

Success Rate of Simple Coil Embolization in Wide-Neck Aneurysm with Aneurysmal Shoulder

Abstract

Background and Objective: Wide-necked intracranial aneurysm (WIA) is one of the challenging diseases for neuro-interventionist to treat by simple coiling technique. The purpose of this study is to identify the morphology associated with successful simple coil embolization in wide neck aneurysm patients. **Materials and Methods:** Between January 2002 and August 2018, 102 patients with total 115 ruptured or unruptured WIA which received endovascular treatment were retrospective reviewed. Data were analyzed including demographics, aneurysm morphology, endovascular technique, angiographic outcome, complication, regrowth, and retreatment rate. **Results:** The mean age of patients was 61.6 years with female predominant (72.5%). Ruptured WIA was diagnosed in 71 patients (61.7%). Majority of aneurysms were located in an anterior circulation which were 74 cases (64.3%), mainly paraclinoid aneurysm (30/115). Endovascular treatment was successful in 113 cases (98.3%) which can be mainly divided into simple coil embolization 50 cases (43.5%), balloon-assisted coil embolization 26 cases (22.6%), and stent-assisted coil embolization 32 cases (27.8%). Complete, subtotal, and incomplete occlusion of WIA was achieved in 32 cases (27.8%), 62 cases (53.9%), and 18 cases (15.7%), respectively. There was 9.6% complication occurred. Regrowth and retreatment were found 20% and 15.7%, respectively. **Conclusion:** WIA with two-sided aneurysmal shoulder or neck width <3.6 mm. are significantly associated with successful coil embolization using simple coiling technique.

Keywords: Aneurysmal shoulder, coil embolization, intracranial aneurysm, shoulder of aneurysm, wide-necked aneurysm

Introduction

Intracranial saccular-type aneurysms occur in 3%–5% of general population.^[1] Nowadays, endovascular treatment has been increasingly used as a less physiologically stressful alternative to aneurysmal clipping. Since the publication of the results of the International Subarachnoid Aneurysm Trial, in 2002, endovascular treatment of intracranial aneurysm has been regarded as the treatment of choice.^[2]

In the early era, wide-necked intracranial aneurysm (WIA), defined by neck diameters greater than 4 mm or dome-to-neck ratios <2, are difficult to treat with the endovascular method.^[3,4] Complete coil embolization in WIA is often technically difficult owing to the risks of distal coil migration or coil impingement on the parent vessel.^[5-7] Later, the technical advance of complex coil shapes allowed successful endovascular therapy of aneurysms with a dome-to-neck ratio

of 1.5.^[8] Despite advances in devices and techniques, WIA are still one of the most challenging disease for neuro-interventionist. Stent-assisted coil embolization or flow diverter is possible tools to tackle with WIA. However, they come with the necessity of dual antiplatelet therapy. Many neuro-interventionists are reluctant to give dual antiplatelet in acute phase of ruptured aneurysm with subarachnoid hemorrhage. In addition, the incidence of periprocedural rupture was higher in SAH than in unruptured aneurysm.^[9] Balloon-assisted coil embolization in acute ruptured WIA is another good option, but it comes with increased periprocedural risk such as thromboembolic complication or arterial dissection compare with simple coiling technique. In terms of cost-effectiveness between simple coiling and device-assisted technique, simple coiling is more economical friendly especially in developing countries.

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Payothorn Decharin¹, Anchalee Churojana^{1,2}, Thaweesak Aurboonyawat^{2,3}, Ekawut Chankaew^{2,3}, Dittapong Songsaeng¹, Boonrerk Sangpetngam^{1,2}, Pattarawit Withayasuk^{1,2}

¹Department of Radiology, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, ²Siriraj Center of Interventional Radiology, Siriraj Hospital, Bangkok, ³Department of Surgery, Neurosurgery Unit, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand

Address for correspondence:

Dr. Pattarawit Withayasuk, Department of Radiology, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand.
E-mail: pattarawit.wit@mahidol.edu

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In our institution, consideration of treatment technique in saccular-type aneurysm was performed after the evaluation of 3D angiogram. In WIA, some operators decided to use simple coiling technique instead of device-assisted technique, especially, when WIA have shoulder or small size.

