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Stent-assisted coiling versus coiling alone of ruptured anterior communicating artery aneurysms: A single-center experience

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ABSTRACT

Objective: Endovascular coiling of anterior communicating artery (ACoA) aneurysms has evolved; however, stent-assisted coiling of ruptured aneurysms remains controversial. We aimed to compare periprocedural complications, angiographic and clinical outcomes after stent-assisted coiling with coiling alone of ruptured ACoA aneurysms.

Methods: We performed a retrospective review of consecutive 222 patients with ruptured ACoA aneurysms treated with endovascular coiling within 7 days after ictus. Patients were grouped into stent-assisted coiling and coiling alone groups. Baseline characteristics, periprocedural complications, clinical outcomes, and angiographic results were compared between the two groups.

Results: 63 (28.4%) patients underwent stent-assisted coiling and 159 (71.6%) underwent coiling alone. There were no statistically significant differences in age, sex, clinical grading and Fisher grade. Larger aneurysms ($P = 0.002$) and wider-neck aneurysms ($P < 0.001$) were more often treated with stent-assisted coiling within 72 h ($P = 0.025$). Intraprocedural aneurysm rupture occurred in 6 (9.5%) patients treated with stent-assisted coiling compared with in 5 (3.1%) treated with coiling alone ($P < 0.048$). Thrombus formation occurred in 10 (15.9%) patients after stent-assisted coiling compared with 6 (3.8%) after coiling alone ($P = 0.002$). Stent-assisted coiling achieved a lower rate of immediate occlusion than coiling alone ($P = 0.045$). Postoperative complications, clinical outcomes, and follow-up aneurysm occlusion did not significantly differ.

Conclusions: Stent-assisted coiling of ruptured ACoA aneurysms was associated with a higher rate of intraprocedural complications and associated with a lower immediate occlusion rate. However, Postoperative complications and clinical outcomes did not differ. Long-term angiographic results require further study.

1. Introduction

Anterior communicating artery (ACoA) aneurysms are very common in ruptured intracranial aneurysms. Traditionally ruptured ACoA aneurysms are treated with surgical clipping because of complex morphological features [1,2]. Currently, with advances of endovascular technology, endovascular coiling of ACoA aneurysms has evolved dramatically and has been a safe and effective treatment option for ruptured ACoA aneurysms [3–6]. Recently stent-assisted coiling has been reported to be used in the treatment of ACoA aneurysms [7–10]. However, the majority of ACoA aneurysms included in these studies are unruptured.

Although stent-assisted coiling of ruptured intracranial aneurysms remains controversial [11–14], several studies have reported that stent-assisted coiling of ruptured ACoA aneurysms is feasible and safe [8,12,14].We hypothesized that stent-assisted coiling of ruptured ACoA aneurysms could achieve similar complications, angiographic and clinical results compared with coiling alone. In the report, we presented a single institution series of patients with ruptured ACoA aneurysms treated with endovascular coiling. We aimed to compare periprocedural complications,

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Table 1
Baseline characteristics.

Characteristics	All (n = 222)	Sent-assisted coiling (n = 63)	Coiling alone (n = 159)	*P* value
Age (years)	53.8 (11.2)	53.7 (10.9)	53.9 (11.4)	0.914
Women	108 (48.6%)	29 (46.0%)	79 (49.6%)	0.623
Smoking	76 (34.2%)	25 (39.7%)	51 (32.1%)	0.282
Hypertension	112 (50.5%)	34 (54.0%)	78 (49.1%)	0.509
Coronary artery disease	3 (1.4%)	1 (1.6%)	2 (1.3%)	1.000
Stroke history	6 (2.7%)	1 (1.6%)	5 (3.1%)	0.852
WFNS grade				
WFNS I	172 (77.5%)	45 (71.4%)	127 (79.9%)	0.174
WFNS II	14 (6.3%)	5 (7.9%)	9 (5.7%)	0.529
WFNS III	3 (1.4%)	2 (3.2%)	1 (0.6%)	0.403
WFNS IV	24 (10.8%)	7 (11.1%)	17 (10.7%)	0.928
WFNS V	8 (3.6%)	3 (4.8%)	5 (3.1%)	0.854
Unavailable	1 (0.4%)	1 (1.6%)	0	0.284
Fisher grade				
Fisher I	4 (1.8%)	2 (3.2%)	2 (1.3%)	0.683
Fisher II	17 (7.7%)	3 (4.8%)	14 (8.8%)	0.458
Fisher III	70 (31.5%)	23 (36.5%)	47 (29.6%)	0.315
Fisher IV	117 (52.7%)	31 (49.2%)	86 (54.1%)	0.511
Unavailable	14 (6.3%)	4 (6.3%)	10 (6.2%)	1.000
Aneurysm size (mm)	5.5 (2.3)	6.2 (2.2)	5.2 (2.2)	0.002
Aneurysm neck (mm)	3.0 (1.2)	3.8 (1.3)	2.7 (1.0)	<0.001
Dome-to-neck ratio	1.9 (0.9)	1.8 (0.7)	2.0 (0.9)	0.088
Timing of treatment				0.025
≤72hours	97 (43.7%)	35(55.6%)	62(39.0%)	
73hours–7 days	125 (56.3%)	28(44.4%)	97(61.0%)	

