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Original Article

Safety and efficacy of stent-assisted coiling ruptured intracranial aneurysms: A single-center experience

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Abstract

Objectives: Endovascular coiling is a minimally invasive method to manage intracranial aneurysms. However, patients who undergo stent-assisted coiling (SAC) for acutely ruptured intracranial aneurysms need dual antiplatelet treatment. We reported our experience and outcomes of SAC for ruptured intracranial aneurysm. **Materials and Methods:** We retrospectively collected data on procedure-related complications, rates of aneurysm rebleeding and recurrence, and clinical outcomes of patients with ruptured aneurysms managed by SAC over 2 years. **Results:** Among the 17 patients included in this study, there were 14 (82.4%) women and 3 (17.6%) men, with a mean age of 58.59 years (standard deviation = 13.57; range: 40–82 years). There were no periprocedural hemorrhagic complications and no aneurysm rebleeding before discharge. However, two patients developed acute brain infarction because of symptomatic vasospasm. Linear regression revealed significant associations of posterior circulation involvement with the Glasgow Outcome Score and modified Rankin Scale (mRS) at discharge and 6 months after. Besides, Hunt and Hess grade ≥3 has a significant association with mRS at discharge, 6 months, and 1 year after. **Conclusion:** SAC for ruptured aneurysm was technically feasible and did not carry an additional risk of postoperative aneurysm rebleeding secondary to antiplatelet treatment. Moreover, it had relatively low rates of aneurysm regrowth and coil compaction. Therefore, it can be a safe and effective endovascular treatment for acutely ruptured intracranial aneurysm.

Keywords: *Endovascular coiling, Ruptured intracranial aneurysm, Stent-assisted coiling, Transarterial embolization*

Introduction

Stent-assisted coiling (SAC) is one of the well-established endovascular treatment options for intracranial aneurysms. In 2005, the International Subarachnoid Aneurysm Trial (ISAT) showed that endovascular treatment was a safe and effective treatment modality for ruptured intracranial aneurysms [1]. In 2012, another prospective randomized clinical trial (i.e., Barrow Ruptured Aneurysm Trial) demonstrated fewer poor outcomes after coil embolization than after microsurgical clipping [2]. SAC has been reported to significantly promote complete aneurysm occlusion and had lower long-term recurrence rates when compared with coiling alone [3,4]. The advantages of using a stent include the provision of a mechanical support to prevent coil protrusion or migration into the parent artery, thereby enabling dense packing and decreasing turbulent blood flow around the aneurysm, which promotes aneurysmal thrombosis [3].

However, to reduce stent-associated thromboembolic complications, dual antiplatelet therapy (DAPT) with drugs, such as aspirin and clopidogrel, are routinely administered during and after SAC. Patients on DAPT were reported to have an increased risk of aneurysm rebleeding or subsequent ventriculoperitoneal shunt surgery for secondary hydrocephalus [5,6]. Therefore, the safety of SAC in terms of the routine need for DAPT must be clarified in patients with acutely ruptured intracranial aneurysms. In this study, we aimed to evaluate the safety and efficacy of SAC for such patients.

Materials and methods

After receiving approval from the Ethical Board of Hualien Tzu Chi Hospital, Taiwan (reference no: IRB 112-114-B) for this retrospective cohort study, we performed medical data

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collection and chart review. Informed consent was waived by the IRB because of the retrospective nature of the study. This study was conducted in accordance with the Declaration of Helsinki. We reviewed the database of Hualien Tzu Chi Hospital to identify patients who underwent SAC for ruptured intracranial aneurysm between May 2020 and May 2022.

At our center, one experienced endovascular surgeon performed all the endovascular interventions. An independent reviewer retrospectively analyzed all medical charts to obtain patient data on basic characteristics, initial neurological examination, imaging study of the brain by computed tomography (CT) and CT angiography, procedure reports, aneurysm morphology and characteristics, hospital stay, procedure-related and periprocedural complications, clinical outcomes, and clinical and angiographic follow-ups.

Patient selection and data

Over 2 years, 17 patients with ruptured aneurysms were managed by SAC.

The inclusion criteria were (1) spontaneous subarachnoid hemorrhage (SAH) secondary to ruptured intracranial aneurysm and (2) endovascular treatment by SAC. The exclusion criteria were (1) unruptured intracranial aneurysm, (2) traumatic ruptured aneurysm, (3) coiling alone, and (4) previous surgical clipping at the same side. The collected clinical data included (1) age and sex; (2) Glasgow Coma Scale (GCS) at arrival; (3) Hunt and Hess grade (HHG) of the severity of spontaneous aneurysm rupture; (4) modified Fisher grade (mFG) of the brain CT; (5) aneurysm type (morphology), number, location, size, and dome-and-neck ratio; (6) postprocedure (i.e., at discharge and 6 months after) information, including the Glasgow Outcome Score (GOS) and modified Rankin Scale (mRS) of the clinical outcomes; (7) Raymond–Roy classification of the degree of aneurysm occlusion; and (8) rates of periprocedural hemorrhagic complications.

The primary outcome was the complication rate of aneurysm rebleeding during the SAC, based on immediate postoperative imaging evaluation by cone-beam CT (Dyna CT) to detect or rule out intracranial complications. The secondary outcomes were the (1) factors associated with the GOS and mRS at discharge, 6 months, and 1 year after, and (2) the GCS, GOS, and mRS at different time points to transarterial embolization (TAE).

