



Original Article

# Clipping versus coiling in unruptured anterior cerebral circulation aneurysms

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Received : 02 January 20

Accepted : 01 March 20

Published : 21 March 20

DOI

10.25259/SNI\_1\_2020

Quick Response Code:



## ABSTRACT

**Background:** Unruptured intracranial aneurysms (UIAs) are not uncommon, especially in Japan. Treatment strategy for UIAs has evolved in the past decades in Western countries with the increased use of endovascular treatment as the primary option, but in Japan, clipping still has the upper hand.

**Methods:** This study retrospectively included 200 patients treated by clipping or coiling for UIAs located in the anterior cerebral circulation. Postoperative angiographic and clinical outcomes were evaluated.

**Results:** Of 200 UIAs, 147 and 53 were treated by surgery and coiling, respectively. The average follow-up duration was  $30.2 \pm 18.8$  months for clipping and  $29.3 \pm 17.6$  months for coiling. Complete occlusion was greater in the surgery group (78.9%) than the endovascular group (18.8%). Regrowth occurred in 1.4% of the clipping group and 13.2% of the coiling group. Ischemic events were encountered in both groups; asymptomatic ones were higher in the coiling group (24.5%) than in the clipping group (2%), while symptomatic ischemic complications were equal (7.5%) in both groups. The deterioration of modified Rankin scale was detected totally in 13 UIAs (6.5%) with no statistical difference between groups. Postoperative hospital period was longer in clipping ( $P = 0.01$ ).

**Conclusion:** Clipping and coiling were both safe and feasible in the treatment of unruptured aneurysms. The clipping was advantageous in durability, while the rate of morbidity was lower, and hospitalization period was shorter in the coiling group. The clipping and coiling should coexist while complementing each other by understanding the advantages and disadvantages of both.

**Keywords:** Anterior circulation, Clipping, Coiling, Unruptured aneurysm

## INTRODUCTION

For patients with unruptured intracranial aneurysms (UIAs), the options of treatment are variable, including microsurgical clipping and endovascular coil embolization.<sup>[19]</sup> In the USA and many advanced European countries, the strategy for the treatment of UIA has changed with an increasing trend to use endovascular coiling to become the primary option for treatment.<sup>[5,19]</sup> On the other side in Japan, microsurgical clipping still has the upper hand in the treatment of UIA.<sup>[3]</sup>

The detection of UIA in Japanese has been common and increased because of the countrywide development of medical brain checkup systems using magnetic resonance angiography (MRA) for asymptomatic persons. As a result, a large meta-analysis demonstrated that by comparison

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with populations from North America and European countries, Japanese people had a 2.8 times increased risk of aneurysm rupture.<sup>[2,10,20]</sup> Moreover, recent Japanese cohort studies revealed the high ratio of poor outcome (death or severe disability) in the cases with rupture of UIA.<sup>[20]</sup> The derivation data from the Unruptured Cerebral Aneurysm Study Japan showed a wide range of 3-year rupture risk (from <1% to >15%).<sup>[28]</sup> The clinical question, however, how to treat the patients with UIA to achieve the durable protection from aneurysm rupture with quite low mortality and morbidity rate has been still controversial.

There have been several articles concerning ruptured cerebral aneurysms such as ISAT and BRAT, but, for unruptured aneurysms, only one small randomized controlled trial (RCT) has been reported and the optimization of these two treatments has not been well established.<sup>[7]</sup> This study was retrospectively performed in Japan where we saw the rapid transition from microsurgery to endovascular treatment, and despite the limited number of cases in a single center, we believe that this study will facilitate the discussion on optimization of each treatment.

## MATERIALS AND METHODS

We retrospectively reviewed 200 UIAs treated in our institution from January 2012 to December 2016. The current study included patients treated by microsurgical clipping or endovascular coiling for UIA located in anterior circulation either symptomatic or larger than 3 mm. The cases with complicated UIA such as giant (>25 mm), thrombosed, dissection, or located in the cavernous portion were excluded from the study. The selection of treatment for each case was based on characteristics of individual patients and aneurysms offering both modalities of treatment taking into account patient preference. All clipping and coiling cases were performed on with monitoring of motor evoked potential and somatosensory evoked potential. In clipping cases, the patency of the parent artery, major branches, and visible perforators was confirmed with laser Doppler flowmetry and indocyanine green angiography.