WFNS, World Federation of Neurological Societies.

angiographic results and clinical outcomes after stent-assisted coiling with coiling alone of ruptured ACoA aneurysms.

2. Methods

2.1. Study design

The institution review committee approved the study and we retrospectively reviewed data on ACoA aneurysms treated with endovascular coiling from January 2008 to February 2015. 254 consecutive patients with ACoA aneurysms underwent endovascular coiling. Patients were included if they presented with subarachnoid hemorrhage secondary to a ruptured ACoA aneurysm and were treated with stent-assisted coiling or coiling alone within 7 days after ictus. Of the 254 patients, 3 patients presenting with unruptured ACoA aneurysms and 27 patients undergoing coiling over 7 days were excluded. 224 patients with 224 ruptured ACoA aneurysms were included in this study. Patients were then grouped into sent-assisted coiling and coiling alone groups.

2.2. Endovascular procedure protocol

All patients were treated under general anesthesia and systemic heparinization. A bolus of 50–75 IU/kg of heparin was given after femoral sheath placement, and intermittent boluses of 1250 IU per hour were given during the procedure. Activated clotting time was maintained at 2–3 times baseline level. Stent-assisted coiling was considered in ruptured aneurysms with an unfavorable morphology (aneurysm neck ≥ 4.0 mm or dome/neck ≤2.0). Balloon-assisted coiling was not routinely used for ACoA aneurysms because of complex morphologies of ACoA and perforators. The Neuroform stent (Stryker Neurovascular, Fremont, California), the Enterprise stent (Cordis Neurovascular, Miami, Florida) and the Solitaire AB stent (Covidien, Irvine, California) were used. Most patients were treated with the Solitaire AB stent because of its retrievability. Stent-assisted coiling was often performed using microcatheter jailing technique in which stent was deployed after the aneurysm was microcatheterized or semi-jailing technique in which stent was partially deployed to cover the aneurysm neck. Standard technique was not used in our patients because of small vessel size and complex morphologies of surrounding arteries associated AcoA aneurysms.

2.3. Antiplatelet therapy in stent-assisted coiling

For stent-assisted coiling, 100 mg of aspirin and 75 mg of clopidogrel were administered daily for 3 days before the procedure. For emergency stent-assisted coiling, a loading dose of 450 mg clopidogrel was used either by a nasogastric tube or rectally before 2 h of stent deployment. The individual response to antiplatelet agents was not routinely measured during the study. After stent-assisted coiling, 100 mg of aspirin and 75 mg of clopidogrel were administrated daily for 12 weeks, and 100 mg of aspirin was given for 12 months.

2.4. Outcomes measures

The primary outcomes were intraprocedural complications (introprocedural rupture and thrombus formation), postoperative complications (early rebleeding and ischemia) and clinical outcomes. Postoperative ischemia was defined as symptomatic ischemia or a new hypo-density located in a vessel distribution on CT scan. Clinical outcomes at discharge were recorded with Glasgow coma score and those at the latest follow-up were measured with modified Rankin Scale (mRS).The secondary outcomes were immediate and follow-up angiographic results. Angiographic follow-ups were performed by digital subtraction angiography. Aneurysm occlusion was assessed using the Raymond occlusion scale. Complete occlusion was defined as a Raymond grade of I. Aneurysm recurrence was defined as aneurysm occlusion grade decreasing from initial Raymond grade on follow-up angiography. Periprocedural complications, clinical outcomes, and angiographic results were reviewed by both interventionalist and neurosurgeon who were independent of the treatment.

Table 2
Periprocedural complications and clinical outcomes.

