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Risk factors for recurrence and retreatment after endovascular treatment of intracranial saccular aneurysm larger than 8 mm

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Abstract

Background Large intracranial aneurysm is challenging for both surgical and endovascular treatment. High recurrence and retreatment rates are still limitations for endovascular treatment. Analysing risk factors of recurrence after endovascular treatment can be useful for planning future treatment strategies.

Method We retrospectively reviewed patients with intracranial saccular aneurysm (≥ 8 mm) who underwent endovascular treatment from 2008 to 2017 at our institution. The demographic features, clinical information and angiographic results were analysed to reveal the risk factors for recurrence and retreatment. Subgroup analysis was performed according to packing density (PD) and stent insertion status.

Results The total recurrence and retreatment rates were 25.7% (44/171) and 10.5% (18/171), respectively. Independent risk factors for recurrence after endovascular treatment were larger aneurysm size (OR 1.32; 95% CI 1.17–1.51; $p < 0.001$), ruptured status (OR 3.91; 95%CI 1.44–10.90; $p = 0.008$), initial incomplete occlusion (OR 2.72; 95%CI 1.18–6.41; $p = 0.020$), and low dome-to-neck ratio (OR 0.61; 95%CI 0.36–0.97; $p = 0.047$). The recurrence rate for the no-stent with low PD (< 17.5%) group was 50% (14/28); 37.5% (6/16) for stent-assisted coil (SAC) with low PD group, 22.0% (20/91) for no-stent with high PD group and 11.1% (4/36) for SAC with high PD group.

Conclusion The independent risk factors for recurrence after endovascular treatment in large (≥ 8 mm) intracranial saccular aneurysm were larger aneurysm size, ruptured status, low dome-to-neck ratio and initial incomplete occlusion state. SAC is a useful method for lowering recurrence after endovascular treatment for relatively large (≥ 8 mm) cerebral aneurysm.

Keywords Intracranial aneurysm · Endovascular procedure · Recurrence · Stents

Introduction

Since the International Subarachnoid Aneurysm Trial, intracranial aneurysm treatment has shifted from surgical clipping to endovascular treatment [10]. The major disadvantage of endovascular treatment is higher recurrence and retreatment rate, which increases the risk for aneurysm rupture. As the proportion of endovascular treatment increases, identifying risk factors for recurrence and retreatment is useful for planning treatment strategies.

Large aneurysm size, unfavourable morphology (wide neck and low dome-to-neck ratio), ruptured status, incomplete occlusion, posterior circulation, young age, incorporating artery involvement and length of follow-up are the known risk factors for recurrence after endovascular treatment of intracranial aneurysm [2, 3, 6, 11, 13, 15, 16, 18, 19, 22]. Other studies have shown that remodelling techniques such as balloon or stent-assisted coil (SAC) embolization can result in lower recurrence and further occlusion compared to simple conventional coil [9, 12, 14].

A relatively small aneurysm shows a lower risk of recanalization due to benign natural history, low intra-aneurysmal flow velocity and higher possibility of dense coil packing. Aneurysm size is the most important factor related to recurrence and

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retreatment after endovascular treatment. Nguyen et al. showed a higher recanalization rate with larger aneurysm size with 8-mm cut point (47% vs. 23%, $p < 0.01$) [11]. Other retrospective series showed that packing density (PD) was not related to recurrence in small cerebral aneurysm [5].

Because of the relatively benign nature of a small aneurysm, we included large aneurysm with 8-mm cut-off in this study. The purpose of this study was to identify risk factors for recurrence and retreatment after endovascular treatment of intracranial saccular aneurysm. Furthermore, we hypothesised that dense coil packing and stent insertion are the primary contributing factors for recurrence.

Methods and materials

Patient population

We retrospectively reviewed the patients who underwent endovascular treatment of intracranial aneurysm from 2008 to 2017 at our institution. Patients of all ages with an aneurysm equal or larger than 8 mm were included. Less than 6-month angiographic follow-up, stent only treatment including flow diversion stent, parent artery occlusion, fusiform or dissecting aneurysm, insufficient data and previously treated cases were excluded from the study. The Institutional Review Board at the author's institution (KC18RESI0538) approved this study.

