Outcome of ruptured anterior communicating artery aneurysm treatment compared between surgical clipping and endovascular coiling
A single-center analysis

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Abstract

The optimal treatment modality for ruptured anterior communicating artery (ACoA) aneurysms is unclear. Therefore, in this study, we aimed to compare the outcomes of endovascular coiling and surgical clipping to treat ruptured ACoA aneurysms. A retrospective analysis of 213 consecutive patients with ruptured AcoA aneurysms, who were treated with coiling or clipping between January 2010 and December 2020, was conducted. Of the 213 patients, 94 and 119 underwent clipping and coiling, respectively. The mean age was higher in the coiling group than in the clipping group (60.3 ± 13.2 vs. 53.5 ± 13.4, $P < .001$). The mean diameter of the aneurysmal neck was larger in the clipping group (3.4 mm vs. 3.0 mm, $P = .022$), whereas the dome-to-neck ratio (1.53 ± 0.52 vs. 1.70 ± 0.60, $P = .031$) and aspect ratio (1.67 ± 0.51 vs. 1.92 ± 0.77, $P = .005$) were larger in the coiling group. The prevalence of vasospasm was higher in the clipping than in the coiling group (42.6% vs. 26.9%, $P = .016$). The coiling group had a shorter mean intensive care unit hospitalization (18.3 vs. 12.1, $P = .002$) and more frequently showed favorable outcomes (Glasgow Outcome Scale 4, 5; 57.4% vs 73.1%, $P = .016$) compared to the clipping group. Multivariable logistic analysis showed that good initial WFNS grade (odds ratio [OR] = 6.69, 95% confidence interval [CI]: 2.69–16.65, $P < .001$), treatment with coiling (OR = 3.67, 95% CI: 1.70–7.90, $P = .001$), and absence of the need for cerebrospinal fluid diversion (OR = 5.21, 95% CI: 2.38–11.39, $P < .001$) were independent predictors of favorable outcomes in patients with ruptured ACoA aneurysms. Ruptured ACoA aneurysms can be safely and effectively treated using both clipping and coiling modalities. However, it may be beneficial to consider coiling as the first option for treating these aneurysms.

Abbreviations: AcoA = anterior communicating artery, CSF = cerebrospinal fluid, CT = computed tomography, CTA = computed tomography angiography, DSA = digital subtraction angiography, GOS = Glasgow Outcome Scale, ISAT = International Subarachnoid Aneurysm Trial, SAH = subarachnoid hemorrhage, WFNS = World Federation of Neurosurgical Surgeons.

Keywords: clipping, coiling, aneurysm, anterior communicating artery, rupture

1. Introduction

Anterior communicating artery (AcoA) aneurysms are the most common intracranial aneurysms and account for approximately 30%–40% of aneurysmal subarachnoid hemorrhages (SAHs) in adults.[1,2] Surgical clipping of AcoA aneurysms via an interhemispheric or pterional approach can be technically challenging because of complex regional flow dynamics, frequent anatomical variations, variable geometry, presence of critical perforators, barriers presented by the diencephalon, or recent hemorrhage.[3,4] Over the past 3 decades, since the introduction of Guglielmi

Detachable Coils in 1991, the endovascular approach has become a feasible and acceptable treatment option for ruptured AcoA aneurysms.[4,5] Several studies have reported that endovascular coiling for the treatment of patients with an overall ruptured aneurysm may offer significant advantages in functional outcomes in comparison with surgical clipping.[6,7] In particular, for posterior circulation aneurysms, the evidence of the benefits of endovascular coiling is becoming clearer.[8,9] However, in patients with ruptured AcoA aneurysms, there are limited data on the safety and efficacy of endovascular coiling compared with surgical clipping with a focus on durability or rebleeding.[10,11]

We performed a retrospective analysis of consecutive patients with ruptured AcoA aneurysms and aimed to evaluate the outcomes of ruptured ACoA aneurysm treatment with endovascular coiling and surgical clipping and to investigate the predictors for favorable outcomes.