For cases of recurrence after SAC of the intracranial aneurysm, we used the Raymond–Roy classification to describe the extent of occlusion, as follows: (1) Class I, complete obliteration; (2) Class II, residual neck; (3) Class IIIa, contrast opacification within the coil interstices of a residual aneurysm; and (4) Class IIIb, contrast opacification outside the coil interstices, along the residual aneurysm wall. Cases in which the aneurysm was occluded completely after SAC but revealed to have residual neck or sac on follow-up angiography were also counted as recurrence.

Angiography protocol and endovascular procedure

Under general anesthesia and ultrasound-guided puncture, an 8F-long femoral artery sheath was placed into the abdominal aorta. Conventional digital subtraction angiography (DSA) of the parent artery and rotational and three-dimensional reconstruction DSA were routinely performed to evaluate the angioarchitecture of the aneurysm and parent artery. The 8F guiding catheter was introduced and navigated into the proximal cervical internal carotid artery (ICA), whereas a 6F intermediate catheter was coaxially placed in the cavernous ICA. A 2.1F microcatheter was navigated to the distal parent artery or its branch, whereas a 1.7F microcatheter was navigated into the aneurysm. Subsequently, a self-expandable stent (LVIS; MicroVention, Tustin, CA, USA) of the appropriate size and length was selected and deployed into the parent artery through the 2.1F microcatheter to bridge the aneurysm neck. Aneurysm coiling was achieved by selecting the proper detachable coils (MicroVention, Tustin, CA, USA).

Postembolization DSA and Dyna CT were routinely obtained to assess for hemodynamic alterations in the aneurysm sac and patency of the parent artery. Immediately, after aneurysm coiling was achieved, we routinely administered an intravenous bolus of 3000 U of heparin and gave loading doses of clopidogrel 150 mg and aspirin 200 mg. Thereafter, daily clopidogrel 75 mg and aspirin 100 mg were prescribed for 6 months, followed by aspirin 100 mg daily for the next 6 months. In cases of ventriculoperitoneal shunt placement for secondary hydrocephalus, we adjusted the dosage or temporarily discontinued the antiplatelet drug.

Follow-up imaging with DSA or magnetic resonance imaging (MRI) was scheduled at 6 months after discharge, then every 1 year for 2 years, and every 2 years thereafter, if the condition is stable. During admission after the procedure, brain CT or MRI was performed in cases of clinical deterioration, new-onset neurological deficit, or change in the level of consciousness.

Clinical follow-up

The GCS, GOS, and mRS were assessed and recorded by an independent reviewer at the time of discharge, 6 months, and 1 year thereafter. The GOS was classified as follows: (1) death; (2) vegetative with coma state; (3) severe disability; (4) moderate disability; or (5) mild disability or good recovery. The mRS was classified as follows: (0) no symptoms; (1) no significant disability; (2) mild disability; (3) moderate disability; (4) severe disability; (5) bedridden with coma status; or (6) death. The same independent reviewer evaluated the follow-up DSA studies.

Statistical analysis

Data were expressed as frequency, proportion, or mean ± standard deviation (SD), as appropriate. Median (Q1 and Q3) was adopted for noncontinuous variables. Continuous variables were compared between admission and discharge using a paired *t*-test. A one-way analysis of variance with the Bonferroni correction was used to compare the GCS at admission and discharge and the GOS and mRS at discharge, 6 months, and 1 year after among the different intervals from admission to TAE. Linear regression was adopted to analyze the association between the risk factors and the GOS and mRS at the aforementioned time points. Univariable linear regression was used to adjust for confounding variables;

Table 1: Patient demographics and parameters

Item	Value
Number of patients	17
Age	58.59±13.57
Age >64	7 (41.2)
Male	3 (17.6)
Female	14 (82.4)
Aneurysm counts	
1	11 (64.7)
2	3 (17.6)
3	2 (11.8)
6	1 (5.9)
Circulation (*n*=29)	
Anterior	26 (89.7)
Posterior	3 (10.3)
HHG	
1	3 (17.6)
2	7 (41.2)
3	0
4	5 (29.4)
5	2 (11.8)
mFG	
1	6 (35.3)
2	1 (5.9)
3	2 (11.8)
4	8 (47.1)
Hydrocephalus	10 (58.8)
GCS (admission)	15 (8.5–15)
GCS (discharge)	14 (11.5–15)
Time to TAE (h)	54.24±46.59
<24	6 (35.3)
24–72	6 (35.3)
>72	5 (29.4)
Raymond-Roy classification	
Class I	16 (66.7)
Class II	3 (12.5)
Class IIIa	5 (20.8)
Class IIIb	0
Complication	
Intraprocedural aneurysm rupture	0
Acute brain infarction	2 (11.8)
In-stent stenosis	0
Early rebleeding	0
IVH	9 (52.9)
ICH	3 (17.6)
Symptomatic vasospasm	3 (17.6)
Recurrence after coiling	1 (5.9)
EVD insertion	13 (76.5)
EVD related IVH	1 (7.7)
Compaction after coiling	3 (17.6)
Retreatment	0
Shunt dependent	12 (70.6)
GOS	
Discharge	3 (3–5)
6 months	3.5 (2.25–5)
1 year	4 (2–5)
mRS	
Discharge	4 (0.25–5)
6 months	3 (0–5)
1 year	2.5 (0–5)

Data are presented as *n* (%) or mean±SD or median (Q1−Q3). HHG: Hunt and Hess grade, mFG: Modified Fisher grade, GCS: Glasgow coma score, TAE: Transarterial embolization, IVH: Intraventricular hemorrhage, ICH: Intracerebral hemorrhage, EVD: Extraventricular drainage, GOS: Glasgow outcome score, mRS: Modified Rankin scale, SD: Standard deviation

variables with $P < 0.1$ were entered into the multivariable linear regression analysis. Statistical significance was defined as $P < 0.05$. All statistical analyses were performed using the SPSS Statistics for Windows, version 17.0 (SPSS Inc., Chicago, IL, USA).