Baseline characteristics

The data included sex, age, hypertension, diabetes mellitus, current smoking status, aneurysm location, circulation (anterior or posterior), bifurcation or non-bifurcation, initial rupture status, aneurysm size, neck and dome diameters, packing density (PD), initial angiographic result after treatment, angiographic follow-up duration and treatment modalities. Paraclinoid internal carotid artery (ICA) aneurysm included ICA aneurysm originating proximal to the posterior communicating artery (PCoA). Distal ICA aneurysm included PCoA and anterior choroidal artery (AChoA) aneurysms. Aneurysm size was estimated using 3D rotation images from digital subtraction angiography and defined as the largest diameter of the aneurysm. Neck and dome diameters were measured using identical methods. Aneurysm volume, coil volume and packing density were calculated using an on-line system available at www.angiocalc.com. PD was calculated by dividing coil volume by total aneurysm volume. Initial angiographic results after treatment were categorised as complete and incomplete, using Raymond-Roy occlusion classification: class I (complete occlusion) as complete and class II (residual neck) or class III (residual aneurysm) as incomplete [17]. Treatment modality was divided into no stent (including simple coil and balloon assist coil) and SAC groups.

Endovascular procedure

All procedures were performed under general anaesthesia with bi-plane X-ray angiography suite (Allura Xper FD20/20, Philips Electronics, Netherland & Siemens axiom artis, Siemens, Erlangen, Germany). In un-ruptured aneurysms, pre-medication with antiplatelet drugs (aspirin or/and clopidogrel) was administrated for at least 7 days. Systemic anticoagulation was held with intravenous heparin after femoral artery puncture to maintain activated clotting time 2~3 times higher than normal range. In ruptured aneurysms, antiplatelet drugs were not administrated in simple coil cases, and the loading dose of dual antiplatelet (aspirin 400 mg and clopidogrel 400 mg) was administered previous to stent deployment in SAC cases. Systemic anticoagulation was held after securing ruptured aneurysm with coils. The Neuroform (Boston Scientific, Natick, MA, USA), Enterprise (Codman, Raynham, MA, USA) or Low-profile Visualized Intraluminal Support (LVIS, Microvention, Tustin, CA, USA) stent was used in SAC cases. Majority of the patients who were treated with flow diverter stent did not use coil but only stent. So, these patients, with stent only treatment cases, were excluded from study. In SAC patients, antiplatelet medication was continued for at least 2 years.

Procedural complication

All procedural complication was recorded in all procedure. Ischaemic complication was defined as thrombus formation during procedure or infarction confirmed by radiologic evaluation. Haemorrhagic complication was defined as intraprocedural rupture confirmed by contrast extravasation during procedure or newly developed haemorrhage confirmed by radiologic evaluation. Coil protrusion to parent artery, coil stretching or stent migration was also considered as procedural complication. Procedure-related morbidity was defined as newly developed neurological deficits lasting more than 7 days.

Angiographic follow-up

Patients were scheduled for angiographic follow-up, either magnetic resonance angiography including time-of-flight image or catheter-based angiography, at 3 to 6 months, 1 year and 2 to 3 years after treatment. Early follow-up was considered in ruptured aneurysm or incomplete occlusion cases. Recurrence was defined as coil compaction, recanalization through the coil mesh, aneurysm regrowth or neck enlargement [4]. Remnant neck without change compared to postoperative state or tiny (< 2 mm) neck growth was not considered recurrence. Angiographic data were reviewed by one neuro-interventionist (J-H Choi) and one neuro-radiologist (B-S Kim), in a blind fashion. Retreatment was determined considering degree of recurrence, age, aneurysm location and previous rupture status. Important factors deciding retreatment for recurred aneurysm were initial rupture status and high degree of recurrence such as rapid aneurysm growth or coil loosening. Recurrence within a short-term period after treatment or younger patients was considered for retreatment. Small (< 2 mm) neck growth or older patients was less considered for retreatment.

Subgroup analysis

Patients were divided into four groups according to PD, which was dichotomized by the threshold for recurrence (< 17.5 and ≥ 17.5%) by using area under receiver operating characteristics curve and stent insertion status (no-stent and SAC). Subgroup analysis was performed to evaluate the effects of these parameters on recurrence and retreatment.