Outcomes	Total n/N (%)	Sent-assisted coiling	Coiling alone	*P* value
Intraprocedrual aneurysm rupture	11/222 (5.0%)	6/63 (9.5%)	5/159 (3.1%)	0.048
Intraprocedural thrombus formation	16/222 (7.2%)	10/63 (15.9%)	6/159 (3.8%)	0.002
Postoperative early rebleeding	6/222 (2.7%)	1/63 (1.6%)	5/159 (3.1%)	0.852
Postoperative ischemia	24/222 (10.8%)	10 (15.9%)	14/159 (8.8%)	0.126
Clinical outcomes at discharge				
GOS 5	174/222 (78.4%)	47/63 (74.6%)	127/159 (79.9%)	0.390
GOS 4	23/222 (10.4%)	7/63 (11.1%)	16/159 (10.1%)	0.917
GOS 2–3	15/222 (6.8%)	5/63 (7.9%)	10/159 (6.3%)	0.659
GOS 1	10/222 (4.4%)	4/63 (6.4%)	6/159 (3.7%)	0.635
Clinical outcomes at follow-up†				
mRS 0	141/173 (81.5%)	46/57 (80.6%)	95/116 (81.9%)	0.849
mRS 1	9/173 (5.2%)	3/57 (5.3%)	6/116 (5.2%)	1.000
mRS 2	3/173 (1.7%)	1/57 (1.8%)	2/116 (1.7%)	1.000
mRS 3	2/173 (1.2%)	1/57 (1.8%)	1/116 (0.9%)	1.000
mRS 4–5	1/173 (0.6%)	0	1/116 (0.9%)	1.000
mRS 6	17/173 (9.8%)	6/57 (10.5%)	11/116 (9.4%)	0.828

GOS, Glasgow coma score; mRS, modified Rankin scale; Clinical follow-up was available for 173 patients.

2.5. Statistical analysis

Baseline characteristics, perioperative complications, immediate angiographic and follow-up angiographic results, clinical outcomes at discharge and at last follow-up were compared between stent-assisted coiling and coiling alone groups. An independent samples *t*-test was used for continuous variables, and a chi-square test or Fisher's exact test for categorical variables. Multivariate analyses were not performed because patient age, sex, World Federation of Neurosurgical Societies (WFNS) grade and Fisher grade were comparable between the two groups. A *P* value <0.05 was considered statistically significant. Statistical analysis was used with IBM SPSS version 22.0 (IBM SPSS; Armonk, NY, USA).

3. Results

3.1. Baseline characteristics

Of the 224 patients, 1 patient failed coiling and underwent conservative treatment because of procedure-related A1 segment dissection, and 1 patient failed stent-assisted coiling and underwent surgical clipping. 222 patients were successfully treated with endovascular coiling. 108 (48.6%) of 222 patients were female. The mean age was 53.8 ± 11.2 years (range 24–84years). The mean size of the aneurysms was 5.5 ± 2.3 mm (range 2.0–18.0 mm). 159 (71.6%) were treated with coiling alone. 63(28.4%) patients were treated with stent-assisted coiling including the Neuroform stent in 2 (3.2%) patients, the Enterprise stent in 9 (14.3%) patients and the Solitaire AB stent in 52 (82.5%) patients. Patient and aneurysm characteristics are presented in Table 1. Three were no statistically significant differences in patient age, sex, medical history, WFNS grade and Fisher grade between the two groups. Larger aneurysms (*P* = 0.002) and wider-neck aneurysms (*P* < 0.001) were more often treated with stent-assisted coiling. Stent-assisted coiling was more often performed within 72 h (*P* = 0.025).

3.2. Periprocedural complications and clinical outcomes

Periprocedural complications and clinical outcomes are presented in Table 2. Intraprocedural aneurysm rupture occurred in 6 (9.5%) patients treated with stent-assisted coiling compared with in 5 (3.1%) patients treated with coiling alone (*P* < 0.048). Thrombus formation occurred in 10 (15.9%) patients after stent-assisted coiling compared with 6 (3.8%) after coiling alone (*P* = 0.002). There were no statistically significant differences in postoperative complications (early rebleeding, *P* = 0.852 and postoperative ischemia, *P* = 0.126; respectively). There were no statistically significant differences in intraprocedural rupture, thrombosis formation, early rebleeding and postoperative ischemia between the Solitaire sent and the Neuroform or Enterprise stent groups (Table 3).