2. Material and Methods

2.1. Patients

Our institutional review board approved this retrospective study, and the requirement for patient informed consent was waived for the review of patient records and images. We retrospectively reviewed the findings for consecutive patients with ruptured AcoA aneurysms who underwent neurosurgical clipping or endovascular coiling between January 2010 and December 2020 at a single tertiary neurosurgical center in South Korea. The procedures were performed by 2 vascular neurosurgeons and 2 neurointerventionists with at least 5 years of clinical experience, each. (Rev#2-b) The treatment modality (coiling or clipping) was selected by a multidisciplinary consultation between vascular neurosurgeons and neurointerventionists in consideration of the characteristics of the aneurysms. (Rev#2-a). The diagnosis of SAH was based on brain computed tomography (CT) data, and the diagnosis of AcoA aneurysms was based on computed tomography angiography (CTA) or digital subtraction angiography (DSA). We analyzed the patients' medical records to determine demographic characteristics, comorbidities, clinical presentation (World Federation of Neurosurgical Surgeons [WFNS] grade, modified Fisher grade), and aneurysmal characteristics. All patients underwent follow-up CTA or DSA within 2 weeks of the procedure. (Rev#2-d). Postoperative complications, such as vasospasm and cortical hematoma, were identified from medical records and radiologic findings. Treatment outcomes were assessed using the Glasgow Outcome Scale (GOS) at the outpatient clinic follow-up at 3 months, and a favorable functional outcome was defined as a GOS of 4–5.

2.2. Statistical analysis

Statistical analysis was performed using SPSS software (version 21.0; IBM SPSS, Chicago, IL, USA). Baseline demographics and outcome variables were analyzed and compared between the 2 treatment modalities (clipping and coiling). Continuous variables were summarized as mean with standard deviation or mean with range, while categorical variables were summarized as counts and percentages. We performed a univariate comparison of groups using an independent t test or Wilcoxon rank-sum test for continuous variables and a Pearson χ^2 test or Fisher's exact test for categorical variables. Multivariable logistic regression analyses were performed to identify the variables serving as independent prognostic factors for favorable functional outcomes. Statistical significance was set at a P value of $<.05$.

3. Results

There were 213 eligible patients, including 94 (44.1%) in the surgical clipping group and 119 (55.9%) in the endovascular clipping group. The patients in the coiling group were significantly older than those in the clipping group (60.3 ± 13.2 vs. 53.5 ± 13.4 years, $P < .001$). The 2 groups showed no significant differences in initial clinical neurological status (WFSN grade) and radiological SAH grade (modified Fisher grade) (Table 1). Table 2 shows the aneurysmal characteristics of the 2 groups. The aneurysmal neck size was smaller in the coiling group (3.4 mm vs. 3.0 mm, $P = .022$), whereas the dome-to-neck ratio (1.53 ± 0.52 vs. 1.70 ± 0.60, $P = .031$) and aspect ratio (1.67 ± 0.51 vs. 1.92 ± 0.77, $P = .005$) were lower in the clipping group. The 2 groups showed no significant differences in aneurysmal directions. Outcomes and complications are summarized in Table 3. The prevalence of vasospasm was higher in the clipping group (42.6% vs. 26.9%, $P = .016$). The 2 groups also showed no significant differences in the rate of cerebrospinal fluid (CSF) diversion or shunt-dependent hydrocephalus. The total length of hospital stay (36.1 vs. 24.2 days, $P <.001$) and intensive care unit (ICU) stay during hospitalization (18.3 days vs. 12.1 days, $P = .002$) were significantly shorter in the coiling group. The 2 groups showed no significant difference in mortality (GOS 1), but the coiling group more frequently showed favorable outcomes (GOS 4–5; 54/94 [57.4%] vs. 87/119 [73.1%], $P = .016$) and good recovery (GOS 5; 38/94 [40.4%] vs. 68/119 [57.1%], $P = .015$). Multivariable logistic analysis showed that good initial WFNS grade (odds ratio [OR] = 6.69, 95% confidence interval [CI]: 2.69–16.65, $P < .001$), treatment with coiling (OR = 3.67, 95% CI: 1.70–7.90, $P = .001$), and absence of the need for CSF diversion (OR = 5.21, 95% CI: 2.38–11.39, $P < .001$) were independent predictors of favorable outcomes in patients with ACoA ruptured aneurysms (Table 4).

Table 1

Baseline characteristics of the patients.