### Angiographic results

Angiographic results were divided into complete occlusion, presence of postoperative neck remnant, and re-growth on follow-up. Postoperative computed tomography (CT) images were obtained in the 1<sup>st</sup> and 7<sup>th</sup> postoperative days after clipping. In coil embolization, CT was obtained in the 1<sup>st</sup> postoperative day and magnetic resonance imaging (MRI) in the 5<sup>th</sup> postoperative day, other follow-up imaging was done at variable intervals depending on the case. Imaging included CT angiography, MRA, and/or digital subtraction angiography [Table 1].

**Table 1:** Imaging modalities during follow-up.

CTA (%)	19 cases (9.5)
MRA (%)	79 cases (39.5)
CTA+MRA (%)	80 cases (40)
MRA+DSA (%)	18 cases (9)
CTA+MRA+DSA (%)	4 cases (2)

CTA: Computed tomography angiography, MRA: Magnetic resonance angiography, DSA: Digital subtraction angiography

### Ischemic events and clinical outcomes

Ischemic events were defined by the presence of infarction on subsequent CT scan or MRI or angiographic occlusion of a blood vessel by the time of hospital discharge regardless of the presence of symptoms.

The primary outcomes were evaluated as operative complications such as neurological morbidity (irrespective of duration), the presence of postprocedure hemorrhage (subdural, extradural, cerebral, and subarachnoid hemorrhage), or infection (wound infection, meningitis, and pneumonia). The secondary clinical outcome was evaluated by the worsening of the modified Rankin scale (mRS) at discharge.

### Independent variables

Independent variables investigated as possible risk factors for outcomes included demographic data of patients (age, sex, presence of diabetes mellitus, hyperlipidemia, and hypertension), aneurysm data (location, neck width, dome diameter – parallel to the neck and measured at the largest separation between the aneurysm walls, aneurysm height – the maximum perpendicular distance of the dome from the neck plane, presence of daughter sac, incorporate artery – a branch that is incorporated into the aneurysm wall apart from the normal parent artery, and multiple aneurysms), procedure-related data (temporary arterial occlusion in surgery – the use of balloon and stent in coiling).

### Statistics

Categorical variables expressed as a percentile, continuous variables as mean  $\pm$  SD. Univariate analysis is done using Chi-square test, Fisher's exact test, and unpaired *t*-test as appropriate. Multivariate analysis is conducted by multivariate logistic regression and included independent variables that are significant in univariate analysis ( $P < 0.05$ ), there was only one variable  $<0.05$  in two occasions, in which we considered variables  $<0.1$  for multivariate analysis.

### Informed consent

Informed consent is obtained from the patients by the way of the opt-out condition. The present study was approved by

the Ethics Committee of Keio University School of Medicine and was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

## RESULTS

### Characteristics of patients and aneurysms

The baseline characteristics of patients and aneurysms are shown in Table 2. Of 200 UIAs, 147 and 53 were treated by surgery and coiling, respectively. Between treatment groups, the location of the aneurysms, the dome diameter, and the presence of a daughter sac showed a significant difference. In the coiling group, 47 UIAs (88.7%) were located at internal carotid artery (ICA). In contrast, UIAs located at MCA and ACA treated by coiling were only 1 (1.9%) and 5 (9.4%), respectively. The daughter sac was obtained 42 (79.2%) and 92 (62.6%) in the endovascular group and the surgery group, respectively. The length of dome was significantly longer in the endovascular group.

### Ischemic events and clinical outcomes

In this study, the average follow-up duration was  $30.2 \pm 18.8$  months for the surgery group and  $29.3 \pm$

17.6 months for the coiling group. As shown in Table 3, the deterioration of mRS was detected totally in 13 UIAs (6.5%). The occurrence rate was not statistically significant in the clipping group (10 of 147) and the coiling group (3 of 53).