54 (85.7%) of 63 patients treated with stent-assisted coiling had GOS of 4 or 5 compared with 143 (89.9%) of 159 patients treated with coiling alone without statistically significant difference (*P* = 0.370). Clinical follow-up was available for 57 (90.5%) patients in stent-assisted coiling group and 116 (73.0%) patients in coiling alone group. The mean time to clinical follow-up was 25.7 ± 16.5 months (range 5–79 months) in stent-assisted coiling group and 35.6 ± 22.4 months (range 5–88 months). There was no statistically significant difference in clinical outcomes at last follow-up (Table 2).

3.3. Immediate and follow-up angiographic results

Immediate and follow-up angiographic results are presented in Table 4. Aneurysm complete occlusion was achieved in 40 (63.5%) aneurysms on immediate angiography in stent-assisted coiling group and in 122 (76.7%) patients in coiling alone group (*P* = 0.045). Dome filling occurred in 15 (23.8%) in stent-assisted coiling group compared with 13 (8.2%) in coiling alone group (*P* = 0.002). Angiographic follow-up was available for 24 patients in stent-assisted coiling group and 64 patients in coiling alone group. The mean time to angiographic follow-up was 11.0 ± 4.8 months (range, 6–26 months) in stent-assisted coiling group and 16.5 ± 11.4 months (range, 2–50 months). There was no statistically significant difference in follow-up angiographic results (Table 4). Aneurysm recurrence occurred in 1 (4.2%) of follow-up aneurysms after sent-assisted coiling and 10 (15.6%) aneurysms after coiling alone without statistically significant difference (*P* = 0.278).

4. Discussion

We presented a large number of patients with ruptured ACoA aneurysms treated with stent-assisted coiling or coiling alone within 7 days after ictus and found no statistically significant differences of postoperative complications, clinical outcomes at discharge and at last follow-up, and follow-up angiographic results between stent-assisted coiling and coiling alone groups. However, stent-assisted coiling was associated with higher rates of intraprocedural rupture and thrombus formation compared with coiling alone and associated with a lower immediate occlusion rate.

Table 3
Perioperative complications in different stent types.

Complications	Neuroform or Enterprise stent (n = 11)	Solitaire sent (n = 52)	*P* value
Intraprocedrual aneurysm rupture	1 (9.1%)	5 (9.6%)	1.000
Intraprocedural thrombus formation	1 (9.1%)	9 (17.3%)	0.676
Postoperative early rebleeding	1 (9.1%)	0	0.175
Postoperative ischemia	3 (27.3%)	7 (13.5%)	0.360

Table 4
Immediate and follow-up angiographic results.

Outcomes	Total n/N (%)	Sent-assisted coiling	Coiling alone	*P* value
Immediate aneurysm occlusion				
Complete occlusion	162/222 (73.0%)	40/63 (63.5%)	122/159 (76.7%)	0.045
Residual neck	32/222 (14.4%)	8/63 (12.7%)	24/159 (15.1%)	0.647
Dome filling	28/222 (12.6%)	15/63 (23.8%)	13/159 (8.2%)	0.002
Follow-up aneurysm occlusion*				0.348
Complete occlusion	58/88 (65.9%)	17/24 (70.8%)	41/64 (64.1%)	0.551
Residual neck	23/88 (26.1%)	4/24 (16.7%)	19/64 (29.7%)	0.334
Dome filling	7/88 (8.0%)	3/24 (12.5%)	4/64 (6.2%)	0.601
Angiographic outcomes*				
Aneurysm recurrence	11/88 (12.5%)	1/24 (4.2%)	10/64 (15.6%)	0.278
Stable	70/88 (79.5%)	20/24 (83.3%)	50/64 (78.1%)	0.590
Progressive thrombosis	7/88 (8.0%)	3/24 (12.5%)	4/64 (6.3%)	0.601

* Follow-up angiographic results was available for 88 aneurysms.

Clinical outcomes and follow-up angiographic results were similar probably because of aggressive management of intraoperative compilations and progressive thrombosis of aneurysms.

Our results are in line with previous study showing intraoperative rupture rate of 9.0% during stent-assisted coiling of ruptured ACoA aneurysms [14]. Intraprocedural rupture were relatively higher during stent-assisted coiling than during coiling alone probably because of aggressive coiling of acutely ruptured aneurysms to achieve tighter packing. Thromboembolic complications were still common during stent-assisted coiling probably because stent-assisted coiling was more often performed within 72 h and dual-antiplatelet therapy was not sufficient in our study. In addition, antiplatelet therapy resistance was not assessed and may increase the incidence of thromboembolic complications in patients had clopidogrel resistance [15]. Prabhakaran et al. [16] reported that 28 (50.9%) of patients treated with stent-assisted coiling had clopidogrel resistance defined as percentage platelet inhibition <40% which was calculated by the P2Y12 assay. P2Y12 reaction units value may predict periprocedural thromboembolic complication. However, recently Wong et al. [17] found that use of P2Y12 reaction test to guide clopidogrel therapy did not decrease the incidence of thromboembolic complications compared to standard therapy. The development of newer devices that may not require anti-platelet therapy is needed to reduce the risk of thromboembolic complication. On the other hand, intravenous tirofiban may be an effective alternative approach to anti-platelet therapy to decrease thromboembolic complications of ruptured aneurysms [18].