Variables	Over all, n = 213	Clipping (n = 94)	Coiling (n = 119)	P value
Mean age, y	57.3 ± 13.7	53.5 ± 13.4	60.3 ± 13.2	<.001
Men, no. (%)	112 (52.6)	46 (48.9)	66 (55.5)	.344
WFNS grade, no. (%)				
I	51 (23.9)	23 (24.5)	28 (23.5)	.873
II	73 (34.3)	34 (36.2)	39 (32.8)	.604
III	34 (16.0)	17 (18.1)	17 (14.3)	.452
IV	33 (15.5)	13 (13.8)	20 (16.8)	.551
V	22 (10.3)	7 (7.4)	15 (12.6)	.219
Good grade (I–II)	124 (58.2)	57 (60.6)	67 (56.3)	.524
Poor grade (III–V)	89 (41.8)	37 (39.4)	52 (43.7)	.524
Modified Fisher grade				
1	55 (25.8)	18 (19.1)	37 (31.1)	.048
2	30 (14.1)	18 (19.1)	12 (10.1)	.059
3	61 (28.6)	31 (33.0)	30 (25.2)	.213
4	67 (31.5)	27 (28.8)	40 (33.6)	.445
Risk factors, no. (%)				
Hypertension	77 (36.2)	30 (31.9)	47 (39.5)	.253
Smoking	76 (35.7)	34 (36.2)	42 (35.3)	.895

WFNS, World Federation of Neurological Surgeons.

Table 2

Aneurysmal characteristics of the patients.

Variables	Over all, n = 213	Clipping (n = 94)	Coiling (n = 119)	P value
Neck (mm), mean (range)	3.2 (0.9–9.0)	3.4 (1.8–8.0)	3.0 (0.9–9.0)	.022
Dome width(mm), mean (range)	5.0 (1.2–15.0)	5.1 (1.2–13.0)	4.9 (2.0–15.0)	.6765
Height (mm), mean (range)	5.6 (2.0–18.0)	5.6 (2.0–14.0)	5.6 (2.0–18.0)	.888
Dome to neck ratio, mean (SD)	1.63 ± 0.57	1.53 ± 0.52	1.70 ± 0.60	.031
Aspect ratio, mean (SD)	1.81 ± 0.68	1.67 ± 0.51	1.92 ± 0.77	.005
Aneurysmal direction, no. (%)				
Anterior	91 (42.7)	38 (40.4)	53 (44.5)	.547
Inferior	50 (23.5)	21 (22.4)	29 (24.4)	.729
Posterior	4 (1.9)	2 (2.1)	2 (1.7)	.811
Superior	68 (31.9)	33 (35.1)	35 (29.4)	.376
Subgroup direction				.347
Anterior + inferior	141 (66.2)	59 (62.8)	82 (68.9)	
Posterior + superior	72 (33.8)	35 (37.2)	37 (31.1)	

Table 3

Outcomes and complications of aneurysmal treatments.

Variables	Over all, n = 213	Clipping (n = 94)	Coiling (n = 119)	P values
Symptomatic vasospasm	72 (33.8)	40 (42.6)	32 (26.9)	.016
Cortical hematoma	19 (8.9)	9 (9.6)	10 (8.4)	.766
Rebleeding, no.(%)	8 (3.8)	3 (3.2)	5 (4.2)	.700
CSF diversion, no. (%)	87 (40.1)	37 (39.4)	50 (42.0)	.695
Shunt-dependent hydrocephalus, no. (%)	45 (21.1)	24 (25.5)	21 (17.6)	.162
Total length of Hospitalization (days), mean	29.4 ± 23.9	36.1 ± 28.5	24.2 ± 18.1	<.001
ICU hospitalization (days), mean	14.8 (1–142)	18.3 ± 16.9	12.1 ± 12.3	.002
GOS score at 3 months, no. (%)				
5 = good recovery	106 (49.8)	38 (40.4)	68 (57.1)	.015
4 = moderate disability	35 (16.4)	16 (17.0)	19 (16.0)	.837
3 = severe disability	36 (16.9)	24 (25.5)	12 (10.1)	.003
2 = vegetative state	15 (7.0)	7 (7.5)	8 (6.7)	.837
1 = dead	21 (9.9)	9 (9.6)	12 (10.1)	.901
Favorable outcome (4 + 5)	141 (66.2)	54 (57.4)	87 (73.1)	.016

CSF = cerebrospinal fluid, GOS = Glasgow outcome scale.

