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Comparison of Stent-Assisted Coil Placement and Coiling-Only for the Treatment of Ruptured Intracranial Aneurysms

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Background: The use of a stent during the acute post-hemorrhage period is controversial. We conducted a retrospective analysis on the clinical and angiographic outcomes of the ruptured aneurysms that were embolized with stent-assisted coiling or coiling-only.

Material/Methods: We reviewed data of 279 patients with 279 ruptured intracranial aneurysms who underwent coil embolization between July 2004 and June 2015. The baseline data on age, sex, medical history, aneurysm size, location, and Hunt and Hess grade were recorded.

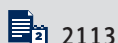
Results: One hundred and thirteen aneurysms were treated with stent-assisted coiling. Adverse events occurred in similar proportions of patients in the two groups (11.5% in the stenting group and 9.0% in the coiling alone group). The incidence of permanent disabling neurologic deficit was also similar in the two groups (7.1% and 5.4% in the stenting group and coiling alone group respectively). Clinical follow-up data were available in 207 patients with a median period of 28 months. Angiographic follow-up was available in 106 aneurysms with a median period of 7.5 months. Clinical outcomes were correlated with adverse events ($p=0.043$, odds ratio=4.59), large aneurysms ($p=0.013$, odds ratio=10.24), and Hunt and Hess grade ($p=0.001$, odds ratio=13.51). Stent-assisted coiling for ruptured aneurysm, as compared with coiling-only, was not associated with an increased incidence of poor clinical outcome at follow-up. Aneurysm-occlusion status at follow-up were correlated with stent placement ($p<0.001$, odds ratio=5.85) and initial aneurysm-occlusion status ($p=0.027$, odds ratio=3.78).

Conclusions: Compared with coiling-only, stent-assisted coil placement may have better durability, with comparable safety for ruptured intracranial aneurysm.

MeSH Keywords: **Embolization, Therapeutic • Intracranial Aneurysm • Stents**

Abbreviations: **SAC** – stent-assisted coiling; **non-SAC** – non-stent-assisted coiling; **mRS** – modified Rankin scale; **DSA** – digital subtraction angiography

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Background

With advances in endovascular techniques, endovascular coil embolization of intracranial aneurysms is considered a valid alternative to surgical clipping [1,2]. However, the treatment of wide-necked aneurysms is still a challenge because of the risk of coils protrusion from the aneurysm into the parent artery. Several endovascular techniques have been described to treat wide-necked aneurysms, including balloon-assisted coil placement and double microcatheter technique. The use of balloon-assisted coil placement or double microcatheter technique can sometimes be limited, owing to the lack of permanent support for the coil mass inside the aneurysm sac. Stent-assisted technology has been developed to obtain a safe coil packing into the sac in these aneurysms.

Some scholars have demonstrated stent-assisted technology for the treatment of aneurysms facilitates a higher coil packing density and a more stable aneurysm neck sealing [3–7]. Some operators are reluctant to use this technique because sequent antiplatelet therapy after stenting may increase the risk of rebleeding and recurrence [8]. A number of investigators have compared the results of stent-assisted coiling (SAC) and non-stent-assisted coiling (non-SAC) for intracranial aneurysms [6,9,10]. Only a few studies have compared the efficacy and safety of SAC and non-SAC for ruptured intracranial aneurysms [6,10]. In the present study, we conducted a retrospective single-center analysis on the clinical and angiographic outcomes of the ruptured aneurysms that were embolized with SAC or non-SAC.

Material and Methods

Patient characteristics

The study was approved by the local Institutional Review Board and Ethics Committee. We retrospectively reviewed data of patients with ruptured intracranial aneurysms who underwent coil embolization between July 2004 and June 2015 in our institution. Inclusion criteria for this study were ruptured aneurysms treated no more than 28 days after the initial rupture [11]. The exclusion criteria included dissecting, infectious, or traumatic aneurysms, blood blister-like aneurysms, patients presenting with large (>50 mL) intraparenchymal hematomas, staged stent placement, and those who were treated by sole stenting.

A total of 279 ruptured aneurysms (279 patients) were treated with endovascular embolization. The study consisted of 101 males (36.2%) and 178 females (63.8%), with a median age of 56.0 years (range, 16–82 years). The baseline data on age, sex, medical history, aneurysm size, location, and Hunt and Hess grade were recorded.