Although a previous study has shown that procedure-related complications did not differ between stent-assisted coiling and coiling alone of ruptured aneurysms [19],patients with ACoA aneurysms were not separately reported in their study. Our results are consistent with the recent study that showed that stent-assisted coiling of ruptured ACoA aneurysms was associated with a higher incidence of complications compared with other location aneurysms [14]. Therefore, stent-assisted coiling of acutely ruptured ACoA aneurysms is still challenging despite improvement of endovascular technology. However, intraprocedure-related complications did not affect clinical outcomes and this risk may be minimized with very low morbidity and mortality after aggressive treatment [20–22]. Therefore, Clinical outcome may not differ between the two groups.

Our results are in agreement with previous studies showing immediate complete occlusion rate of 50.0%-85.7% and follow-up complete collusion rate of 70.9%-83.3% after stent-assisted coiling of AcoA aneurysms [7–9]. The immediate occlusion rate after stent-assisted coiling was lower than that after coiling alone probably because larger aneurysms and wider-neck aneurysms were treated with stent-assisted coiling and these aneurysms were also difficult to repair regardless of treatment modality. Recently Broeders et al. [23] performed a systematic review and meta-analysis to compare periprocedural results and mid-term outcomes between bioactive and bare platinum coiling and they found that periprocedural outcome was similar but bioactive coils increased the rate of complete occlusion and reduced the rate of residual neck aneurysms. Bioactive coils may improve aneurysm occlusion and durability of endovascular coiling. In addition, our results showed that aneurysm occlusion improved over time and stent-assisted coiling achieved a lower aneurysm recurrence rate because of progressive thrombosis after stent-assisted coiling.

Currently flow diverters such as the Pipeline Device and the Silk Device are increasingly being used in the treatment of large or giant aneurysms in the internal carotid artery. However, the use of flow diverters for the treatment of ACoA aneurysms is difficult because of difficult navigability or risk of occlusion of small perforators. In recent several years, intrasaccular flow diverters such as the Woven EndoBridge device (Web) have emerged as a treatment option for wide-neck bifurcation aneurysms without a need for dual anti-platelet therapy. Gherasim et al. [24] have reported the feasibility, safety, and efficacy of the WEB device for the treatment of unruptured ACoA aneurysms and they found the technique success rate of 70% in 10 aneurysms and thecomplete occlusion rate of 33.3% at last follow-up. The limitations of the WEB device navigation may affect the technique success in AcoA aneurysms.

4.1. Limitations

First, this was a retrospective study from one single center, which may have limited generalization. We did not record stent deployment techniques and the relationship between these

approaches (microcatheter jailing and semi-jailing technique) and intraoperative complications is unknown. In addition, external ventricular drainage-related complications were not defined and compared between stent-assisted coiling and coiling along group. Chung et al. [25] reported that ventricular drainage was relatively safe but might increase the risk of perioperative complications (thromboembolic and hemorrhagic complications) in patients with acute hydrocephalus or poor clinical grade. Ventricular drainage have been suggested to place before stent-assisted coiling and anti-platelet therapy [26]. However, the association between anti-platelet therapy and ventricular drainage-related complications still requires additional study. Second, this was not a randomization study, but it is difficult to randomize patients to stent-assisted coiling or to coiling alone because larger and wider-neck aneurysms often require stent assistance. Third, although most patients had clinical follow-ups, angiographic follow-up results were insufficient. Nevertheless, a higher risk of intraprocedural complication should be considered and managed appropriately during stent-assisted coiling to improve the overall outcomes.

5. Conclusions

Although stent-assisted coiling was associated with a higher risk of intraprocedural complications and associated with a lower immediate aneurysm occlusion rate, postoperative complications, follow-up angiographic results and clinical outcomes did not differ between stent-assisted coiling and coiling alone groups. However, long-term angiographic results require further validation.

Disclosure

The authors declare that they have no competing interests.

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