The other evaluated factors of outcome are shown in Table 4. The efficacy of treatment with complete occlusion was greater in the surgery group (78.9%) than the endovascular group (18.8%). Likewise, the occurrence rate of neck remnant and residual neck was higher in the coiling group than the clipping group. Of these incomplete treated UIAs, regrowth occurred in 1.4% of the clipping group (both were treated by IVR later) and in 13.2% of the coiling group (three were recoiled) ( $P = 0.001$ ).

During surgery, six UIAs were judged as difficult cases to apply the clip and coating was done (two treated later by coiling and four continued under follow-up). In four UIAs, coiling was renounced during the procedure (one is treated by clipping and three continued under follow-up).

Ischemic events were encountered in both groups; the rate of asymptomatic ones is statistically higher in the coiling group (24.5%) than in the clipping group (2%). In contrast, the occurrence rate of symptomatic ischemic complication is almost equal (7.5%) in both groups. Only one case in the

**Table 2:** Demographic criteria of patients and aneurysms.

Characteristics	Microsurgery (147) (%)	Endovascular (53) (%)	P-value
Age (years)	64±9.5 95% CI (62.5–65.6)	60.8±12.5 95% CI (57–64)	0.1
Gender			
Female	96 (65.3)	39 (73.6)	0.3
Male	51 (34.7)	14 (26.4)	0.3
Hypertension	53 (36)	24 (45.3)	0.2
DM	18 (12.2)	4 (7.6)	0.4
Hyperlipidemia	17 (11.5)	8 (15.1)	0.5
Other comorbidities	99 (67.3)	32 (60.4)	0.4
Asymptomatic presentation	144 (98)	53 (100)	0.6
Aneurysm criteria			
Location of aneurysm			
ICA	50 (34)	47 (88.7)	<0.001*
MCA	56 (38.1)	1 (1.9)	<0.001*
ACA	41 (27.9)	5 (9.4)	0.006*
Maximum diameter of dome (mm)	5.1±2.3 95% CI (4.7–5.5)	6.13±3.1 95% CI (5.3–7)	0.03*
Maximum height of the sac (mm)	5.03±2.1 95% CI (4.7–5.4)	5.6±1.8 95% CI (5.1–6.1)	0.05
Neck width (mm)	3.6±1.5 95% CI (3.4–3.9)	3.6±1.7 95%CI (3.2–4.1)	0.9
Presence of daughter sac	92 (62.6)	42 (79.2)	0.03*
Presence of incorporate artery	26 (17.7)	16 (30.1)	0.05
ICA	14 (28)	15 (32)	0.7
MCA	9 (16)	0	0.9
ACA	3 (7.3)	1 (20)	0.4
Operative			
Temporary arterial occlusion	39 (26.5)		
Balloon-assisted coiling		28 (52.8)	
Stent-assisted coiling		3 (5.6)	

\*Statistically significant. DM: Diabetes mellitus, ICA: Internal carotid artery, MCA: Middle cerebral artery, ACA: Anterior cerebral artery, IA: Incorporate artery

**Table 3:** Cases with permanent morbidity.

Sex	Age	Location	Dome mm	Neck mm	Modality	Drop-in mRS	Clinical	Etiology	Notes
F	58	Lt. MCA	3.7	2.4	Clipping	4	Rt. hemiplegia-aphasia-Rt. facial spasm	Infarction	M1 perforator
M	70	Lt. MCA	5.3	2.8	Clipping	2	Parkinsonism-Rt. hemiparesis-Lt. ptosis-dysphasia	Infarction in Lt. basal ganglia	M1 perforator
F	54	Rt. IC. Oph. A.	14.8	6.1	Clipping	2	Cognitive impairment	Corpus callosum infarction	Use of balloon in ICA
F	47	Rt. ICA	4.3	3	Clipping	2	Lt. sided weakness	Infarction	Use of balloon in ICA
F	60	Rt. IC. Oph. A.	11.1	10.9	Clipping	1	Rt. ptosis-Rt. eye movement disorder +diplopia	Third nerve injury	
M	56	Acom. A.	5.7	3.1	Clipping	1	Smell impairment	Olfactory N. injury	
F	59	Lt. ICPC A.	5.1	2.3	Clipping	1	Smell impairment	Olfactory N. injury	
F	71	Acom. A.	11.4	6.9	Clipping	1	Smell impairment	Olfactory N. injury	
M	80	Lt. MCA Acom. A.	4.2 3.3	3.9 2.1	Clipping	3	Lt. upper limb weakness- urinary incontinence	Acute subdural hematoma	Patient fell down
F	50	Rt. ICPC A.	5.1	2.7	Clipping	2	Visual field defect of Rt. eye	Unknown	
M	75	Lt. ICA	17.9	10.1	Coiling	2	Rt. upper limb paralysis	Infarction	ACA occlusion due to stent occlusion
F	56	Lt. ICA	8.2	5.4	Coiling	1	Lt. visual field defect	Lt. retinal a. occlusion	Embolitic complication
F	32	Rt. ICA	9.2	6.1	Coiling	1	Lt. lower limb numbness	Infarction	Embolitic complication