Pharmacologic therapy protocol and endovascular procedures

For wide-neck aneurysms (neck >4 mm and/or dome/neck ratio ≤ 2), a stent-assisted technique (Enterprise stent, Codman Neurovascular; Neuroform stent, Boston Scientific; Solitaire stent, ev3) was required. Pharmacologic therapy protocol was based on the literatures [11,12]. Patients were pre-medicated with 100 mg aspirin and a loading dose of 75 mg clopidogrel for two to three days before stent-assisted embolization (92 patients). For the stent used without premedication, 300 mg clopidogrel and 300 mg aspirin was administered via a nasogastric tube (21 patients).

All of the coil embolization surgeries were performed under general anesthesia. A bolus of 3,000 IU of heparin was administered after femoral arterial sheath placement and intermittent boluses of 1,000 IU per hour were subsequently administered. Coils used in the study were platinum coils. The antiplatelet regimen after SAC was 100 mg daily and clopidogrel 75 mg daily for six weeks, followed by a 100 mg dose of aspirin daily, for an indefinite length of time.

Two different stent placement strategies were used in this series: a) “coil through” technique, which means that the stent was first fully deployed across the aneurysm neck and then the aneurysm was catheterized by navigating through the tines of the stent; and b) “jailing” technique, which means that some or part of the coils were introduced into the aneurysm sac before implanting the stent.

Occlusion status initially and at follow-up was classified as complete (100%), near complete (90% to 99%), or incomplete (<90%). Angiographic results were assessed by two experienced neuro-interventionists (YL and FW) independently. Disagreements were resolved by consensus.

Follow-up data

During the follow-up period, angiographic evaluation with digital subtraction angiography (DSA) was performed at three to six months after endovascular treatment. If no recanalization evidence was observed, the subsequent angiographic evaluation was performed at 18 months after treatment. Changes in angiographic outcomes were classified as follows: stable occlusion (no change in coil configuration, obliteration grade, or contrast filling), further occlusion (progressive occlusion or involution of the neck remnant or contrast filling in aneurysm), and recanalization (aneurysm recurrence evident due to neck growth, coil compaction, coil extrusion by aneurysm degradation, or new sac formation).

Clinically, the neurological and functional status was evaluated according to the modified Rankin scale (mRS). Good outcomes

Table 1. Comparison of stent-assisted coiling (SAC) and non-stent-assisted coiling (non-SAC).

	SAC (n=113)		non-SAC (n=166)		p Value
Characteristics					
Female	79	(69.9)	99	(59.6)	0.080*
Hypertension	59	(52.2)	70	(42.2)	0.099*
Hunt and Hess grade					
I-II	60	(53.1)	82	(49.4)	0.544*
III-IV	53	(46.9)	84	(50.6)	
Median age (y)	57.0		56.0		0.133##
Size					
Tiny (<3 mm)	28	(24.8)	24	(14.5)	0.100*
Small (3–10 mm)	80	(70.8)	130	(78.3)	
Large (11–25 mm)	5	(4.4)	11	(6.6)	
Giant (>25 mm)	0	(0)	1	(0.6)	
Location					
Anterior circulation	101	(89.4)	155	(93.4)	0.234*
Posterior circulation	12	(10.6)	11	(6.6)	
Occlusion status					
Complete	29	(25.7)	52	(31.3)	0.194*
Near complete	69	(61.0)	102	(61.5)	
Incomplete	15	(13.3)	12	(7.2)	
Adverse events					
Ischemic events	8	(7.1)	6	(3.6)	0.193*
Intraoperative rupture	3	(2.7)	7	(4.2)	0.745*
Other adverse events	2	(1.8) [§]	2	(1.4) [#]	1.000*
Permanent disabling neurologic deficit**	8	(7.1)	9	(5.4)	0.570*
Periprocedural mortality	2	(1.8)	9	(5.4)	0.209*

Unless indicated otherwise, data are number of cases, with percentages in parentheses. * χ^2 test or Fisher's exact test; ## Mann-Whitney U test; [§] One case of coil migration, and one case of rebleeding; [#] One case of gastrointestinal bleeding, and one case of coil stretching; ** Because of treatment-related complications, complications of SAH, or unfavorable evolution of SAH.

were defined as a mRS score of 0–2; poor outcomes were defined as a mRS score of 3–6.

analysis was $p < 0.20$. The level of statistical significance was set at 0.05.