Statistical analysis

Parametric variables with normal distribution were compared with independent *t* test and those without normal distribution with Mann-Whitney *U* test. Non-parametric variables were compared with Fisher's exact or Chi-square test. Descriptions were reported as frequency (percentage) for categorical variables, mean (±standard deviation) for continuous variables with normal distribution and median [interquartile range (IQR)] for continuous variables without normal distribution. Variables with a value of $p < 0.10$ in univariate analysis were re-entered into the multivariate logistic regression model in a backward stepwise method. The odds ratio and 95% confidence index (CI) were presented for statistically significant factors ($p < 0.05$). Area under receiver operating characteristic curves were used to assess the model's predictive ability and to determine the packing density thresholds that separate the recurrence and no-recurrence groups. All data were analysed with R version 3.3.2 (https://www.r-project.org/; R Foundation for Statistical Computing, Vienna, Austria).

Results

A total of 264 patients with intracranial saccular aneurysm larger than 8 mm were treated by endovascular approach in our institution from 2008 to 2017. Among them, 93 patients were excluded due to follow-up loss, stent only treatment, flow diversion stent usage, parent artery occlusion, fusiform or dissecting aneurysm and insufficient data. A total of 171 patients were involved in the current study, and baseline values are shown in Table 1. The most common aneurysm location was paraclinoid ICA (42.1%), followed by distal ICA (22.2%), anterior communicating artery (ACoA), middle cerebral artery (MCA) bifurcation and basilar tip. The percentage of patients presenting with subarachnoid haemorrhage with ruptured aneurysm was 17.0% (29/171). The median aneurysm size was 9.9 [8.8; 12.8] mm, and mean PD was 21.9 ± 7.3%. Percentage of complete occlusion at initial treatment was 64.9% (111/171). Total recurrence and retreatment rate were 25.7% (44/171) and 10.5% (18/171), respectively, over a 42-month median follow-up duration (42.0 [24.0; 48.5]).

Table 1 Demographic data and angiographic findings of intracranial saccular aneurysm larger than 8 mm treated with endovascular treatment

	Total patients (*N* = 171)
Female sex	136 (79.5%)
Age	59.0 [52.0;67.0]
Hypertension	88 (51.5%)
Diabetes mellitus	18 (10.5%)
Smoking	20 (11.7%)
Aneurysm location	
Paraclinoid ICA	72 (42.1%)
Distal ICA (PCoA, AChoA)	38 (22.2%)
ACoA	23 (13.5%)
MCA bifurcation	13 (7.6%)
Basilar tip	9 (5.3%)
Others	16 (9.4%)
Posterior circulation	19 (11.1%)
Bifurcation aneurysm	47 (27.5%)
Ruptured status	29 (17.0%)
Aneurysm size (mm)	9.9 [8.8;12.8]
Neck diameter (mm)	5.2 [4.3;6.5]
Neck ≥ 4 mm	138 (80.7%)
Dome-to-neck ratio	1.6 [1.3;2.0]
Aneurysm volume (mm^3)	279.9 [185.0;563.5]
Coil volume (mm^3)	66.1 [44.0;121.5]
Packing density (%)	21.9 ± 7.3
Initial angiographic result	
Complete occlusion	111 (64.9%)
Incomplete occlusion	60 (35.1%)
Last follow-up (months)	42.0 [24.0;48.5]
Treatment modality	
No-stent	119 (69.6%)
Stent-assisted coil	52 (30.4%)
Type of stent used	
Enterprise	46 (88.5%)
Neuroform	3 (5.8%)
LVIS	3 (5.8%)
Duration to recurrence (months)	13 [7;24]
Duration to retreatment (months)	10 [3;17]
Recurrence	44 (25.7%)
Retreatment	18 (10.5%)

ICA internal carotid artery, *PCoA* posterior communicating artery, *AChoA* anterior choroidal artery, *ACoA* anterior communicating artery, *MCA* middle cerebral artery, *LVIS* low-profile visualised intraluminal support

Table 2 Comparison between recurrence and no recurrence groups and retreatment and no-retreatment groups