Results

Patient and aneurysm characteristics

As shown in Table 1, among the 17 patients in the study population, there were 14 (82.4%) women and 3 (17.6%) men, with a mean age of 58.59 years (SD = 13.57; range: 40–82 years). Figure 1 demonstrates that there were 29 aneurysms in total; 26 were in the anterior circulation and 3 were in the posterior circulation. The number of aneurysms was 12 (41%) in the ICA Pcom segment, 5 (17%) in the Acom, 4 (14%) in the ICA, 2 (7%) in the ICA ophthalmic segment, 2 (7%) in the anterior cerebral artery (ACA), 1 (3%) in the middle cerebral artery (MCA), 2 (7%) in the basilar tip, and 1 (3%) in the posterior inferior cerebellar artery (PICA).

As shown in Table 1, the SAH severity at the emergency department was HHG 1 in three patients (17.6%), HHG 2 in seven patients (41.2%), HHG 3 in zero patients (0%), HHG 4 in five patients (29.4%), and HHG 5 in two patients (11.8%). The mFG of the brain CT was Grade 1 in six patients (35.3%), Grade 2 in one patient (5.9%), Grade 3 in two patients (11.8%), and Grade 4 in eight patients (47.1%). The average GCS was 11.68 (SD = 4.11; range: 3–15) on admission and 12.65 (SD = 3.32; range: 3–15) on discharge. The mean interval from SAH to SAC was 54.24 h (SD = 46.59 h; range: 6–172 h).

Embolization results

As shown in Table 1, of the 29 aneurysms, 24 were treated with SAC. The occlusion was Raymond–Roy Class I in 16 aneurysms (66.7%), Class II in three aneurysms (12.5%), and Class IIIa in five aneurysms (20.8%).

Complications

In this cohort, there were no cases of aneurysm rebleeding during and after the procedure, but one patient (7.7%) developed intraventricular hemorrhage (IVH) secondary to extraventricular drainage (EVD) insertion. Moreover, there were no cases of in-stent stenosis.

Clinical outcome

As shown in Table 1, there was no aneurysm recurrence, which needed retreatment before discharge. Only one patient (5.9%) had aneurysm regrowth on follow-up angiography after discharge. After the procedure, three patients presented with severe vasospasm despite routine

administration of nimodipine 60 mg every 4 h. These cases were treated at the DSA room by administration of intra-arterial nicardipine drip through the femoral sheath in the bilateral ICA and vertebral artery. One of these three patients underwent decompressive craniectomy after the brain MRI revealed acute brain infarction secondary to vasospasm. At the end of the follow-up period, two patients expired; one died of hypovolemic shock secondary to upper gastrointestinal bleeding, and the other expired in the hospice after being lost to follow-up after discharge.

For the secondary outcomes at discharge, the GOS was 5 in five patients (29.41%); 4 in one patient (5.88%); 3 in seven patients (41.18%); 2 in three patients (17.65%); and 1 in one patient (5.88%), who eventually died, whereas the mRS was 0 in four patients (23.53%); 1 in one patient (5.88%); 3 in one patient (5.88%); 4 in five patients (29.41%); 5 in five patients (29.41%); and 6 in one patient (5.88%), who eventually died; no patient had an mRS of 2 at the time of discharge. At 6 months after discharge, the GOS was 1 in two patients (11.76%), 2 in three patients (17.65%), 3 in four patients (23.53%), 4 in one patient (5.88%), and 5 in seven patients (41.18%), whereas the mRS was 0 in six patients (35.29%), 1 in one patient (5.88%), 2 in one patient (5.88%), 4 in three patients (17.65%), 5 in four patients (23.53%), and 6 in the two patients (11.76%) who died; no patient had an mRS of 3 at 6 months after discharge. At 1 year after discharge, one patient was lost to follow-up; the GOS was 1 in two patients (12.50%), 2 in three patients (18.75%), 3 in three patients (18.75%), 4 in one patient (5.88%), and 5 in eight patients (50.0%); and the mRS was 0 in seven patients (43.75%), 1 in one patient (6.25%), 4 in three patients (18.75%), 5 in three patients (18.75%), and 6 in the two patients (12.50%) who expired. No patient had a GOS of 4 or an mRS of 2 or 3 at 1 year after discharge. Except for one patient who was lost to follow-up and the two patients who expired, all patients followed up at our center for at least 1 year after discharge.

As shown in Figure 2, among patients with HHG 1–2, the percentage of those with GOS of 5 increased from 50% at discharge to 60% after 6 months and 78% after 1 year. Some patients who had GOS of 3 at baseline improved to GOS of 4 and 5 after treatment. The percentage of patients with GOS of 2 at discharge slightly decreased to 11% after 1 year. In the HHG 3–5 group, one patient (14%) who had a GOS of 3 at discharge demonstrated improved GOS to 5 at 6 months and until 1 year after; one patient (14%) who had a GOS of 2 at discharge expired after 6 months; and one patient (14%) who had a GOS of 3 at discharge deteriorated to GOS 2 after 6 months. After 1 year, the percentage of patients with GOS 3 decreased from 71% to 43%, but that of patients with GOS 2 increased from 14% to 29%.

