,40,44,48]. The morbidity and mortality rates following coil embolization were found to be equal to or better than those of published surgical series of similar aneurysms, indicating that an endovascular approach should be considered in the treatment of paraclinoid aneurysms[26,46,51]. In our series, the complication rate was less than 9%, which is somewhat lower than that of surgery[15,25,31,35,47]. Although embolization has been reported to be a safe and efficient alternative modality for paraclinoid aneurysms, aneurysm recurrence and repeated procedures are great disadvantages. Long-term analysis of detachable coil embolization is therefore necessary. One of the limitations of our study was the lack of a surgical control group that may preclude direct comparison of endovascular coiling with surgical clipping. However, when compared with historical controls, detachable coil embolization was a safer and more efficient treatment modality than direct clipping if indications of embolization was applied appropriately to paraclinoid aneurysms[15,25,31,35,47].

CONCLUSION

Our experience with coil embolization for the treatment of intracranial aneurysms suggests that procedural risks are fairly low. As our study demonstrates, detachable coil embolization is an efficient and safe treatment modality for paraclinoid aneurysms. However, to prove the efficacy of endovascular detachable coiling compared with microsurgery in paraclinoid aneurysms, radominzed multicenter case-control study is necessary.

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