	No Recur (*N* = 127)	Recur (*N* = 44)	*p* value	No-retreatment (*N* = 153)	Retreatment (*N* = 18)	*p* value
Female sex	104 (81.9%)	32 (72.7%)	0.280	125 (81.7%)	11 (61.1%)	0.082
Age	58.0 [51.0;65.0]	65.0 [55.5;71.0]	0.012	59.0 [52.0;67.0]	65.0 [48.0;70.0]	0.924
Hypertension	63 (49.6%)	25 (56.8%)	0.516	80 (52.3%)	8 (44.4%)	0.704
Diabetes Mellitus	13 (10.2%)	5 (11.4%)	1.000	18 (11.8%)	0 (0.0%)	0.257
Smoking	15 (11.8%)	5 (11.4%)	1.000	18 (11.8%)	2 (11.1%)	1.000
Aneurysm location						
Paraclinoid ICA	63 (49.6%)	9 (20.5%)	0.001	66 (43.1%)	6 (33.3%)	0.586
Distal ICA	22 (17.3%)	16 (36.4%)	0.016	34 (22.2%)	4 (22.2%)	1.000
ACoA	18 (14.2%)	5 (11.4%)	0.830	22 (14.4%)	1 (5.6%)	0.473
MCA bifurcation	8 (6.3%)	5 (11.4%)	0.323	13 (8.5%)	0 (0.0%)	0.365
Basilar tip	6 (4.7%)	3 (6.8%)	0.696	7 (4.6%)	2 (11.1%)	0.242
Others	10 (7.9%)	6 (13.6%)		11 (7.2%)	5 (27.8%)	
Posterior circulation	13 (10.2%)	6 (13.6%)	0.734	14 (9.2%)	5 (27.8%)	0.047
Bifurcation	33 (26.0%)	14 (31.8%)	0.582	43 (28.1%)	4 (22.2%)	0.803
Ruptured status	14 (11.0%)	15 (34.1%)	0.001	21 (13.7%)	8 (44.4%)	0.003
Aneurysm size	9.5 [8.7;11.2]	13.1 [10.1;16.7]	< 0.001	9.7 [8.8;12.0]	16.4 [11.5;18.2]	< 0.001
Neck diameter	4.9 [4.2; 6.0]	6.0 [4.4; 8.2]	0.001	5.1 [4.2; 6.3]	6.0 [4.6; 8.4]	0.052
Dome-to-neck ratio	1.6 [1.3; 2.0]	1.6 [1.3; 2.0]	0.679	1.6 [1.3; 1.9]	1.8 [1.104; 2.5]	0.182
Packing density (%)	23.0 ± 6.8	18.8 ± 7.8	0.001	22.2 ± 7.2	19.5 ± 8.4	0.146
Angiographic result			0.001			0.096
Incomplete	35 (27.6%)	25 (56.8%)		50 (32.7%)	10 (55.6%)	
Complete	92 (72.4%)	19 (43.2%)		103 (67.3%)	8 (44.4%)	
Last follow-up	48.0 [24.0;51.5]	32.0 [18.5;48.0]	0.062	48.0 [24.0;49.0]	34.0 [18.0;43.0]	0.234
Treatment modality			0.273			0.598
No stent	85 (66.9%)	34 (77.3%)		105 (68.6%)	14 (77.8%)	
Stent-assisted coil	42 (33.1%)	10 (22.7%)		48 (31.4%)	4 (22.2%)	

ICA internal carotid artery, *PCoA* posterior communicating artery, *AChoA* anterior choroidal artery, *ACoA* anterior communicating artery, *MCA* middle cerebral artery

Total procedural complication and procedure-related morbidity rate were 6.4% (11/171) and 3.5% (6/171), respectively. Among 52 SAC patients, procedural complication occurred in three patients (5.8%, 3/52). Among these, ischaemic complication occurred in one patient (1.9%, 1/52) which led to procedure-related morbidity.

Comparisons of demographic and angiographic findings according to recurrence (recurrence vs. no-recurrence group) and retreatment (retreatment vs. no-retreatment group) status are shown in Table 2. According to aneurysm location, paraclinoid ICA showed the lowest (12.5%, 9/72) and distal ICA aneurysm showed the highest recurrence rate (42.1%, 16/38). According to treatment modalities, SAC group showed lower recurrence rate (19.2%, 10/52) compared to no stent group (28.6%, 34/119), but did not reach statistical significance. In univariate analysis, aneurysm location (paraclinoid and distal ICA), ruptured status, aneurysm size, neck diameter, packing density and incomplete angiographic result were related to recurrence, with statistical significance.