Figure 3 demonstrates that in the HHG 1–2 group, the number of patients with mRS 0 increased from 40% at discharge to 60% after 6 months and 78% after 1 year. Patients with mRS 2–4 at discharge improved to mRS 1 or 2 after 1 year, but those with mRS 5 (20%) at discharge remained in the same condition after 6 months. In the HHG 3–5 group, all patients had an mRS 4–5 at the time of discharge; one patient (14%) with mRS 4 improved to mRS 2 after 6 months and mRS 1 after 1 year, whereas one patient (14%) with mRS 5 expired after 6 months.

Glasgow Outcome Score, modified Rankin Scale, and Glasgow Coma Scale among the different time points to transarterial embolization

The 17 patients underwent TAE at different time points after admission. We recorded and grouped the interval between admission and TAE to <24 h, 24–72 h, and >72 h. After admission, TAE was performed <24 h in six patients, 24–72 h in six patients, and >72 h in five patients. As shown in Table 2, the GCS at admission and discharge and the GOS

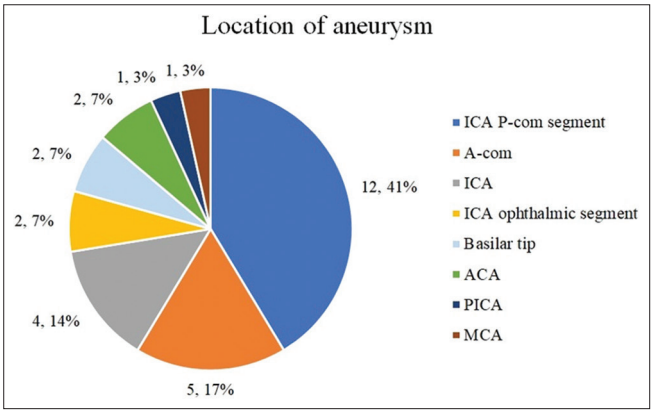

Figure 1: The pie chart demonstrates the distribution of all 29 aneurysms. ACA: Anterior cerebral artery, A-com: Anterior communicating artery, ICA: Internal carotid artery, MCA: Middle cerebral artery, PICA: Posterior inferior cerebellar artery, P-com: Posterior communicating artery

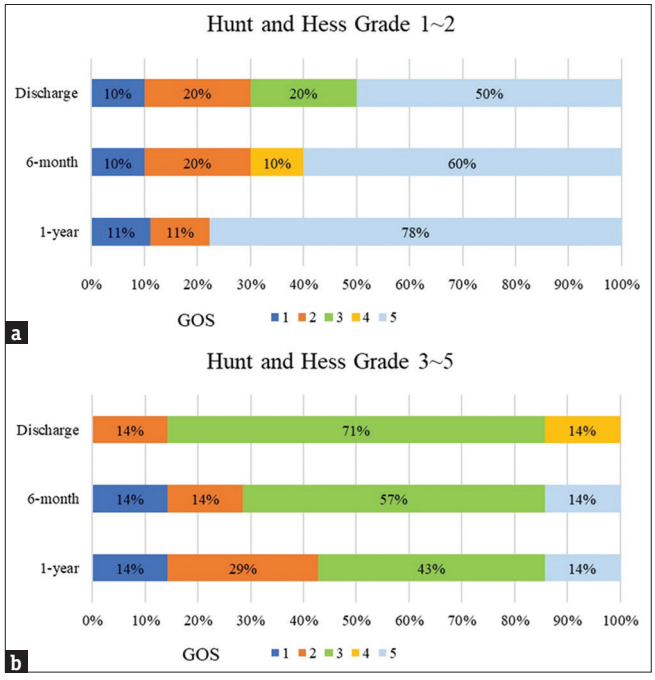

Figure 2: This demonstrates the trend of the percentage of patients with different Glasgow Outcome Score (GOS) in Hunt and Hess grade (HHG) 1~2 and HHG 3~5 groups at three scheduled time points. (a) In the HHG 1~2 group, the percentage of those with GOS of 5 increased from 50% at discharge to 60% after 6 months and 78% after 1 year. (b) In the HHG 3~5 group, only 14% of patients improved GOS to 5 at 6 months and until 1 year after discharge. GOS: Glasgow Outcome Score