F: Female, M: Male, Lt.: Left, Rt.: Right, ICA: Internal carotid artery, ICPC A.: Internal carotid-posterior communicating artery, IC. Oph. A.: Internal carotid-ophthalmic artery, A.com A.: Anterior communicating, artery, MCA: Middle cerebral artery, ACA: Anterior cerebral artery, M1: First part of MCA, mRS: Modified Rankin scale

coiling group showed both symptomatic and asymptomatic ischemic events.

The occurrence rate of temporary morbidity, including limb paralysis, dysphasia, cognitive dysfunction, cranial nerve affection, CSF leak, diabetes insipidus, and encephalopathy, was significantly higher in the surgery group. The other complications and occurrence rate in each group are also shown in Table 4. Postoperative hospital period was longer in clipping 11.4 days  $\pm$  6.3 than in coiling 7.4 days  $\pm$  10.6 ( $P = 0.01$ )

#### Predictors for neck remnant and regrowth

Cases, in which clipping and coiling could not be achieved, were excluded from the analysis of postoperative neck remnants. For the surgery group, univariate analysis of risk

factors presented the dome diameter  $>10$  mm ( $P = 0.004$ ), neck width  $> 4$  mm ( $P = 0.0007$ ), and the presence of incorporate artery (IA) ( $P = 0.005$ ) to be significant independent variables. Neck width and the presence of IA are significant in multivariate analysis [Table 5].

For the coiling group, only the presence of IA was significant in univariate analysis ( $P = 0.02$ ). Multivariate analysis was done with variables  $<0.1$ , the presence of IA was significant [Table 5].

For the regrowth, univariate analysis revealed that the dome diameter  $>10$  mm [ $P = 0.02$ ], the height of an aneurysm  $>10$  mm ( $P = 0.02$ ), neck width  $>4$  mm ( $P = 0.002$ ), and the presence of dome filling after coiling ( $P = 0.0006$ ) to be significant independent variables, but none was significant in multivariate analysis [Table 6]. Residual dome filling is strongly associated with the size of the dome [ $P = 0.005$ ].

**Table 4:** Summary of results.

Outcome	Microsurgery (147) (%)	Endovascular (53) (%)	P-value
Complete occlusion	116 (78.9)	10 (18.8)	<0.001*
Neck remnant	25 (17)	32 (60.3)	<0.001*
Regrowth	2 (1.4)	7 (13.2)	0.001*
Retreatment for regrowth	2 (1.4)	3 (5.7)	0.1
Failure	6 (4.1)	4 (7.5)	0.5
Asymptomatic thromboembolism	3 (2)	13 (24.5)	<0.001*
Symptomatic thromboembolism	11 (7.5)	4 (7.5)	0.9
SDH (asymptomatic+symptomatic)	19+6 (17)	0	0.0004*
EDH (asymptomatic)	11 (7.5)	0	0.03*
Contusions+hemorrhage (asymptomatic+symptomatic)	5+5 (6.8)	1+0 (1.9)	0.3
Temporary morbidity	26 (17.7)	2 (3.8)	0.01*
Permanent morbidity	9 (6.1)	2 (3.8)	0.7
Operation for complications	10 (6.8)	3 (5.7)	0.8
Wound infection/meningitis	3 (2)	0	0.6
Pneumonia	2 (1.4)	0	0.9
Postoperative hospital period (day)	11.4±6.3 95% CI (9.9–12.9)	7.4±10.6 95% CI (5.3–9.5)	0.01*

