Outcomes Analysis of Ruptured Distal Anterior Cerebral Artery Aneurysms Treated by Endosaccular Embolization and Surgical Clipping

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Key words: distal ACA, aneurysm, endovascular surgery, clipping surgery

Summary

Although endovascular surgery is now widely used to treat intracranial aneurysms, no comparative studies of clipping versus endovascular surgery to address distal ACA aneurysms at the same institution are available. We compared the results of these treatment modalities to address distal ACA aneurysms at our institution.

We treated 68 patients with ruptured distal ACA aneurysms (endovascular surgery, $n=13$; clipping surgery, $n=55$). We performed a retrospective comparison of the treatment outcomes. To study the efficacy of endovascular surgery we classified all our cases into three types: type A were small-necked aneurysms, type B were wide-necked aneurysms on the parent artery, and type C were aneurysms in which the A3 portion of the ACA arose from the aneurysmal dome near the neck.

Intraoperative hemorrhage occurred in 7.7% of aneurysms treated by endovascular surgery and in 34.5% treated by clipping surgery. In 7.7% of the endovascularly-treated aneurysms we noted coil migration during embolization surgery; venous infarction due to cortical vein injury occurred in 7.3% of clipped aneurysms. Of the endovascularly-treated aneurysms, 7.7% manifested post-embolization hemorrhage; 23.1% manifested coil compaction. In clipping surgery, postoperative rerupture occurred in 1.8% of the aneurysms; one patient presented with postoperative acute epidural hematoma. Clip dislocation was noted in 1.8% of aneu-

rysms. Angiography was indicative of post-treatment vasospasm in 7.7% of aneurysms treated endovascularly and in 50.9% of the clipped aneurysms.

The clinical outcome showed no significant difference between endovascular surgery and clipping surgery.

Introduction

Distal anterior cerebral artery (ACA) aneurysms are relatively rare, comprising between 1.5 and 9.0% of all intracranial aneurysms^{1,2}, and tend to develop at the pericallosal-callosomarginal junction¹. Ohno et al.³ reported that 67% of ruptured distal ACA aneurysms were less than 5 mm in diameter. As these aneurysms are characterized by several anatomical features such as an azygous-type ACA anomaly, a persistent anatomical communication between the right and left sides, an anterior communicating artery complex, or a developing bridging vein disturbing the access route, the depth of the surgical exposure and relative narrow surgical corridors, their treatment by direct surgery is difficult. Rupture of distal ACA aneurysms may result in subarachnoid hemorrhage and the development of intracerebral or intraventricular hematoma (ICH, IVH)³⁻⁵.

Among patients with distal ACA aneurysms a high rate (40-55%) of multiple aneurysms at other vessels has been reported³⁻⁵. According to a recent ISAT report⁶, endovascular surgery

Figure 1 The aneurysms are classified into 3 types and the results of treatment are compared. Type A, small-necked aneurysms. Type B, wide-necked aneurysms on the parent artery. Type C, aneurysms in which the A3 portion of the ACA is separated from the aneurysmal dome.

is more effective than clipping surgery for the treatment of ruptured anterior circulation aneurysms and endovascular surgery is now widely used to manage intracranial aneurysms. However, at present there are no comparative studies examining the outcomes in patients treated at the same institution by clipping or endovascular surgery to address distal ACA aneurysms. We compared the results of these treatment modalities to address ruptured distal ACA aneurysms at our institution.

Materials and Methods

Between 1987 and 2009 we treated 68 patients with non-bacterial saccular ruptured distal ACA aneurysms at our hospital. Thirteen aneurysms were treated by endovascular sur-

gery, and 55 aneurysms treated by clipping surgery. Thirteen patients were treated by endovascular surgery, six men and seven women aged from 36 to 81 years (mean 56.6 years). Fifty-five patients were treated by clipping surgery, 23 men and 32 women aged from 35 to 83 years (mean 58.0 years).

Selection of the treatment method was not randomized in this study. In selecting embolization, we considered the patients' age older than 65 years or overall health (WFNS grade IV or V) or the patient's wishes or hematoma volume which does not present a symptom of high intracranial pressure or possible complications.