Table 4

Variables associated with favorable outcome (GOS 4 + 5).

	Univariate analysis		Multivariate analysis	
	Odds ratio (95%CI)	P values	Odds ratio (95%CI)	P values
Age >70	1.95 (1.01–3.76)	.047	1.19 (0.49–2.93)	.702
Good initial WFNS grade (1 + 2)	9.07 (4.71–17.51)	<.001	6.69 (2.69–16.65)	<.001
Minimal SAH (fisher 1 + 2)	2.72 (1.45–5.09)	.002	0.68 (0.27–1.71)	.412
Hypertension	0.64 (0.36–1.15)	.135	0.66 (0.32–1.37)	.267
Smoking	1.89 (1.01–3.53)	.045	2.07 (0.90–4.80)	.087
Coiling procedure	2.01 (1.13–3.58)	.017	3.67(1.70–7.90)	.001
Early surgery (<48 h)	0.91 (0.51–1.62)	.750		
Maximal diameter (<7 mm)	1.308 (0.71–2.42)	.391		
Pt did not need to CSF diversion	8.78 (4.58–16.83)	<.001	5.21(2.38–11.39)	<.001

4. Discussion

The International Subarachnoid Aneurysm Trial (ISAT), a randomized trial comparing 2 treatment modalities in patients with ruptured intracranial aneurysms, showed a higher likelihood of endovascular coiling resulting in independent survival at 1 year than neurosurgical clipping, and the survival benefit persisted for at least 7 years.2 However, these results were for the overall ruptured aneurysm and did not account for the location of the aneurysms. Thus, generalizing the results of the ISAT study to all intracranial aneurysms is inadequate. After the publication of the ISAT, a comparative analysis of each treatment method for ruptured aneurysms at specific locations has been reported. In particular, comparative observational studies showed better

outcomes after endovascular coiling for posterior circulation aneurysms.[8,9] However, in patients with ruptured anterior circulation aneurysms, except for middle cerebral artery aneurysms, there are limited data on the safety and efficacy of endovascular coiling compared with surgical clipping with a focus on durability or rebleeding.[10–13]

Although the present study was a single-center retrospective analysis, we evaluated the data for 213 patients with ruptured AcoA aneurysms to compare the 2 treatment modalities and identified several findings. First, there were no significant differences in baseline characteristics between the 2 groups, but the mean age was higher in the coiling group. In fact, in our study, the proportion of patients over 70 years of

age was significantly greater in the coiling group than in the clipping room (15/94 [16.0%] vs. 35/114 [30.7%], $P = .023$) (Fig. 1). These results may have been influenced by selection bias, but they may also imply that the probability of being excluded from SAH treatment due to old age was less in the coiling group. Older patients tended to have more comorbidities. In addition, surgical clipping requires a longer procedure time than endovascular coiling, and this may cause greater hemodynamic stress. For these reasons, the American Heart Association/American Stroke Association guidelines state that endovascular coiling should receive increased consideration in older adults (>70 years of age).[14] Considering these points, the higher mean age in the coiling group does not imply a selection bias, but rather appears to be a result of broadening the spectrum of treatment targets for SAH patients due to endovascular coiling.

Second, the aneurysmal neck size was smaller in the coiling group (3.4 mm vs. 3.0 mm, $P = .022$), whereas the dome-to-neck ratio (1.53 ± 0.52 vs. 1.70 ± 0.60, $P = .031$) and aspect ratio (1.67 ± 0.51 vs. 1.92 ± 0.77, $P = .005$) were lower in the clipping group. Although coiling appeared to be performed preferentially for patients with suitable aneurysmal morphology for endovascular procedures, the aspect ratio and dome-to-neck ratio of the clipping group were also in the appropriate range (>1.5) for endovascular coiling. Because AcoA aneurysms have an anatomically narrow range of origin sites, the neck may have been smaller and the aspect ratio or dome-to-neck ratio was generally larger than the corresponding values for aneurysms originating from other sites. In addition, successful treatment results for overwide (dome-to-neck ratio ≤ 1.2) and undertall (aspect ratio ≤ 1.2) aneurysms with endovascular coiling have been reported using the double microcatheter technique and balloon or stent-assisted technique.[15] Although neck size and aneurysmal morphology are still some of the considerations in determining the treatment method in patients with AcoA ruptured aneurysms, they cannot be applied as absolute exclusion or inclusion criteria for endovascular coiling.