\*Statistically significant. SDH: Subdural hematoma, EDH: Extradural hematoma

**Table 5:** Predictors for neck remnant after clipping and coil embolization.

	Univariate analysis		Multivariate analysis		
	Variable	P-value	P-value	Odds ratio	Confidence interval 95%
Microsurgical clipping	Presence of IA	0.005*	0.03*	3.4	1.1–10.1
	Neck width		0.04*	1.5	1.03–2.3
	Continuous	0.02*			
	Categorical (>4 mm)	0.0007*			
	Dome diameter		0.8	1.03	0.8–1.3
Coil embolization	Continuous	0.02*			
	Categorical (>10 mm)	0.004*			
	Presence of IA	0.02*	0.02*	14.8	2.2–321
	Presence of daughter sac	0.07	0.05	5.7	1.1–43

\*Statistically significant. IA: Incorporate artery

**Table 6:** Predictors of regrowth after coil embolization.

Univariate analysis	Multivariate analysis	
Variable	P-value	P-value
Dome filling	0.0006*	0.9
Neck width		0.9
Continuous	0.04*	
Categorical (>4 mm)	0.002*	
Dome diameter		0.1
Continuous	0.02*	
Categorical (>10 mm)	0.02*	
Height of aneurysm		0.2
Continuous	0.04*	
Categorical (>10 mm)	0.02*	

\*Statistically significant

On analysis of cases with ischemic events (symptomatic and asymptomatic) in the surgery group, the height of the

aneurysm (> 10 mm), presence of daughter sac, presence of IA, and temporary arterial occlusion were statistically significant predictor by univariate analysis. On multivariate analysis, the presence of IA was the only significant risk for postsurgical ischemic events. There was a strong association between two of these risk factors (height of aneurysm and the presence of daughter sac,  $P = 0.03$ ).

In the coiling group, the neck width (> 4 mm) is a significant predictor of the ischemic events by univariate analysis. The neck width and location of aneurysm both were statistically significant in multivariate analysis [Table 7]. There is no association between the use of balloon and the ischemic events.

The predictors for temporary and permanent morbidity of clipping are shown in Table 8. The presence of multiple aneurysms was the only significant risk factor for permanent morbidity in multivariate analysis.

**Table 7:** Predictors for ischemic events.

	Univariate analysis		Multivariate analysis		
	Variable	P-value	P-value	Odds ratio	Confidence interval
Microsurgical clipping	Presence of IA	0.009*	0.04*	3.5	0.9–11.8
	Presence of daughter sac	0.02*	0.13	5.3	0.9–102
	Temporary arterial occlusion	0.04*	0.23	2.2	0.6–8.04
	Height of aneurysm		0.7	1.05	0.8–1.3
	Continuous	0.2			
	Categorical (>10 mm)	0.03*			
Coil embolization	Location	0.06	0.03*	3.06	1.2–9.3
	Neck width		0.04*	1.5	1.05–2.6
	Continuous	0.1			
	Categorical (>4 mm)	0.04*			

\*Statistically significant. IA: Incorporate artery

**Table 8:** Predictors for temporary and permanent morbidity in clipping.

	Univariate analysis		Multivariate analysis		
	Variable	P-value	P-value	Odds ratio	Confidence interval
Temporary morbidity	Presence of multiple aneurysms	0.03*	0.03*	2.7	1.09–7.1
	Height of aneurysm		0.06	1.2	0.9–1.5
	Continuous	0.05			
	Categorical (>10 mm)	0.003*			
	Temporary arterial occlusion	0.02*	0.3	1.6	0.6–4.6
Permanent morbidity	Presence of multiple aneurysms	0.0002*	0.03*	5.7	1.3–39.2
	The use of balloon	0.0004*	0.8	1.2	0.2–5

\*Statistically significant

## DISCUSSION

The present study demonstrated that small to moderate size UIAs located in anterior circulation were possible to be treated safely by clipping or coiling. The durability was greater in the clipping group than in the coiling group. Although the conclusive outcome was almost even between treatments, the ratio of the ischemic events was higher in the coiling group than the clipping group. In contrast, the risks of specific complications involved in surgical procedure led to the extent of the postoperative hospital period following clipping. We also evaluated the character of UIA as the predictors of some unfavorable postoperative events. These results help to select a more appropriate treatment and suggest the usefulness of hybrid (combination of clipping and coiling) surgery as for UIAs.