The main purpose of this study is to identify the appropriate morphology of WIA that associated with successful coil embolization using simple coiling technique.

Materials and Methods

Patient characteristics

In this retrospective analysis, every patient who were diagnosed as ruptured or unruptured WIA treated in Siriraj hospital, Mahidol University, Thailand, between January 2002 and August 2018 were included. Every intracranial saccular-type aneurysm in our institute were evaluated at least one time by diagnostic cerebral angiogram with 3D reconstruction image, alternately through two biplane digital subtraction angiography system (GE and Philips). The exclusion criteria were WIA which were treated by other mean of treatments except endovascular treatment, for example, surgical clipping and observation. The dissecting, blister, or giant aneurysm was excluded. The other exclusion criteria were the patients who had incomplete clinical data or inadequate imaging data for interpretation. We obtained approval for this study from the institutional review board committee which waived informed consent.

Definitions and terms

Definition for WIA is the intracranial saccular-type aneurysm that has dome height (D)/neck width (N) ratio ≤ 1.5 (D/N ratio is the same meaning with aspect ratio).^[10] Aneurysmal shoulder mean WIA which has dome width (W)/neck width (N) > 1 [Figure 1], estimated by visual assessment on working projection of aneurysm. One WIA may have one or two shoulders, defined as S1 and S2. One-sided shoulder mean WIA which has only S1, distance > 0 mm. Two-sided shoulder mean aneurysm that has S1 and S2, distance > 0 mm [Figure 2]. Angiographic outcome using Raymond–Roy classification (RROC) which can be divided into complete obliteration, subtotal obliteration (residual neck), and incomplete obliteration (residual aneurysmal sac) [Figure 3].^[11] According to our protocol, we performed follow-up cerebral angiogram by 3, 6, 12 months then annually for ruptured aneurysm and 6, 12 months then annually for unruptured aneurysm. Consideration of regrowth when there is evidence of recurrent aneurysmal sac after complete endovascular treatment. In every morphology aspect of aneurysm were evaluated by 3D reconstruction image from diagnostic cerebral angiogram. The decision of endovascular treatment in each intracranial aneurysm was depended on individual decision of each interventional neuro-interventionist. Dual-antiplatelet is applied only in

case with stent, not in simple coiling or balloon-assisted coiling.

The statistical analysis

The baseline characteristics of the aneurysms and demographic data were report using mean \pm standard deviation or number (%). For categorical variables, Chi-square test was used to determine statistical significance. Receiver operating characteristic (ROC) curve analysis was used in continuous variable. For determining which geometric features of aneurysms and what factors were most predictive of treatment decisions, a multivariable analysis was performed using multiple logistic regression method. For all statistical analyses, $P < 0.05$ was considered statically significant.

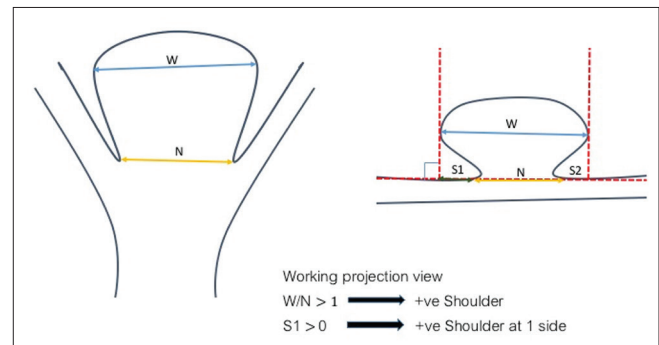


Figure 1: Illustration of shoulder aneurysm: Aneurysm that has shoulder mean aneurysm that has aneurysmal dome width (W)/neck width (N) > 1

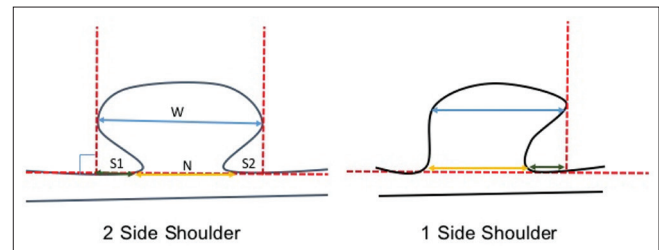


Figure 2: Illustration of one-sided shoulder and two-sided shoulder: One-sided shoulder mean aneurysm that has S1 or S2 distance > 0 mm. and two-sided shoulder mean aneurysm that has S1 and S2 distance > 0 mm