Statistical analyses

SPSS 19.0 software (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. A Mann-Whitney U test was performed for non-normally distributed continuous variables. A Pearson χ^2 or Fisher's exact test was used to compare proportions. The univariate analysis cutoff for inclusion in the logistic regression

Results

The patient characteristics and the aneurysm features are summarized in Table 1. The two groups were similar in all baseline characteristics.

Table 2. Potential risk factors related to follow-up results.

	Good outcome(n=190)	Poor outcome(n=17)	p value	Logistic regression p value
Median age (y)	56.0	56.0	0.338*	
Sex			0.673##	
Women	113 (91.1)	11 (8.9)		
Men	77 (92.8)	6 (7.2)		
Hunt and Hess grade			0.001##	
1–3	181 (96.8)	6 (3.2)		
4	9 (45.0)	11 (55.0)		0.001 (13.51) [3.05–59.9]**
Size			0.066##	
Tiny (<3 mm)	37 (86.0)	6 (14.0)		
Small (3–10 mm)	145 (94.2)	9 (5.8)		
Large (11–25 mm)	8 (80.0)	2 (20.0)		0.013 (10.24) [1.62–64.68]**
Location			0.031##	
Anterior circulation	178 (93.2)	13 (6.8)		
Posterior circulation	12 (75.0)	4 (25.0)		
Stent placement			0.832##	
Yes	87 (91.6)	8 (8.4)		
No	109 (92.4)	9 (7.6)		
Initial aneurysm-occlusion status			0.573##	
Complete occlusion	52 (89.7)	6 (10.3)		
Near or incomplete occlusion	138 (92.6)	11 (7.4)		
Adverse Events			0.009##	
Yes	13 (72.2)	5 (27.8)		0.043 (4.59) [1.05–20.12]**
No	177 (93.7)	12 (6.3)		

Unless indicated otherwise, data are number of cases, with percentages in parentheses. * Mann-Whitney U test; ## χ^2 test or Fisher’s exact test; ** Numbers in parentheses are the odds ratio. Numbers in brackets are the 95% confidence interval. p values were obtained with binary logistic regression.

Stents used in treatment

Among 279 aneurysms, 113 aneurysms were treated with SAC. SAC was performed with the Enterprise stent in 10 aneurysms, the Solitaire stent in 63 aneurysms, and the Neuroform stent in 40 aneurysms.

Adverse events and mortality

Adverse events are summarized in Table 1. Ischemic complications were seen in 14 patients (5.0%). Cumulative adverse events occurred in 28 patients (10.0%). Adverse events occurred in similar proportions of patients in the two groups

(11.5% in the SAC group and 9.0% in the non-SAC group). The incidence of permanent disabling neurologic deficit was also similar in the two groups (7.1% and 5.4% in the SAC and non-SAC respectively).

Follow-up outcomes

Clinical follow-up data were available in 207 patients (74.2%) (Table 2). During a median follow-up period of 28 months (range, 3–124 months), two cases of rebleeding occurred (non-SAC group). The rate of good outcomes was 91.8% (190/207). Statistical analysis demonstrated that clinical outcomes were correlated with adverse events (p=0.043, odds ratio=4.59),

Table 3. Angiographic outcome and angiographic changes at follow-up after stent-assisted coiling and non-stent-assisted coiling embolization.

	SAC (n=54)		non-SAC (n=52)		p Value
Angiographic outcome					<0.001
Complete occlusion	40	(74.1)	21	(40.4)	
Near or incomplete occlusion	14	(25.9)	31	(59.6)	
Angiographic changes					<0.001
Recanalization	4	(7.4)	17	(32.7)	
Stable	18	(33.3)	26	(50.0)	
Further occlusion	32	(59.3)	9	(17.3)	

Table 4. Predictors of aneurysm obliteration at last follow-up.