### Durability

As shown in our data, the lower risk of neck remnant and retreatment is thought to be an advantage of clipping comparing to coiling. This result is in line with the previous reports.<sup>[1,7,9,13,22,23,26]</sup> However, even in the clipping group,

the complete obstruction of the neck is not always possible. Intentional incomplete clipping is necessary with a certain probability to avoid the complications. We demonstrated that UIAs with dome diameter >10 mm, neck width >4 mm, and the presence of IA are risk factors of incomplete clipping. Jabbarli *et al.* pointed out that even if the aneurysm is not large or giant, size (>12 mm) is an independent factor for the presence of neck remnants.<sup>[13]</sup> Wall share stress has been proposed to be the candidate responsible for aneurysm initiation and development.<sup>[8]</sup> In addition, the previous report demonstrated the association between wall share stress and atherosclerotic change.<sup>[24]</sup> We speculate that the strong pathological change at aneurysm neck induced by aneurysm growing with dynamic change of wall share stress may play a key role in the reason of neck remnant. However, as we have shown, the regrowth rate after clipping in the current study is only 1.4%. The previous reports indicated similar results in the range of 0%–4.5%.<sup>[6,9,13,14]</sup> David *et al.* reported that the annual risk for rebleeding from an aneurysm residual after clipping was 1.9%. Taken together, we believe that neck remnant after aneurysm clipping is allowed to preserve the IA and avoid surgical complications.

On the contrary, our presented higher regrowth rate after coil embolization is also in line with other studies.<sup>[9,22,23]</sup> In our analysis, the significant predictors for regrowth after coil embolization are aneurysm anatomy (height of aneurysm >10 mm, dome diameter > 10 mm, and neck width >4 mm) and dome filling, but not neck remnant. Raymond *et al.* found that the aneurysm size of more than 10 mm or neck width more than 4 mm has a higher risk of recurrence than smaller aneurysms.<sup>[22]</sup> The difficulty of tight packing in larger aneurysms is thought to be one reason for dome filling after endovascular surgery. In the current study, IA is the predictor only for neck remnant but not dome filling after coiling. However, Kawabata *et al.* reported to find the postoperative neck remnant and incomplete occlusion after coiling with various endovascular techniques in 50% and 19.3%, respectively, of the cases of aneurysms with IA.<sup>[15]</sup> These results suggest that regarding durability, the clipping has the advantage for the UIA with the dome diameter >10 mm, neck width >4 mm, and with IA, rather than endovascular treatment.

### Ischemic events

In our study, symptomatic ischemic events occurred in 11 cases (7.5%) and the neurological deterioration persisted in 4 cases (2.7%) after clipping. The incidence of cerebral infarction was reported to be 11–12% after clipping.<sup>[30]</sup> Li *et al.* reported 7.5% symptomatic infarction in his study<sup>[18]</sup> and identified large aneurysm size as a risk factor for cerebral infarction. We demonstrated that large aneurysm size >10 mm, presence of IA, the presence of a daughter sac, and temporary occlusion were identified as risk factors for any ischemic events after surgery. Especially in the permanently deteriorated group, the cause of ischemic complications was confined to M1 perforator occlusion (2 cases) and the temporary occlusion of the ICA with a balloon (2 cases).

Regarding M1 perforator obstruction, both aneurysms were of a small size and located on M1 trunk with superior projection. In the previous literature, M1 perforator injury was more frequently associated with superior projection aneurysms.<sup>[31]</sup> Such an aneurysm was in close contact with M1 perforators running superiorly and medially to the anterior perforated substance. It is not always possible to avoid injury of perforators during dissection and clipping of aneurysm. Although MCA aneurysms are favorable for surgery being superficial with easy proximal control and familial surgical approach,<sup>[4]</sup> M1 aneurysms with superior projections should be considered separately with a higher risk of complications.<sup>[12]</sup> Recently, Kim *et al.* reported the feasibility of endovascular coil embolization of UIA located on the middle cerebral artery with an incorporated branch.<sup>[16]</sup>

During clipping with craniotomy, the systemic enough heparinization to prevent thrombotic events induced by

balloon occlusion of the parent artery is difficult because of bleeding during surgery. Although there is a cosmetic problem, proximal flow control of the parent artery with direct exposure of the cervical carotid artery is a considerable method to avoid ischemic complications.