The results of the multivariate logistic regression test for recurrence and retreatment are shown in Table 3. Four variables remained significant risk factors for recurrence: (1) larger aneurysm size (OR 1.37; 95%CI 1.17–1.51; $p < 0.001$), (2) ruptured status (OR 3.91; 95%CI 1.144–10.90; $p = 0.008$), (3) incomplete occlusion (OR 2.72; 95%CI 1.18–6.41; $p = 0.020$) and (4) low dome-to-neck ratio (OR 0.61; 95%CI 0.36–0.97; $p = 0.047$). Paraclinoid ICA tended to recur less and distal ICA aneurysm to recur more often, but the difference was not statistically significant. Four variables remained significant risk factors for retreatment: (1) larger aneurysm size (OR 1.57; 95%CI 1.19–2.20; $p = 0.004$), (2) ruptured status (OR 4.88; 95%CI 1.04–24.88; $p = 0.047$), (3) posterior circulation (OR 13.17; 95%CI 1.78–118.06; $p = 0.014$) and (4) male sex (OR 7.42; 95%CI 1.36–45.86; $p = 0.023$). The threshold of packing density separating the recurrence and no-recurrence groups was 17.51% with a sensitivity 45.5% and a specificity 81.9% (area under curve = 0.659, $p < 0.001$). The threshold of dome-to-neck ratio separating the recurrence and no-recurrence groups was 1.81 with a

Table 3 Multivariate logistic regression model for recurrence and retreatment

	Recurrence			Retreatment		
	OR	95% CI	*p* value	OR	95% CI	*p* value
Aneurysm size	1.32	1.17–1.51	< 0.001	1.57	1.19–2.20	0.004
Ruptured status	3.91	1.44–10.90	0.008	4.88	1.04–24.88	0.047
Incomplete occlusion	2.72	1.18–6.41	0.020	3.04	0.66–15.92	0.164
Dome/neck ratio	0.61	0.36–0.97	0.047	0.45	0.11–1.33	0.237
Posterior circulation				13.17	1.78–118.06	0.014
Male sex				7.42	1.36–45.86	0.023
Bifurcation aneurysm				4.08	0.80–29.00	0.119
Paraclinoid ICA	0.42	0.14–1.15	0.099			
Distal ICA	2.06	0.77–5.65	0.151			

ICA internal carotid artery, *Distal ICA* represents posterior communicating artery and anterior choroidal artery aneurysm

sensitivity 40.9% and a specificity 68.5% (area under curve = 0.596, $p < 0.001$).

Patients were divided to four groups according to packing density (< 17.5 and ≥ 17.5%) and stent insertion status (no-stent and SAC). Figure 1 displays the recurrence and retreatment rate of each group. Among the four groups, the no stent with low PD (< 17.5%) group showed the highest recurrence (50.0%, 14/28) and retreatment rates (17.9%, 5/28). The SAC with high PD (≥ 17.9%) group show the lowest recurrence (11.1%, 4/36) and retreatment rates (5.6%, 2/36). There was no difference of procedural complications between four subgroups. The characteristics of the four subgroups are shown in Table 4.

Discussion

In the current study, large aneurysm size and ruptured status were both independent risk factors for recurrence and retreatment after adjusting for confounding factors. Sluzewiski et al. showed that, as the size of an aneurysm increases, the packing density decreases [19]. Dead space