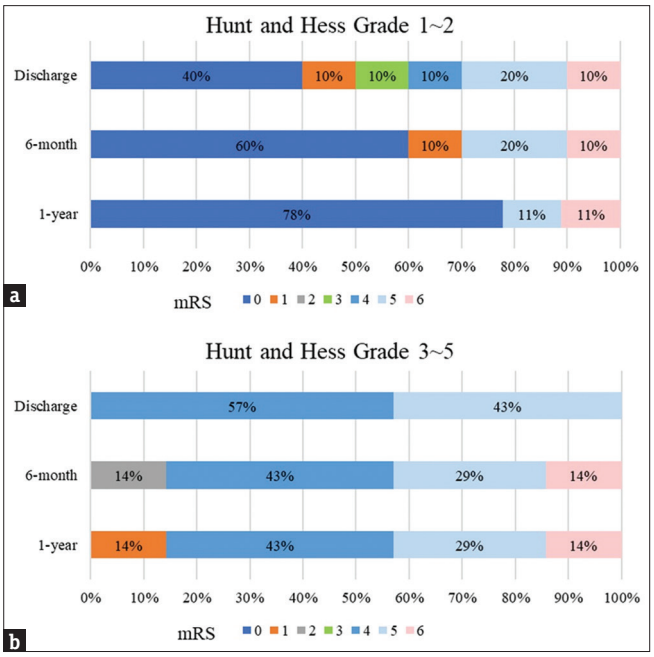

Figure 3: This demonstrates the trend of the percentage of patients with different modified Rankin Scale (mRS) in Hunt and Hess grade (HHG) 1~2 and HHG 3~5 groups at three scheduled time points. (a) In the HHG 1~2 group, the number of patients with mRS 0 increased from 40% at discharge to 60% after 6 months and 78% after 1 year. (b) In the HHG 3~5 group, only 14% with mRS 4 improved to mRS 2 after 6 months and mRS 1 after 1 year. mRS: Modified Rankin Scale

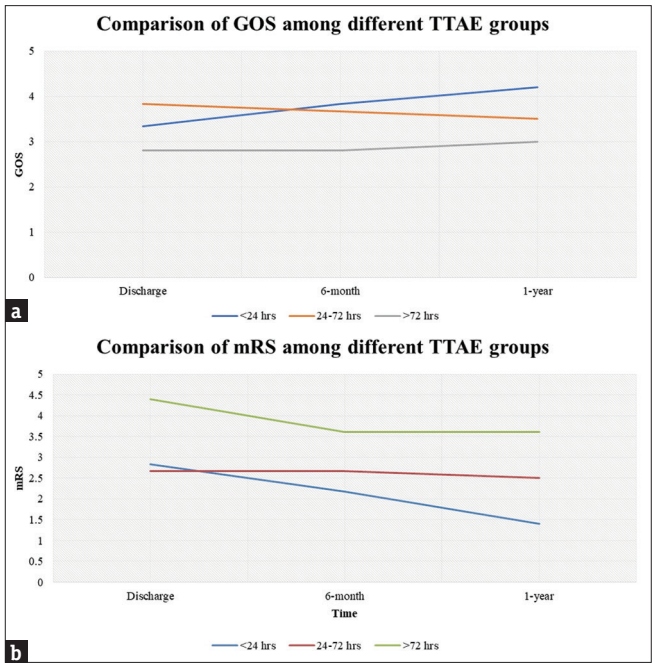

Figure 4: This demonstrates the relation between the outcomes and the time to transarterial embolization (TAE). (a) The Glasgow Outcome Score (GOS) at discharge was better when the time to TAE was within 24–72 h than <24 h and >72 h. The GOS after 6 months and 1 year was better when the interval to TAE was <24 h than within 24–72 h and >72 h. (b) The modified Rankin Scale (mRS) at discharge was better when the time to TAE was within 24–72 h than <24 h and >72 h. The mRS after 6 months and 1 year was better when the interval to TAE was <24 h than within 24–72 h and >72 h. GOS: Glasgow Outcome Score, mRS: Modified Rankin Scale

and mRS at discharge and 6 months and 1 year after were not significantly associated with the different intervals of TAE. Figure 4 demonstrates that an earlier time to TAE (<24 h) increased the risk of aneurysm rebleeding but was not significantly associated with the outcomes. The outcomes at discharge were better when the interval to TAE was within 24–72 h than <24 h and >72 h. However, the outcomes after 6 months and 1 year were better when the interval to TAE was <24 h than within 24–72 h and >72 h.

Factors associated with the Glasgow Outcome Score

As shown in Table 3 and Figure 5, we used linear regression to analyze the association of the following factors with the GOS and mRS at discharge and after 6 months and 1 year: age >64 years; number of aneurysms; posterior circulation involvement; presence of hydrocephalus, IVH, symptomatic vasospasm, and/or intracerebral hemorrhage; HHG ≥3; mFG ≥3; and shunt dependence.

On univariable analysis, four factors, including age >64 years, number of aneurysms, posterior circulation involvement, and HHG ≥3, were associated with the GOS at different time points. Multivariable linear regression revealed that posterior circulation involvement was a significant predictor of GOS at discharge and 6 months after.

Factors associated with the modified Rankin Scale

As shown in Table 4 and Figure 6, on univariable analysis, four factors, including age >64 years, number of aneurysms, posterior circulation involvement, and HHG ≥3, were associated with the GOS at different time points. Multivariable linear regression revealed that posterior circulation involvement was a significant predictor of mRS at discharge and 6 months after and HHG ≥3 was a significant predictor of mRS at discharge and at 6 months and 1 year after.