In our coiling group, symptomatic ischemic events occurred in 4 cases (7.5%) and the neurological deterioration persisted in 3 cases (5.6%). Thromboembolic events are the most encountered complication in the endovascular treatment of aneurysms.<sup>[25]</sup> Soeda *et al.* identified wide neck to be a risk factor<sup>[27]</sup> and it was the only predictor for thromboembolic events in Layton *et al.*<sup>[17]</sup> The previous studies reported the use of a balloon to be associated with thromboembolic events.<sup>[27,29]</sup> In the current study, balloon assist was used in 28 cases of the 53 coiling cases, only four cases had silent cerebral infarction and three cases had symptomatic infarction with no statistical association. Seo *et al.* reported the highest incidence of thromboembolic events in ACA aneurysms although it was not statistically significant.<sup>[25]</sup> In the current study, 60% of ACA aneurysms had postoperative cerebral infarction in comparison to 25.5% of ICA aneurysms which is statistically significant in multivariate analysis ( $P = 0.03$ ).

### Functional outcome and morbidity

In the current study, the rate of the patients with mRS >2 was 1.3% in clipping and 0% in coiling. Whereas it showed no statistical significance, better outcome was obtained in the coiling group than in the clipping group. Moreover, the length of hospital stay was significantly longer in clipping than coiling. Hoh *et al.* and Darsaut *et al.* have documented the similar trends related to hospitalization period.<sup>[7,11]</sup> As we have shown, the temporary morbidity rate was significantly higher in the clipping group than the coiling group. Subdural or epidural hematoma, cerebral contusions, and cranial nerve injuries are thought to be the characteristic complications of craniotomy. We believed that the issue of elongating hospitalization period was correlated with the invasiveness of both treatments.

The rate of permanent morbidity in the current study was 5.6% and 6.8% after coiling and clipping, respectively. It was not possible to analyze the predictors for this low number of cases in the coiling group, while the presence of multiple aneurysms and temporary parent artery occlusion with a balloon was significant predictors of post clipping permanent morbidity. Orz *et al.* demonstrated the risk of multiple aneurysms for the unfavorable functional outcome.<sup>[21]</sup> The increased manipulation of the brain with prolonged surgical time or additive invasion to the different areas of the brain was speculated to yield the morbidity after clipping.

Cases with postoperative permanent morbidity in endovascular treatment were all related to thromboembolic

events, all of them possess a wide neck more than 4 mm, a significant risk factor for thromboembolic events is identified in the current study. Cases with such a risk factor should have proper antiplatelet management with strict preoperative and postoperative monitoring of patient response to antiplatelet therapy.

### Limitations

This study has some limitations, first, with the retrospective study reviewed from medical records only. Surgical indication and treating methods were determined by neurosurgeon individually. Secondary, the refinement of endovascular devices associated with a better outcome was not fully considered. The technique of clipping has been established well by expert surgeons, while the endovascular treatment for UIA has continued to develop along with the advancement of devices. Third, the follow-up period was short to evaluate the regrowth and rupture of UIA in the future. Therefore, further investigation in a large-scale RCT for its durability and long-term follow-up is warranted to help physicians when determining an appropriate decision in the treatment of UIAs.

### CONCLUSION

As the treatment for UIA, the clipping and endovascular coiling were safe and feasible. The clipping was advantageous in durability, while the rate of morbidity was lower and the hospitalization period was shorter in the coiling group. It is appropriate for Japan to follow the recent world trend in coiling. Nonetheless, we must consider a system that inherits the skills of the clipping. The clipping and coiling should coexist while complementing each other by understanding the advantages and disadvantages of both.

### Declaration of patient consent

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

### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.

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**How to cite this article:** Mohammad F, Horiguchi T, Mizutani K, Yoshida K. Clipping versus coiling in unruptured anterior cerebral circulation aneurysms. *Surg Neurol Int* 2020;11:50.