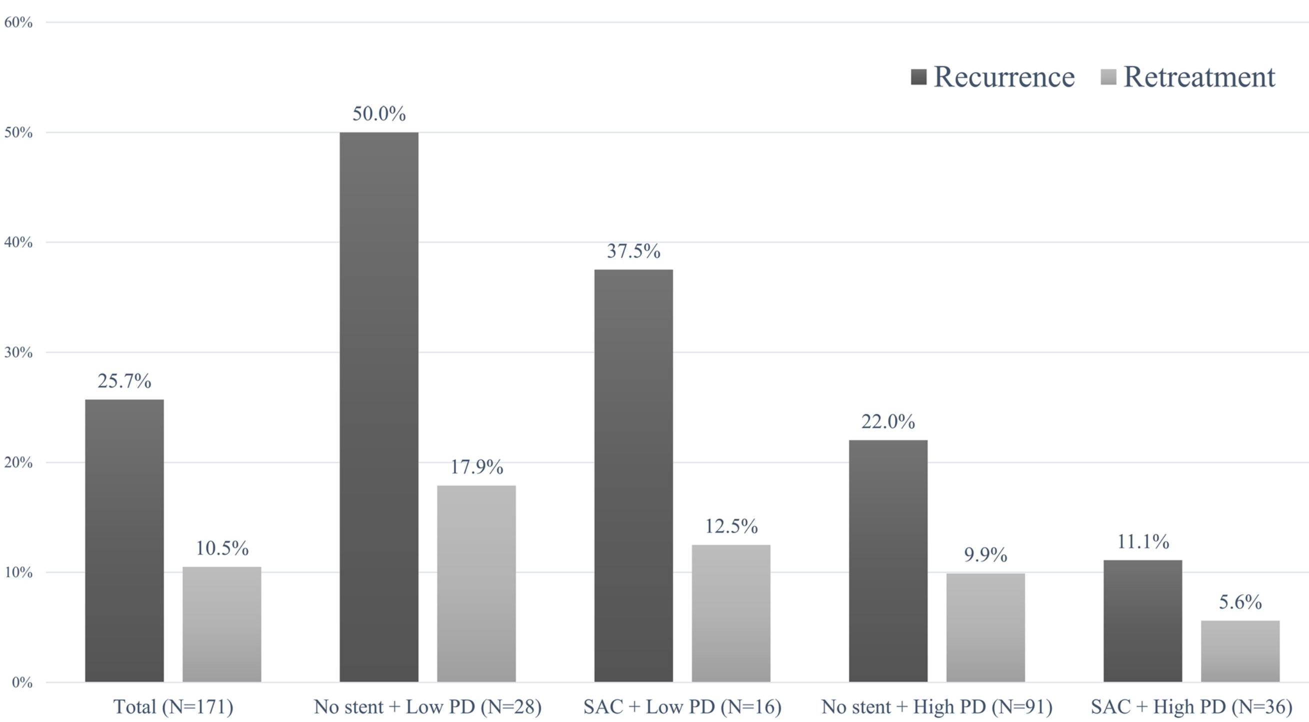

Fig. 1 Recurrence and retreatment rates of subgroups and total patients. PD, packing density; SAC, stent-assisted coil. The threshold, using AUC curve separating the recurrence and no recurrence groups, dichotomized by packing density (low PD < 17.5%; high PD ≥ 17.5%)

between the coils increases with use of multiple coils, allowing for persistent intra-aneurysmal flow, which can disturb thrombosis between coils [20]. Persistent arterial flow into the aneurysm disturbs endothelialisation of the aneurysm neck and results in coil compaction, coil loosening and aneurysm regrowth [7, 8]. High intra-aneurysmal flow rate can be estimated in large aneurysm itself, and low PD contributes to higher chance for aneurysm recanalization and regrowth.

Dense coil packing is difficult to achieve in ruptured cases because of fear of intra-procedural rupture. Furthermore, stent insertion is not preferred due to thromboembolism risk and hesitation to use anti-platelet medication. Staged embolization should be kept in mind as a treatment option in ruptured aneurysm, especially when a high recurrence rate is expected. Coil embolization of the aneurysm dome portion at the acute stage and additional coil with or without stent insertion can be planned when antiplatelet medication can be used safely. Short-term angiographic follow-up and an early treatment plan may be necessary in this situation.

Incomplete occlusion (residual neck or residual aneurysm) and low dome-to-neck ratio were related to recurrence in multivariate analysis, but not with retreatment. Unfavourable morphology such as wide neck and low dome-to-neck ratio leads to inappropriate coil framing and more cases of incomplete occlusion. In the current study, a neck diameter larger than 4 mm was found in 80.7% of cases (138/171), and the median dome-to-neck ratio was 1.6 [1.3; 2.0]. The majority of aneurysms showed unfavourable morphology, and this feature itself contributed to high recurrence.

In the current study, high recurrence rate was observed most frequently at distal ICA (42.1%, 16/38) and posterior circulation aneurysm (31.6%, 6/19) compared to other aneurysm locations. Distal ICA tended to show higher recurrence, but 25% (4/16) of cases led to retreatment. Among six patients who recurred from posterior circulation, five patients (83.3%, 5/6) were retreated in the current study. Posterior circulation aneurysm was not related to recurrence but tended to show rapid increase of aneurysm size, after recurrence which leads to retreatment. Therefore, more aggressive and definite treatment should be initially considered in posterior circulation aneurysm.