	Aneurysm-occlusion status at follow-up		p Value	Logistic regression p value
	Complete (n=61)	Near or incomplete (n=45)		
Median age (y)	55.0	54.0	0.658*	
Stent placement			<0.001 ^{##}	
Yes	40 (74.1)	14 (25.9)		<0.001 (5.85) [2.30–14.91] ^{**}
No	21 (40.4)	31 (59.6)		
Size			0.144 ^{##}	
Tiny	12 (63.2)	7 (36.8)		
Small	48 (59.3)	33 (40.7)		
Large or giant	1 (16.7)	5 (83.3)		
Initial aneurysm-occlusion status			0.049 ^{##}	
Complete occlusion	18 (75.0)	6 (25.0)		0.027 (3.78) [1.16–12.27] ^{**}
Near complete or incomplete occlusion	43 (52.4)	39 (47.6)		
Location			0.696	
Anterior circulation	56 (56.6)	43 (43.4)		
Posterior circulation	5 (71.4)	2 (28.6)		

Unless indicated otherwise, data are number of cases, with percentages in parentheses. * Mann-Whitney U test; ^{##} χ^2 test or Fisher's exact test; ^{**} Numbers in parentheses are the odds ratio. Numbers in brackets are the 95% confidence interval. p Values were obtained with binary logistic regression.

large aneurysms ($p=0.013$, odds ratio=10.24), and Hunt and Hess grade ($p=0.001$, odds ratio=13.51).

Angiographic follow-up was available in 106 aneurysms (38.0%) with a median follow-up period of 7.5 months (range, 3–114 months) (Table 3). Follow-up angiograms showed complete

occlusion in 61 aneurysms (57.5%), and near complete or incomplete occlusion in 45 aneurysms (42.5%).

Changes in angiographic outcomes at follow-up after coiling embolization are summarized in Table 3. Statistical analysis demonstrated that stent placement might enhance progressive

Table 5. Initial and follow-up angiographic outcomes of aneurysms treated with coil embolization.

Initial status	Aneurysm-occlusion status at follow-up	
	Complete	Near complete or incomplete
Complete occlusion with non-SAC (n=13)	7 (53.8)	6 (46.2)
Near complete or incomplete with non-SAC (n=39)	14 (35.9)	25 (64.1)
Complete occlusion with SAC (n=11)	11 (100)	0 (0)
Near complete or incomplete with SAC (n=43)	29 (67.4)	14 (32.6)

Unless indicated otherwise, data are number of cases, with percentages in parentheses.

occlusion and reduced the rate of aneurysm recanalization ($p<0.001$).

Aneurysm-occlusion status at follow-up were correlated with stent placement ($p<0.001$, odds ratio=5.85) and initial aneurysm-occlusion status ($p=0.027$, odds ratio=3.78) (Table 4).

Initial and follow-up angiographic outcomes are summarized in Table 5. In the SAC group, complete occlusion at follow-up was seen in 100% (11/11) of the initial complete occlusion group compared with 67.4% (29/43) of the initial near complete or incomplete occlusion group ($p=0.048$ in the Fisher's exact test). The incidence of complete occlusion at follow-up was 67.4% in the initial near completely or incompletely occluded aneurysms with SAC compared with 35.9% in the initial near completely occluded aneurysms with non-SAC ($p=0.004$ in the χ^2 test). The incidence of complete occlusion at follow-up was (100%) in the initial completely occluded aneurysms with SAC compared with 35.9% in the initial near completely or incompletely occluded aneurysms with non-SAC ($p<0.001$ in the Fisher's exact test). The incidence of complete occlusion at follow-up was higher in the initial completely occluded aneurysms with SAC (100%) than in the initial completely occluded aneurysms with non-SAC (53.8%) ($p=0.016$ in the Fisher's exact test).

Discussion

The introduction of stent-assisted coiling (SAC) has led to a conceptual shift in the management of intracranial aneurysm. Nonetheless, stent assistance requires antiplatelet agents to prevent in-stent thrombosis, which may increase the risk of subarachnoid hemorrhage and recanalization of aneurysm. The use of a stent during the acute post-hemorrhage period is controversial because of concerns about the efficacy and risk of dual antiplatelet therapy.

In this study, we noted a comparable complication rate (11.5%) in the SAC group with previously studies. Yang et al. reported a complication rate of 14.2% in a single-center series of 211 consecutive cases [11]. Bodily et al. reported a hemorrhagic

complication rate of 8% and an ischemic complication rate of 6% in a systematic review [13]. The complication rate (9.0%) in our non-SAC group was in line with previous results in the management of acutely ruptured aneurysms, which have ranged from 8.7% to 18.9% [6,10,14].