Third, symptomatic vasospasm occurred in 40 patients (42.6%) after surgical clipping in comparison with 32 patients (26.9%) after endovascular coiling, with the difference being statistically significant ($P = .016$). Several different results have been reported regarding the rate of vasospasm associated with the 2 treatment modalities. Some authors have reported that the incidence of vasospasm was lower in the clipping group due to intraoperative blood clot removal, while other authors reported that the incidence was higher in the clipping group due to the spastic response of cerebral vessels to surgical manipulation.[16–18] Moreover, de Oliveira et al reported in meta-analysis that the risk of cerebral vasospasm development did not differ significantly between the 2 techniques.[19] However, these previous studies did not analyze ruptured aneurysms in specific locations, but in patients with ruptured aneurysms overall. During surgical clipping of AcoA aneurysms, excess vascular manipulations are often required to secure the surgical field of view or for temporary clipping, compared with other locations. In addition, the rectus gyrus is often resected during the surgical clipping of AcoA aneurysms to obtain a better operative view of the anterior basal region. Previous studies have reported that dissection and disruption of brain parenchyma result in the release of lipid peroxides such as arachidonic acid, leading to the synthesis of prostaglandins and free radicals causing vasospasm.[19,20] For these reasons, our study, which was limited to AcoA likely ruptured aneurysms, showed a significantly lower incidence of vasospasm in the coiling group.

Fourth, in agreement with the findings of previous studies, our study showed that the length of total hospital stay was shorter by an average of 11.9 days in the coiling group.[21,22] In particular, ICU stay during hospitalization was significantly shorter in the coiling group (18.3 days vs. 12.1 days, $P = .002$). These results indicate rapid neurological recovery after treatment and may be related to the lower incidence of vasospasm in the coiling group. In addition, Nobutaka et al. reported that clipping may increase postoperative medical complications such as noncardiogenic pulmonary edema in the vasospasm period, as a result of the increased postoperative C-reactive protein level. For these reasons, the total hospital stay in the coiling group may have been shorter, which could be an advantage in terms of cost-effectiveness as well as an early return to daily life by the patient.

In multivariate analysis, our study showed that good initial WFNS grade and coiling procedure without CSF diversion were independent predictors of favorable functional outcomes in patients with AcoA ruptured aneurysms. Unlike previous studies, our study found that the coiling procedure itself as a treatment modality for ruptured AcoA aneurysms was associated with favorable outcomes. Techniques and instruments related to endovascular treatment have been continuously developed over the past 3 decades. With the introduction of effective techniques such as the double-catheter technique,
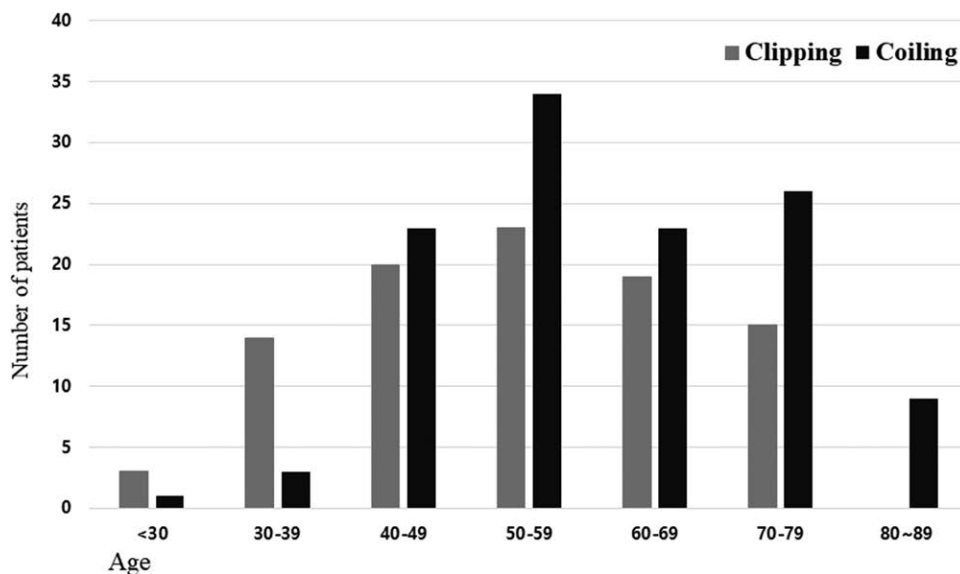