Endovascular surgery was by endosaccular embolization without the balloon neck remodeling technique. Patients with ruptured aneurysms were placed under general anesthesia, those with unruptured aneurysms were treated

Table 1 Clinical and angiographic findings.

		endovascular surgery	clipping surgery
period		1997-2009	1987-2009
cases		13	55
SEX	male	6	23
	female	7	32
Age	mean	56.6	58
H&K grade	I	4	27
	II	1	7
	III	1	2
	IV	4	11
	V	3	8
Location	infracallosal	1	2
	genu	12	51
	supracallosal	0	2
Morphology	saccular	13	55
	fusiform	0	0
	dissecting	0	0
Radiological	azygos	2	4
	ICH/IVH (SAH)	5	36
	multiple	1	18
	spasm	1	31

under local anesthesia. All patients treated by endovascular surgery received systemic heparinization; we delivered a 2000-unit heparin bolus followed by continuous intra-arterial infusion of 200 units/min. The activated coagulation time (ACT) was maintained at more than twice the control value. In attempts to preserve the parent artery, where necessary we left an aneurysmal neck remnant after packing the aneurysmal sac with coils. We used the femoral artery approach to address 11 aneurysms and three aneurysms were approached directly via the common cervical artery first. The approach route was changed in one patient from the femoral artery to the common carotid artery.

Clipping was performed under general anesthesia using the interhemispheric or pterional approach. The goal of direct surgery was preservation of the parent artery. Intraoperatively we monitored the ACA flow by Doppler monitoring. In patients with intracerebral hematoma we attempted removal. Acute hydrocephalus was addressed by ventricular drainage as soon as possible.

Ours is a retrospective comparative study of the outcome following endovascular or clipping surgery to treat patients with distal ACA aneurysms. To assess the efficacy of endovascular surgery we classified all aneurysms as small-necked aneurysms with a dome / neck (D/N) ratio more than 1.5 (type A), as wide-necked aneurysms with a D/N ratio less than 1.5 located on the parent artery (type B), and as aneurysms in which the A3 portion of the ACA arose from the aneurysmal dome near the neck (type C) (Figure 1).

Results

Clinical and angiographic findings

Clinical and angiographic findings are shown in Table 1. Of the 13 aneurysms treated by endovascular surgery, 12 were located at the A2/A3 portion of the ACA, the other arose at the infracallosal portion of the ACA. One of the aneurysms manifested an azygous ACA anomaly. The H&K classification was grade I in four, grade II and III in one each, grade IV in four, and grade V in three aneurysms treated by endovascular surgery. We clipped 55 aneurysms; 51 were located at the A2/A3 portion of the ACA, and two each at the infra and supracallosal part of the ACA, four aneurysms mani-

fested an azygous ACA anomaly (Table 1). Five aneurysms (38.5%) treated endovascularly manifested ICH and/or IVH as did 36 (65.5%) aneurysms treated by clipping surgery. Multiple aneurysms were present in one patient treated by endovascular surgery and in 18 patients who underwent clipping. Of the 13 aneurysms treated by endovascular surgery, we classified six as Type A, five as type B, and two as type C. Of the 55 aneurysms treated by clipping surgery, we classified 29 as Type A, 18 as type B, and eight as type C. Of the distal ACA aneurysms 48.5% were wide-necked in which the A3 portion of the ACA arose from the aneurysmal dome near the neck.

Surgical approaches

As shown in Table 2, in most cases, the approach to endovascular surgery was via the femoral artery. In the course of one endovascular procedure we were forced to change the approach route to direct common cervical artery puncture. Clipping surgery was performed by interhemispheric approach in 54 patients and by pterional approach in one, respectively.

Treatment results

The success rate was 92.3% in endovascular surgery and 98.2% in clipping surgery. Two patients were unable to undergo the originally planned intervention and were treated by other methods. Of the aneurysms addressed by endovascular surgery, four were occluded completely, in eight there was a neck remnant, and in one dome filling was performed; the mean overall follow-up period was 42.7 months (range 3-120 months). Among the clipped aneurysms, 44 underwent complete neck clipping, in eight there was a neck remnant, and three were addressed by dome clipping; the overall mean follow-up period was 26.6 months (range 1-110 months).