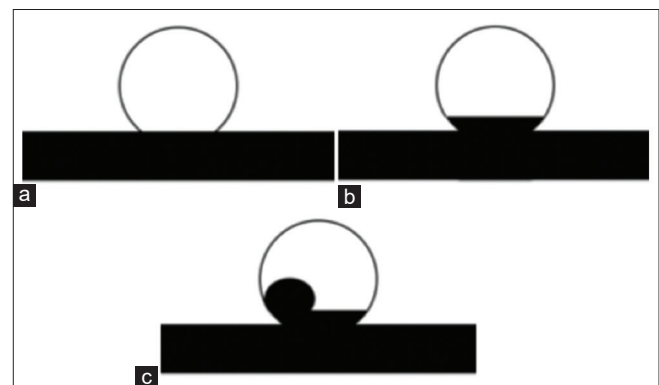


Figure 3: Raymond-Roy classification for aneurysmal occlusions after endovascular treatment. (a) Complete obliteration of the aneurysm. (b) Subtotal obliteration of the aneurysm (residual aneurysmal neck). (c) Incomplete obliteration of the aneurysm (residual aneurysmal sac)

Results

The total of 102 patients with 115 WIA was treated by endovascular treatment. The mean age of patients was 61.61 years ranging from 18 to 88 years with female predominant (74/102, 72.5%). Seventy-one of 115 (61.7%) were diagnosed as ruptured aneurysm. Majority were in anterior circulation which were 74 cases (64.3%), 30 paraclinoid aneurysms (40.5%), 24 posterior communicating artery aneurysm (32.4%), and 11 anterior communicating artery aneurysm (14.9%). In posterior circulation, basilar tip is the most common location (13 in 41 cases; 31.7%). Small number of aneurysm in other location is shown in Table 1. Most of the aneurysms have saccular shape which were 88 cases (77.5%). The rest of aneurysms have bi-lobed, irregular, and other morphology which were 7/115 (6.1%), 19/115 (16.5%), and 1/115 (0.9%), respectively [Table 1]. Eighty-eight percent of aneurysm has size ≤ 7 mm. The mean dome height and width were 3.97 mm (1.3–9.7) and 4.40 mm (1.7–14), respectively. Seventy cases of 115 (60.8%) aneurysm had neck width less than 4 mm. Dome to neck ratio <1.1 was found in 67/115 (58.2%) [Table 1].

Of all WIA which were treated by endovascular treatment, 113 cases (98.3%) were successful. Simple coiling technique was used in 50 cases (43.5%) [Figures 5-7] while balloon- and stent-assisted coil embolization were done in 26 (22.6%) and 32 (27.8%) cases, respectively. Only two cases were using double microcatheter technique and two cases with stent-assisted coil combined with flow diverter. One case was treated solely by flow diverter [Table 2].

For the angiographic outcome of treatment which can be categorized as complete obliteration, subtotal obliteration (residual neck), and incomplete obliteration (residual aneurysm) according to RROC were 33 (28.7%), 62 (53.9%), and 18 (15.7%) cases respectively [Table 2]. If consider only simple coil embolization, RROC was 19 (38%), 26 (52%), and 5 (10%), respectively.

There were periprocedural complications in 11 cases (9.6%) which were 4 cases of minute contrast leakage in flat-panel computed tomography after embolization. Four cases had intraoperative ruptured aneurysm with contrast extravasation which can be successfully secured [Figure 8] but result in parent vessel occlusion in one case. There were 1 case of coil loop protrusion in parent vessel, 1 case of thromboembolic complication (distal emboli) which was recanalized after glycoprotein IIb/IIIa inhibitor administered, and 1 case of groin hematoma [Table 2]. If consider only simple coil embolization, there are 5 cases of complications including 4 cases of intraprocedural rupture with contrast extravasation and one case with small coil loop retaining in parent vessel. In the patient with residual coil loop in parent artery did not receive antiplatelet therapy after embolization, due to the presentation of acute subarachnoid hemorrhage. According to low number