In subgroup analysis, the no-stent with low PD group showed the highest recurrence (50.0%, 14/28) and retreatment rates (17.9%, 5/28), and the SAC with high PD group showed the lowest. Among the low PD patients, SAC group showed 12.5% decrease of recurrence compared to no-stent group. Among the high PD patients, SAC group showed 10.9% decrease of recurrence compared to no-stent group. With large aneurysms, it is sometimes impossible to achieve high PD, and simple coiling even with high PD may not be enough to avoid recurrence. Therefore, stent insertion should be considered to

Table 4 Subgroup analysis according to stent insertion and packing density

	No stent + low PD (*N* = 28)	SAC + low PD (*N* = 16)	No stent + high PD (*N* = 91)	SAC + high PD (*N* = 36)	*p* value
Female sex	21 (75.0%)	13 (81.2%)	68 (74.7%)	34 (94.4%)	0.086
Age	67.0 [57.0;73.5]	60.0 [54.0;68.5]	58.0 [51.0;65.0]	59.5 [51.0;63.5]	0.007
Distal ICA	9 (32.1%)	4 (25.0%)	18 (19.8%)	7 (19.4%)	0.544
Paraclinoid	3 (10.7%)	9 (56.2%)	38 (41.8%)	22 (61.1%)	< 0.001
Bifurcation aneurysm	15 (53.6%)	1 (6.2%)	30 (33.0%)	1 (2.8%)	< 0.001
Circulation					0.444
Anterior	23 (82.1%)	14 (87.5%)	84 (92.3%)	31 (86.1%)	
Posterior	5 (17.9%)	2 (12.5%)	7 (7.7%)	5 (13.9%)	
Ruptured aneurysm	4 (14.3%)	2 (12.5%)	19 (20.9%)	4 (11.1%)	0.525
Aneurysm size	12.8 [8.9;16.2]	10.0 [8.9;14.2]	9.9 [8.8;11.9]	9.5 [8.6;11.5]	0.236
Dome/neck ratio	1.6 [1.4; 2.1]	1.0 [0.8; 1.7]	1.8 [1.5; 2.1]	1.2 [0.8; 1.6]	< 0.001
Packing density	12.9 ± 3.5	11.8 ± 4.2	25.5 ± 5.1	24.2 ± 5.0	0.007
Incomplete occlusion	23 (82.1%)	8 (50.0%)	23 (25.3%)	6 (16.7%)	< 0.001
Procedural complication	2 (7.1%)	6 (6.6%)	1 (6.2%)	2 (5.6%)	0.995
Ischaemic	1 (3.6%)	1 (1.1%)	0 (0.0%)	4 (2.3%)	0.278
Hemorrhagic	1 (3.6%)	2 (2.2%)	0 (0.0%)	0 (0.0%)	0.667
Morbidity	2 (7.1%)	3 (3.3%)	0 (0.0%)	1 (2.8%)	0.627
Recur	14 (50.0%)	6 (37.5%)	20 (22.0%)	4 (11.1%)	0.002
Retreatment	5 (17.9%)	2 (12.5%)	9 (9.9%)	2 (5.6%)	0.449

Distal ICA represents posterior communicating artery and anterior choroidal artery aneurysm, *PD* packing density, *SAC* stent-assisted coil reduce intra-aneurysmal flow and blood-to-coil contact, especially in situations where low PD is expected.

Stent insertion leads to several advantages over endovascular treatment including flow diversion and reduced intra-aneurysmal flow [14]. Scaffold function during coil embolization can lead to higher PD. Creating a mesh and fibro-elastic tissue formation along the neck help obliterate the aneurysm [1, 21]. In contrast, with stent insertion, there is a risk of thromboembolism, which can lead to serious complication. Furthermore, antiplatelet medication exposes the patients to additional risk, especially in ruptured cases. Therefore, stent insertion should be carefully determined by comparing the advantages and disadvantages. We believe that scaffold function during coil embolization and flow diversion effect of stent can reduce recurrence and retreatment rate. Furthermore, multiple or flow diversion stent can be an option to achieve higher flow diversion in challenging cases.

This retrospective study had several limitations. First, the number of retreatment patients was small (18 patients), and this could lead to statistical imprecision. Second, the proportion of unruptured aneurysms was large (83.0%), which made it difficult to analyse the effect of ruptured aneurysms. Third, retreatment was determined without strict objective criteria, which can lead to bias.

Conclusion

Independent risk factors for recurrence of intracranial saccular aneurysm (≥ 8 mm) after endovascular treatment were large aneurysm size, ruptured status, initial incomplete occlusion and low dome-to-neck ratio. Posterior circulation aneurysm was strongly associated with retreatment. SAC is a useful method for lowering the recurrence after endovascular treatment of relatively large (≥ 8 mm) cerebral aneurysm.

Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organisation or entity with any financial interest (such as honoraria; educational grants; participation in speaker's bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licencing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the institutional review board at the author's institute (KC18RESI0538).

Informed consent For this type of study, formal consent is not required.

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