Intra and post-operative complications

Intraoperative hemorrhage occurred during one endovascular and 19 clipping procedures; there was one instance of coil migration during embolization. Venous infarction due to iatrogenic cortical vein injury occurred in four instances of aneurysmal clipping. Post-embolization hemorrhage occurred in one case and coil compaction in three. One aneurysm re-rup-

tured after clipping and one patient manifested acute post-operative epidural hematoma. Clip dislocation occurred in one case and post-operative angiographical vasospasm was recorded in one patient (7.7%) treated by endovascular surgery and in 28 patients (50.9%) treated by clipping surgery.

Treatment outcomes

The outcomes at one month for aneurysms treated by endovascular surgery or clipping are shown in Table 2. Of 13 aneurysms treated by endovascular surgery, 61.5% received a rating of good recovery on the Glasgow Outcome Scale compared to 40% of clipped aneurysms. The rate of moderate and severe disability was higher among clipping surgery than endovascular surgery patients.

Case Presentation

This 60-year-old man suffered sudden-onset headache. On admission to our hospital he manifested no neurological deficits. Computed tomography (CT) demonstrated subarachnoid hemorrhage at the right sylvian and interhemispheric cisterns (Figure 2A, B). Right ICA angiography revealed aneurysms at the right middle cerebral artery (MCA) and the distal portion of the right ACA (Figure 2C). As it was difficult to identify the aneurysmal rupture site we performed endovascular surgery. At the start of the procedure we delivered a 2000 U bolus of heparin, during the procedure heparin was infused systemically (200 U/min). His activated coagulation time was maintained at more than twice the control value. Endovascular surgery was via the right femoral artery using an

Table 2 Results of each treatment.

		endovascular surgery	clipping surgery
Approach	via femoral artery	11	
	via common carotid artery	3	54
	interhemispheric		1
	pterional	1	0
	approach change		
Treatment	endosaccular embolization	13	
	parent artery occlusion	0	
	neck clipping		55
	parent artery trapping		0
Intra-operative complications	bleeding	1	19
	infarction	0	0
	venous infarction	0	4
Post-operative complications	coil migration	1	
	coil compaction	3	
	clip dislocation		1
	re-bleeding	1	1
	post op AEDH	1	1
	spasm (symptomatic+asymptomatic)		28
Occlusion	complete occlusion/clipping	4	44
	neck remnant	8	8
	dome filling/clipping	1	3
Follow up (mean; month)		42.7	26.6
Outcome(GOS)	GR	8	22
	MD	3	18
	SD	2	12
	VS	0	2
	D	0	1

ENVOY guiding catheter (6 Fr; Cordis/Johnson & Johnson, Miami, FL, USA). An Excelsior SL-10 microcatheter (Boston Scientific) was introduced into the distal ACA aneurysm over the guidewire and the aneurysm was embolized with Guglielmi detachable coils (GDC; Boston Scientific) and MicroSpheres (Micrus Co.Ltd, USA). A post-embolization angiograph showed complete aneurysmal occlusion (Figure 2D). Next an Excelsior SL-10 microcatheter was introduced into the MCA aneurysm over the guidewire and the aneurysm was embolized with GDC and MicroSpheres. Systemic heparin infusion was continued during the first 24 h after endovascular surgery and antiplatelet drugs were administered. Angiography after endovascular surgery demonstrated an aneurysmal neck remnant (Figure 2D). This patient suffered no complications during or after endovascular surgery. The original source of magnetic resonance angiography (MRA) images performed 12 months post-treatment demonstrated complete occlusion of the distal ACA aneurysm (Figure 2E) and a neck remnant of the MCA aneurysm (Figure 2F).

Discussion

The characteristics of distal ACA aneurysms are the coexistence of multiple aneurysms and ICH and IVH due to aneurysmal rupture⁵. An azygos ACA was identified in 1.1% of anatomically³ and 1.3% of radiologically studied cases⁷. According to Stefani et al.⁸, the diameter of the proximal ACA (A1 portion) is 2.61 ± 0.34 mm and that of the distal ACA (A2, A3 portion) is only 0.79 ± 0.27 mm: this difference

makes treatment difficult. Although a recent ISAT report⁶ documented that with respect to ruptured aneurysms, endovascular treatment was more efficient than clipping surgery, there are few reports on the efficacy of endovascular surgery to address distal ACA aneurysms.