Table 1: Demographic data and wide-necked intracranial aneurysm characteristics

Patients (n=102) and aneurysm characteristics (n=115)	
Demographic data and aneurysm characteristics	
Age (years), mean (range)	61.61 (18-88)
Gender: Male, n (%)	28/102 (27.5)
Clinical presentation, n (%)	
Ruptured aneurysm	71 (61.7)
Unruptured aneurysm	44 (38.3)
Location	
Anterior, n (%)	74 (64.3)
Paraclinoid aneurysm	30
Pcom	24
Acom	11
M1 segment of MCA	2
Pericallosal artery of ACA	2
MCA bifurcation	1
Others	4
Posterior, n (%)	41 (35.7)
Basilar tip	13
Basilar trunk	9
SCA	9
VA and VBJ	6
PICA	2
PCA	2
Aneurysmal shape, n (%)	
Saccular	88 (77.5)
Bilobed	7 (6.1)
Lobulated	19 (16.5)
Other	1 (0.9)
Size (mm), n (%)	
<7	88/100 (88.0)
≥ 7	12/100 (12.0)
Dome height, mean (range)	3.97 (1.3-9.7)
Dome width, mean (range)	4.40 (1.7-14)
Neck size (mm), n (%)	
<4	70 (60.8)
≥ 4	45 (39.1)
Dome: Neck ratio, n (%)	
<1.1	67 (58.2)
≥ 1.1 - <1.5	48 (41.1)

Pcom – Posterior communicating artery aneurysm; Acom – Anterior communicating artery aneurysm; MCA – Middle cerebral artery; ACA – Anterior cerebral artery; SCA – Superior cerebellar artery; VA – Vertebral artery; VBJ – Vertebrobasilar junction; PICA – Posterior inferior cerebellar artery; PCA – Posterior cerebral artery

of complication, there is no statistic difference between complication rate in simple coiling compares with other techniques.

Of all treatment technique, regrowth rate and retreatment rate of all WIA are 20% and 15.7%, respectively [Table 2]. However, when compares between simple coiling technique and other device-assisted technique, there is no significant difference in these parameters ($P = 0.367$ and 0.787).

ROC curve was used to identify the point that had highest sensitivity and specificity of dome height (D), dome width (W), neck width (N), and D/N ratio [Figure 4].

Factors associated with successful simple coil embolization by univariable analysis were D <4.6 mm, W <3 mm, N <3.6 mm, aspect ratio (D/N ratio) more than 1.1, and

shoulder at least one side of an aneurysm [Table 3]. After analyzed by multivariable analysis using multiple logistic regression method, the factors associated with successful simple coil embolization were neck width <3.6 mm and aneurysm that had two-sided shoulder [Table 4].

Discussion

In this study, WIA which have neck width <3.6 mm are significantly associated with availability for simple coil embolization. Similar results from previous studies by Brinjikji *et al.* found that coiling without adjunctive techniques was favored over coiling with adjunctive techniques in 94/134 (70%) cases of aneurysms with a neck size <4.0 mm.^[10] The study result shows the similar trend which is 61.8% of patients with neck width <3.6 mm that simple coil embolization can be achieved.

Brinjikji *et al.* also found that aneurysms with aspect ratio (D/N ratio) <1.2 often required adjunctive techniques (89% of cases).^[10] According to our study, ROC curve shows aspect ratio more or equal 1.1 is the best cut point for simple coiling technique (>50% of the case with simple coiling). However, multivariate analysis shows no significant difference between simple coiling and device-assisted technique.