Table 2: Comparison of the Glasgow Outcome Score/modified Rankin Scale/Glasgow coma score among different time points to transarterial embolization groups

Item	<24 h	24–72 h	>72 h	Total	*P*
n	6	6	5	17	
GOS					
Discharge	3.33±1.37	3.83±1.60	2.80±0.45	3.35±1.27	0.433
6 months	3.83±1.83	3.67±1.63	2.80±0.84	3.47±1.50	0.516
1 year	4.20±1.79	3.50±1.76	3.00±1.22	3.56±1.59	0.519
mRS					
Discharge	2.83±2.32	2.67±2.66	4.40±0.55	3.24±2.14	0.369
6 months	2.17±2.71	2.67±2.66	3.60±2.07	2.76±2.44	0.649
1 year	1.40±2.61	2.50±2.81	3.60±2.07	2.50±2.53	0.417
GCS					
Admission	12.50±3.99	12.67±3.67	10.20±5.07	11.88±4.11	0.581
Discharge	13.00±2.90	12.67±4.76	12.20±2.17	12.65±3.32	0.932

P<0.05 was considered statistically significant after the test. Data are presented as *n* or mean±SD. GOS: Glasgow outcome score, mRS: Modified Rankin scale, GCS: Glasgow Coma Score, SD: Standard deviation

Discussion

SAC has been developed as a feasible endovascular treatment modality for ruptured intracranial aneurysms [7]. Several studies have demonstrated that compared with coiling

Table 3: Factors associated with the Glasgow Outcome Score

	Discharge				6 months				1 year			
	Univariable		Multivariable		Univariable		Multivariable		Univariable		Multivariable	
	β	*P*	β	*P*	β	*P*	β	*P*	β	*P*	β	*P*
Age >64 (yes vs. no)	−1.09	0.083	−1.12	0.093	−1.53	0.034*	−1.25	0.066	−1.51	0.056	−0.98	0.201
Count	−0.34	0.174	0.35	0.298	−0.64	0.020*	0.12	0.712	−0.77	0.007*	−0.17	0.673
Posterior circulation												
Involvement (yes vs. no)	−1.64	0.038*	−1.95	0.037*	−2.19	0.016*	−2.12	0.026*	−2.36	0.045*	−1.19	0.382
Hydrocephalus (yes vs. no)	−0.61	0.343	-	-	−0.41	0.593	-	-	−0.70	0.413	-	-
IVH (yes vs. no)	−0.28	0.668	-	-	−0.29	0.703	-	-	−0.78	0.349	-	-
Symptomatic												
Vasospasm (yes vs. no)	0.38	0.653	-	-	−0.17	0.868	-	-	0.50	0.692	-	-
ICH (yes vs. no)	0.38	0.653	-	-	1.05	0.288	-	-	0.95	0.370	-	-
HHG ≥3 (yes vs. no)	−0.60	0.355	−1.11	0.122	−1.04	0.166	−1.28	0.080	−1.51	0.056	−1.28	0.122
mFG ≥3 (yes vs. no)	−0.61	0.343	-	-	−0.41	0.593	-	-	−0.70	0.413	-	-
Shunt dependent (yes vs. no)	−0.35	0.621	-	-	−0.18	0.827	-	-	−0.58	0.544	-	-

*P<0.1, statistical significance for multivariable linear regression analysis. Data are presented as β (95% CI). Linear regression to analyze the association of the factors with the GOS at three scheduled time points. CI: Confidence interval, HHG: Hunt and Hess grade, mFG: Modified Fisher grade, IVH: Intraventricular hemorrhage, ICH: Intracerebral hemorrhage, GOS: Glasgow Outcome Score

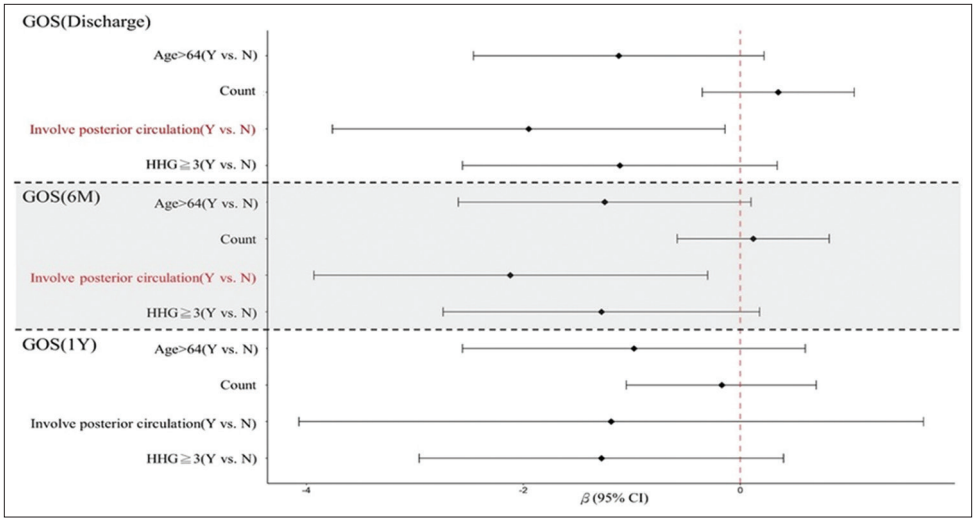

Figure 5: Multivariable linear regression revealed that posterior circulation involvement was a significant predictor of Glasgow Outcome Score at discharge and 6 months after. GOS: Glasgow Outcome Score, HHG: Hunt and Hess grade, CI: Confidence interval

alone, SAC had significantly superior long-term safety and efficacy, a higher complete occlusion rate, and a lower recurrence rate [4]. The stent itself could provide mechanical support by a scaffold effect and can prevent coil prolapse into the vascular lumen, allow dense coil packing to achieve complete occlusion, prevent turbulent blood flow around the aneurysm, and promote thrombosis in the aneurysm, which could decrease the rates of recurrence and retreatment [3].