Clipping of distal ACA aneurysms

As shown in Table 3, the reported morbidity and mortality rates in patients who underwent clipping surgery of distal ACA aneurysms ranged from 0 - 65% and from 0 - 9.3%, respectively^{2,3,9-15}. Furthermore, many patients suffered intra-operative hemorrhage. The pterional and subfrontal approaches tend to be used when the aneurysm is located at the proximal ACA. Because distal aneurysms tend to arise at the pericallosal-callosomarginal artery bifurcation, most are addressed via the interhemispheric approach although this approach is complicated by the aneurysm's relative anatomical orientation. In the case of aneurysmal rupture, the presence of a hematoma raises additional issues regarding the anatomical orientation around the aneurysm. There is a high incidence of venous infarction attributable to iatrogenic cortical vein and brain tissue injury due to strong intraoperative brain retraction. In addition, from the perspective of anatomical positions, intraoperatively, the aneurysmal dome is seen before the neck, raising the incidence of intraoperative hemorrhage. In our series, angiography revealed a high rate of postoperative vasospasm due to mechanical vessel damage. Therefore, a clear understanding of the micro-anatomy is necessary to decrease complications from clipping surgery for distal ACA aneurysms.

Table 3 Summary of previously reported results of clipping surgery.

Series	Number of Patients	success rate	intraoperative hemorrhage	brain contusion	venous infarction	Outcom(GOS); %		
						MD, SD, VS	D	GR
Mann et al. (1984)	11	100	?	?	?	27.3	0	72.7
Ohno et al. (1990)	34	100	?	?	?	?	?	88
de Sousa et al. (1999)	72	100	?	?	?	?	6.9	?
Heresnimi et al. (1992)	54	100	10	?	?	5.6	9.3	85
Inci et al. (1998)	14	100	?	?	?	0	7	93
Martines et al. (1996)	11	?	?	?	?	?	0	?
Miyazawa et al. (2000)	57	100	14	?	?	26	9	65
Oshiro et al. (2007)	20	100	0	?	?	65	5	30
Dinc et al. (2006)	25	96	0	?	?	12	8	80
Our cases (2009)	55	98	19	?	4	58.2	1.8	40

GR; good recovery, MD; moderate disability, SD; severe disability, VS; vegetative state, D; death

Embolization of distal ACA aneurysms

Table 4 lists previously reported¹⁶⁻¹⁹ and our results obtained by the endovascular treatment of distal ACA aneurysm. The successes, morbidity, and mortality rates are 92.3%, 9.2%, and 2.6%, respectively. Intraoperative hemorrhage occurred during 5.3% of the procedures and 1.3% of treated aneurysms bled postoperatively. There were no instances of postoperative infarction; angiographical vasospasm was recorded in 5.3% and coil compaction in 10.5% of reported patients. Embolization under the neck remnant must be complete to avoid brain damage in surgically clipped aneurysms and to eliminate the risk of postoperative vasospasm.

A disadvantage of endovascular surgery for distal ACA aneurysms is the long access route that complicates manipulation of the microcatheter. In two of our patients we were unable to approach the aneurysm via the femoral artery. Elsewhere we reported the efficacy of direct puncture of the common carotid artery in elderly patients in whom the femoral artery ap-

proach is not possible²⁰. We abandoned this approach in two of our current patients and proceeded using direct puncture of the carotid artery. Shortening of the access route facilitates microcatheter manipulation. Another disadvantage of endovascular surgery involves the morphology of distal ACA aneurysms. Table 5 lists treatment results based on aneurysm histology. Type A aneurysms tend to be completely occluded despite a neck remnant and there were no instances of coil compaction during follow-up. The rate of complete occlusion was not higher in Type B and C aneurysms, and the rate of coil compaction was relatively high. Neck remodeling by balloon-assisted techniques tends to be impossible because the diameter of the ACA is only approximately 1 mm. This raises the risk of confinement of the parent artery and of occlusion or stenosis of the A3 portion of the ACA in Type B and C aneurysms subjected to tight coil packing without the balloon neck-remodeling technique. The very important technical points for embolization are the stability of the guiding catheter for approach, the stability

Table 4 Summary of previously reported results of endovascular surgery.