There have been conflicting results regarding the safety of SAC in the management of intracranial aneurysms. Some scholars demonstrated that SAC was associated with a higher rate of complication than non-SAC [10,13]. Whereas other scholars demonstrated SAC was associated with a comparable rate of complication than non-SAC [6,7,9].

SAC might be associated with a higher rate of ischemic events because of the thrombogenicity of stents. In our study, the ischemic complication rate was 7.1% in the SAC group compared with 3.6% in the non-SAC group ($p=0.193$). This finding suggests dual antiplatelet therapy prevents ischemic events for ruptured aneurysms with SAC. The intraoperative rupture rate was 2.7% in the SAC group compared with 4.2% in the non-SAC group ($p=0.745$). SAC for ruptured aneurysm, as compared with non-SAC, was not associated with an increased incidence of adverse events, morbidity, or mortality. Our study confirmed the previous findings that SAC was associated with reasonable complication rates for ruptured aneurysms [6].

Whether stenting might cause poor clinical outcomes in patients with ruptured aneurysms is less clear. Bodily et al. noted that SAC in ruptured aneurysms was associated with worse clinical outcomes compared with data for non-SAC [13]. However, some scholars demonstrated SAC was associated with a comparable rate of clinical outcomes than non-SAC [6,15]. In our study, clinical outcomes at follow-up was correlated with adverse events ($p=0.043$, odds ratio=4.59), large aneurysms ($p=0.013$, odds ratio=10.24), and Hunt and Hess grade ($p=0.001$, odds ratio=13.51). SAC for ruptured aneurysm, as compared with non-SAC, was not associated with an increased incidence of poor clinical outcomes at follow-up.

Theoretically, stent deployment provides a mechanical scaffold for coils inside an aneurysm, allowing for increased packing

density. In previous clinical studies, there have been conflicting results regarding the efficacy between SAC and non-SAC. Some scholars demonstrated SAC facilitated a higher coil packing density and a more stable aneurysm neck sealing [3–7,16]. However, Hwang et al. noted that stent placement provided no better long-term angiographic outcomes for aneurysms, with an unfavorable configuration for coiling [17]. In our study, complete obliteration rate was 25.7% (29/113) in SAC, and was 31.3% (52/166) in non-SAC. A possible explanation is that the flexibility of a microcatheter tip is decreased following stent deployment, and thus, may result in looser aneurysm packing [9].

Embolized aneurysms can develop a worse degree of closure even when the initial occlusion is complete [18]. Choi et al. reported a series of 91 completely coiled aneurysms, with the recanalization rate of 26.4% [19]. Xavier et al. reported a series of 83 completely coiled aneurysms, with the recanalization rate of 24% [20]. In our study, the recanalization rate was 7.4% in the SAC group and was 32.7% in the non-SAC group. In addition, the occlusion rate was 59.3% in the SAC group and 17.3% in the non-SAC group. The *p* value was significant ($p<0.001$). These findings suggest SAC can provide durable closure for ruptured aneurysms, as shown in Tables 3 and 4.

In the condition of SAC, complete occlusion at follow-up was seen in 100% (11/11) of the initial complete occlusion group compared with 67.4% (29/43) of the initial near complete or incomplete occlusion group ($p=0.048$). The incidence of complete

occlusion at follow-up was higher in the initial completely occluded aneurysms with SAC (100%) than in the initial completely occluded aneurysms with non-SAC (53.8%) ($p=0.016$). These findings suggest that complete occlusion should be achievable with SAC as it seems sufficient to provide durable closure for ruptured aneurysms.

Limitations

This was a retrospective study in a single center, which may limit the generalization of our findings. In addition, some patients did not undergo long-term follow-up. Only 106 out of 279 aneurysms were available for angiographic follow-up, which may have introduced bias. Further study with a larger number of patients and adequate follow-up would be necessary to validate our findings. In addition, exclusion of other type of aneurysms may restrict the ability to generalize our results to ruptured aneurysms in general.

Conclusions

Compared with coil placement alone, SAC may have better durability, with comparable safety for ruptured intracranial aneurysms. Complete occlusion should be achievable with SAC as it seems sufficient to provide durable closure for ruptured aneurysms.

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