However, the risk of bleeding remains a major concern after endovascular treatment by SAC, because of the fact that DAPT with drugs, such as aspirin and clopidogrel, is routinely administered intra- and postoperatively to reduce the incidence of thromboembolic complications [5,6]. Although dual- or single-antiplatelet therapy has been proven to be feasible for periprocedural use during acute aneurysmal SAH treatment, there is no standard protocol for the most appropriate dosage regimen [7].

In 2005, the ISAT demonstrated that standard antiplatelet therapy did not affect the outcome of patients with aneurysmal SAH at discharge and 1 year after [1]. One systematic review reported that the overall rate of procedure-related complications, including hemorrhage and thromboembolism, was nearly twice as in ruptured aneurysms than in unruptured aneurysms (13% vs. 6%) [8]. Moreover, the risk of bleeding may be a concern in patients who are under DAPT and need to undergo conversion of an EVD to a permanent ventriculoperitoneal shunt for secondary hydrocephalus [9]. Notably, in such instances, the tract and burr hole of the shunt are at the same site of the previous EVD. To decrease the risk of bleeding, the DAPT would need to be temporarily withheld for 1 day before the shunt surgery.

In this single-center retrospective cohort study, both SAC-related hemorrhagic and ischemic complication rates were low, and only one patient developed IVH secondary to EVD placement. One previous study revealed that EVD was associated with 0%–33% risk of hemorrhagic complications, even in patients who were not receiving any anticoagulation

Table 4: Factors associated with the Modified Rankin Scale

	Discharge				6 months				1 year			
	Univariable		Multivariable		Univariable		Multivariable		Univariable		Multivariable	
	β	*P*	β	*P*	β	*P*	β	*P*	β	*P*	β	*P*
Age >64 (yes vs. no)	1.54	0.148	1.40	0.165	1.61	0.187	1.12	0.284	2.16	0.09	1.51	0.190
Count	0.77	0.056	−0.39	0.438	1.05	0.019*	−0.17	0.750	1.19	0.009*	0.10	0.870
Posterior circulation												
Involvement (yes vs. no)	2.55	0.058	2.99	0.037*	3.12	0.040*	3.32	0.030*	3.43	0.071	2.00	0.330
Hydrocephalus (yes vs. no)	1.61	0.129	-	-	0.81	0.516	-	-	1.33	0.324	-	-
IVH (yes vs. no)	1.15	0.281	-	-	1.21	0.323	-	-	1.65	0.206	-	-
Symptomatic												
Vasospasm (yes vs. no)	−0.29	0.841	-	-	0.29	0.861	-	-	−0.57	0.776	-	-
ICH (yes vs. no)	−0.69	0.627	-	-	−0.93	0.566	-	-	−1.03	0.545	-	-
HHG≥3 (yes vs. no)	2.03	0.050	2.64	0.024*	2.59	0.026*	2.95	0.018*	2.92	0.016*	2.76	0.035*
mFG≥3 (yes vs. no)	1.61	0.129	-	-	0.81	0.516	-	-	1.33	0.324	-	-
Shunt dependent (yes vs. no)	1.47	0.207	-	-	0.80	0.555	-	-	1.33	0.380	-	-

*P<0.1, statistical significance for multivariable linear regression analysis. Data are presented as β (95% CI). Linear regression to analyze the association of the factors with the mRS at three scheduled time points. CI: Confidence interval, HHG: Hunt and Hess grade, mFG: Modified Fisher grade, IVH: Intraventricular hemorrhage, ICH: Intracerebral hemorrhage, mRS: Modified Rankin Scale

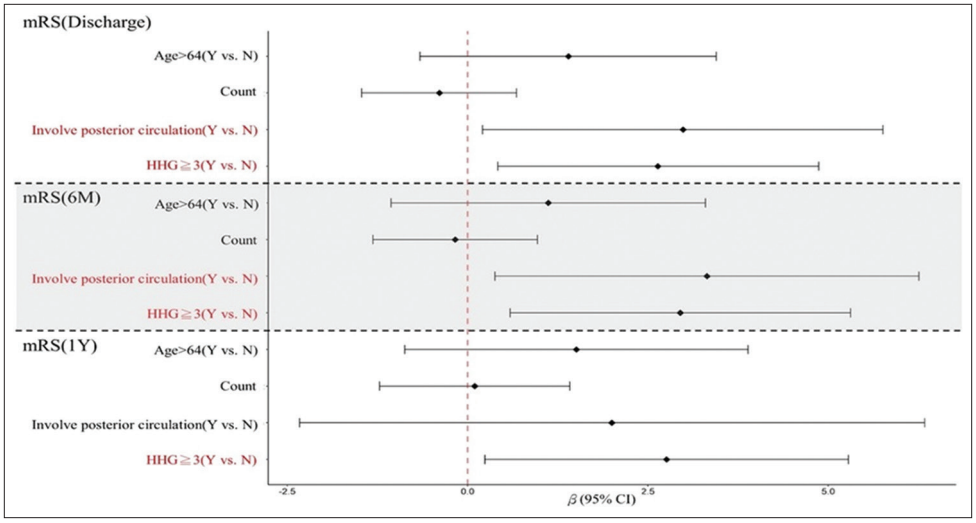

Figure 6: Multivariable linear regression revealed that posterior circulation involvement was a significant predictor of the modified Rankin Scale (mRS) at discharge and 6 months after. Hunt and Hess Grade ≥3 was also a significant predictor of mRS at discharge, at 6 months, and 1 year after. HHG: Hunt and Hess grade, mRS: modified Rankin Scale, CI: Confidence interval

medication [10]. In a retrospective database review, Saladino *et al*. demonstrated that the overall hemorrhagic rate of EVD was ≤10.0% in patients on DAPT and 7.1% in patients who had not received DAPT [11].