Author	case	success rate (%)	hemorrhage		spasm	coil compaction	morbidity	mortality
			during EVS	post EVS				
Menovsky et al. (2002)	12	100	0	0	0	1	1	0
Keston et al. (2004)	18	94	3	0	0	4	0	0
Hussain et al. (2005)	5	100	0	0	2	0	1	0
Vora et al. (2008)	28	93	?	?	?	?	3	2
Our cases (2009)	13	92.3	1	1	2	3	2	0
Total	76	94.7	4 (5.3%)	1 (1.3%)	4 (5.3%)	8 (10.5%)	7 (9.2%)	2 (2.6%)

Table 5 Results of successful endovascular surgery for 15 histologically classified aneurysms.

Type	cases	initial			final			follow up period (mean; months)	coil compaction rate (%)
		CO	NR	DF	CO	NR	DF		
A	6	3	3	0	5	1	0	14.5	0
B	5	1	3	1	2	2	1	14.6	40
C	2	0	2	0	0	2	0	4	50

of the microcatheter for endosaccular embolization and selection of coils for tight packing. The stability of the guiding catheter is important for operability of the microcatheter. A co-axial catheter system can be useful to support the stability of guiding catheter because an access route is long. The shape of the microcatheter is very important for the stability of microcatheter, so shaping the microcatheter is based on the morphological date of each aneurysm. Sometimes a 14 type guide wire produces the driving force of the 10 type microcatheter. Endosaccular embolization must be undertaken without the balloon-assisted technique because the distal ACA is too thin to insert a balloon catheter. So making a cage with the first coil is very important. Sometimes a 3D-coil is used first, but attention is necessary in the ruptured aneurysm. To ensure tight intra-aneurysmal coil packing, ten soft type 2D coils are useful.

Comparison of treatment results in our institution

The success rate was higher in the group of clipping surgery (98.2%) than the group of endovascular surgery (92.3%). In most patients scheduled for endovascular surgery it is possible to determine the appropriate approach route. In 30.8% of patients in the endovascular surgery group we obtained complete aneurysmal occlusion, in 61.5% there was a neck remnant, and in 7.7% we achieved dome filling. In the clipping surgery group, complete neck clipping was successful in 80%, and neck remnant and dome clipping in 20%. Among endovascular surgery group patients the complete occlusion rate was low due to the morphology of their aneurysms; the coil compaction rate was 23.1%. The postoperative hemorrhage rate was higher in the endovascular surgery group (7.7%) than the clipping surgery group (1.8%). Intraoperative hemorrhage occurred in 34.5% of clipping surgery group patients and 7.7% of endovascular surgery group patients. These complications are attributable to strong brain retraction during clipping surgery and the microanatomical loca-

tion of the aneurysms although they did not result in an increase in the mortality rate.

Venous infarction due to injury to the cortical vein during clipping surgery occurred in 7.3% clipping surgery group patients. Postoperative angiographically-confirmed vasospasm, primarily attributable to mechanical manipulation during clipping surgery, was higher in the clipping surgery group (50.9%) than the endovascular surgery group (7.7%). Of the endovascular surgery group patients, 61.5% made a good recovery (GR), 23.1% manifested moderate disability (MD), 15.4% manifested severe disability (SD) and none were in a vegetative state (VS) or died from treatment-associated causes. In the clipping surgery group, 40% of the patients received a rating of GR and 32.7% manifested MD; 5.5% were recorded as VS or deceased. There was no statistically significant difference in the treatment outcome between clipping surgery and endovascular surgery.

In general, clipping offers advantages over endovascular treatment in patients with distal ACA aneurysms, however, it demands expert surgical skills. Clipping tends to decrease the complication rate. However, patients with distal ACA aneurysms tend to harbor additional aneurysms at other locations, and this complicates the development of effective treatment strategies. Endovascular surgery is advantageous in these patients because it allows the treatment of multiple aneurysms during the same non-invasive procedure. To avoid coil compaction, care must be taken to avoid overly tight coil packing and the blood flow in the parent artery must be preserved. We suggest that combined clipping and endovascular surgery may be a useful method to treat patients with aneurysms.

Conclusion

Neither clipping nor endovascular surgery for distal ACA aneurysms is easy. The advantages and disadvantages of both treatment methods must be understood to select the best treatment on a patient-by-patient basis.

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