Figure 1. Number of patients who underwent clipping and coiling by age group.
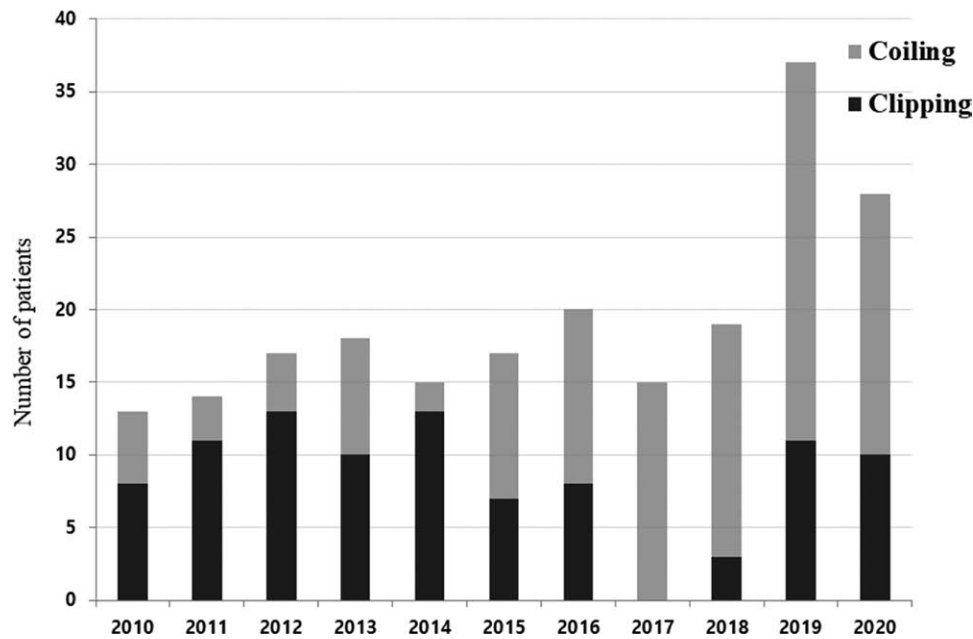
Figure 2. Number of patients who underwent clipping and coiling by year.

balloon- or stent-assisted techniques, and the development of softer coils, the coiling procedure has become less risky.[23,24] Our study suggests that the preference for coiling as a treatment method has increased compared with clipping since 2015 (Fig. 2). This result reflects the recent treatment trend, but it may also have been the cause of the better prognosis of endovascular coiling treatment along with the recent development of endovascular techniques and devices.

Our study had several limitations, including the fact that it was a single-center analysis. Moreover, considering the retrospective design of our study, the conclusions cannot be easily generalized. Therefore, our results should be confirmed by a prospective multicenter study. Second, our study included eligible patients between January 2010 and December 2020. There were some changes in the preferences for treatment modalities or patient care protocols during this relatively long period, which possibly affected the treatment outcomes. Third, in the comparison of outcomes, only GOS at 3 months was evaluated, so long-term outcome and durability analysis such as recurrence were excluded. (Rev#2-c). However, the rebleeding rate during the analysis period was acceptable in comparison with previous studies.

5. Conclusions

Patients with ruptured ACoA aneurysms can be safely and effectively treated using both clipping and coiling modalities. However, in our study, the coiling group showed a significantly better functional outcome, and the findings confirmed coiling treatment as a prognostic factor for favorable outcomes, suggesting that it may be beneficial to consider endovascular coiling as the first option for ruptured ACoA aneurysms. To the best of our knowledge, this is the first study to identify the coiling procedure itself as a prognostic factor of favorable outcomes in patients with AcoA ruptured aneurysms. However, owing to the limitations of a single-center, retrospective study, a prospective study is needed to confirm our findings.

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Author contributions

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