Therefore, the etiology of IVH cannot be entirely attributed to the use of DAPT medications. Meanwhile, another patient in this present cohort had a history of peptic ulcer and died of hypovolemic shock secondary to upper gastrointestinal bleeding. Theoretically, the use of DAPT was reported to aggravate the high risk of hemorrhage after SAC [12]. In this study, we did not encounter any hemorrhagic complications related to ventriculoperitoneal shunt.

None of the patients in this study had aneurysm rebleeding during and after the procedure, and postoperative angiography revealed complete or near-complete occlusion of the aneurysms in 66.7% and 12.5%, respectively. A previous study demonstrated that after SAC for a ruptured aneurysm, the immediate complete occlusion rate was 40.6%–69.0% and 60.0%–91.7% [4]. Moreover, in this study, the overall occlusion rate was satisfactory, with almost 80% classified as Raymond–Roy I and II. Moreover, failure of stent deployment and aneurysm securing were not encountered.

Our patients did not present with in-stent thrombosis, likely because of adequate DAPT after SAC. In cases of thromboembolic events during the SAC, our strategy was to load a glycoprotein IIb/IIIa antagonist (tirofiban) intravenously by drip infusion. After SAC, patients were immediately started on aspirin 200 mg and clopidogrel 150 mg, followed by maintenance DAPT with aspirin 100 mg and clopidogrel 75 mg daily for 6 months, then aspirin 100 mg alone daily for an indefinite period. We believe that DAPT after the procedure can reduce the risks of thromboembolic events and in-stent thrombosis, which are major concerns in these cases [12-14].

Despite routine nimodipine administration, three patients in this study developed symptomatic vasospasm in the bilateral ICA, MCA, ACA, and basilar artery after SAC and were managed by intra-arterial nicardipine infusion through the femoral sheath or decompressive craniectomy. One retrospective review demonstrated the widespread use of intra-arterial nicardipine infusion as the standard treatment can improve outcomes but cannot prevent vasospasm [15]. Moreover, one systematic review and meta-analysis demonstrated that nimodipine did not influence the incidence of vasospasm, but it improved the clinical outcome of patients with SAH-related aneurysm rupture [16]. Therefore, oral administration of nimodipine 60 mg every 4 h for 21 days had been the recommended gold-standard treatment, which should be used as soon as possible to achieve better clinical outcomes [16].

Our results on the significant associations of HHG ≥3 with the mRS and GOS at discharge and follow-up demonstrated that a more critical condition of the patients on admission was related to worse clinical outcomes. The HHG has been a widely accepted grading system for the clinical severity of aneurysmal SAH on admission and can strongly predict the rate of mortality. Our results were consistent with these scales.

Moreover, our results demonstrated the probability of poor clinical outcomes in cases of ruptured aneurysms in the posterior circulation. Aneurysms in the posterior circulation account for about 10%–15% of all intracranial aneurysms, with the most common location in the basilar artery bifurcation (63%), followed by the superior cerebellar artery and PICA [17]. In this cohort, 17.6% presented with acute SAH secondary to ruptured aneurysms in the posterior circulation, such as the PICA (n = 1) and basilar artery (n = 2). These results were consistent with those in previous studies, which revealed a higher risk of rupture and worse clinical outcomes in aneurysms in the posterior circulation than in those in the anterior circulation [18].

Furthermore, the absence of procedure-related complications in this cohort suggested the safety of SAC for acutely ruptured intracranial aneurysms. In addition, the morbidity and mortality rates in this study were lower, compared with those previously reported in the case series. Several cohort studies elucidated higher thromboembolic and hemorrhagic complications after SAC for ruptured aneurysms than for unruptured aneurysms (25% vs. 4.7%) [19,20]. Moreover, a ruptured intracranial aneurysm was reported to be a predictor of poor clinical outcomes [21-23]. Therefore, the use of SAC for ruptured intracranial aneurysms remains controversial [24]. Surprisingly, albeit the small sample size, our study demonstrated that SAC could provide favorable outcomes and decrease the rates of complications and recurrence. These results suggested SAC as a feasible, safe, and effective treatment modality for acutely ruptured intracranial aneurysms.

This study had inevitable limitations, including the retrospective and single-center design, which included only patients who underwent SAC for ruptured aneurysm. Moreover, the total number of patients included was small, because ruptured intracranial aneurysm is an uncommon disease. In fact, only 17 cases were performed at our medical center within 2 years. Owing to this small number of patients, we were unable to provide rigorous comparisons and conclusions. Nevertheless, we mainly aimed to evaluate the safety and efficacy of SAC for ruptured intracranial aneurysm. A well-designed prospective multicenter study may be needed to further clarify the safety and efficacy of this technique, in comparison with the others.

Conclusion

SAC for acutely ruptured intracranial aneurysm is a safe and effective endovascular treatment, which can decrease the rates of hemorrhagic complications, in-stent stenosis, and recurrence. Future well-designed prospective multicenter studies with larger sample sizes are warranted to further confirm the value of SAC in improving clinical outcomes.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Nil.

Conflict of interest

There are no conflicts of interest.

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