To the best of our knowledge, we introduce new term which is “Aneurysmal shoulder.” Instead of neck width or size of

Table 2: Results of treatment and outcome

Endovascular technique in aneurysmal treatment (n=115)	
Treatment parameters	n (%)
Success rate	113 (98.3)
Simple coil embolization	50 (43.5)
Balloon-assisted coil embolization	26 (22.6)
Stent-assisted coil embolization	32 (27.8)
Double microcatheter technique	2 (1.7)
Stent assisted coil combined with flow diverter	2 (1.7)
Flow diverter alone	1 (0.9)
Outcome	
Complete obliteration	33 (28.7)
Subtotal obliteration (residual neck)	62 (53.9)
Incomplete obliteration (residual aneurysmal sac)	18 (15.7)
Complications	11 (9.6)
Intra-procedural rupture of aneurysm	4 (3.5)
Regrowth	23 (20)
Retreatment	18 (15.7)

Table 3: Univariable analysis of factors associated with successful coil embolization

Factors	Simple coil (50) (%)	Device assisted (65) (%)	P
Dome height <4.6 mm	39/50 (78.0)	38/65 (58.5)	0.030*
Dome width <3 mm	17/43 (39.5)	9/56 (16.1)	0.011*
Neck <3.6 mm	34/49 (69.4)	21/65 (32.3)	<0.001*
Aspect ratio ≥1.1	26/49 (53.1)	21/65 (32.3)	0.035*
Shoulder			
No	7/49 (22.6)	24/62 (77.4)	0.004*
1-side	19/49 (44.2)	24/62 (55.8)	
2-side	23/49 (62.2)	14/62 (37.8)	
Morphology: Saccular shape	38/50 (76.0)	50/65 (76.9)	1.000
Location: Anterior circulation	31 (43.1)	41 (56.9)	1.000

*P-value < 0.05 considering statistically significant

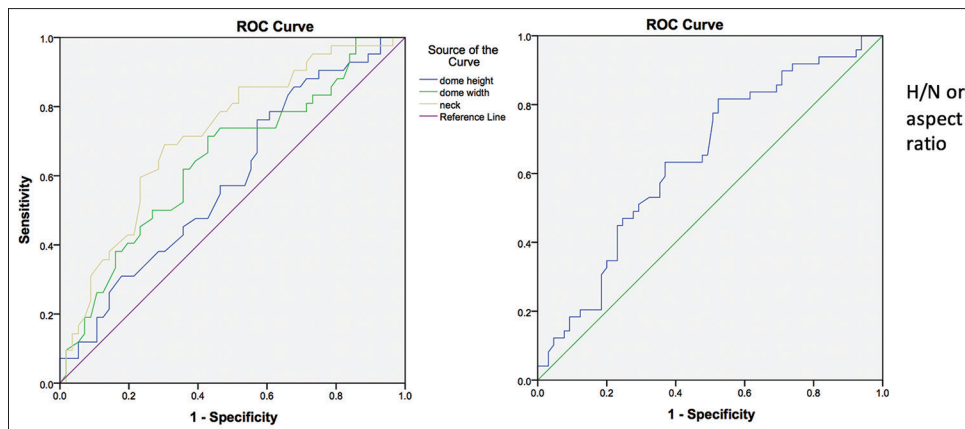


Figure 4: Receiver operating characteristic curve of dome height (D), dome width (W), neck width (N) and D/N ratio (aspect ratio)

aneurysm measurement (dome height and dome width), we believe that aneurysmal shoulder plays an important role to support coil mesh and prevent it from falling or prolapse outside the aneurysm sac. No matter how large or how long of the hole, as long as, we have enough support (shoulder of aneurysm), we can do embolization those WIA with simple coiling technique. In this study, WIA which have two-sided shoulder are significantly associated with successful simple coil embolization. Moreover, WIA with one-sided shoulder is having tendency of successful embolization using simple coil technique.

If we look closer to the measurement, we can find that aneurysms that have two-sided shoulder are the aneurysm that has dome width to neck width ratio more

Table 4: Multivariable analysis: Multiple logistic regression

Factors	OR (95%CI)	P
Aspect ratio ≥ 1.1	1.23 (0.40-3.74)	0.717
Neck <3.6 mm	3.97 (1.04-15.13)	0.043*
Dome width <3 mm	2.34 (0.58-4.38)	0.234
Dome height <4.6 mm	1.10 (0.28-4.38)	0.89
Shoulder		
No	1	
1-side	3.47 (0.84-14.35)	0.080
2-side	11.02 (2.40-50.69)	0.002*

P-value < 0.05 considering statistically significant, OR – Odds ratio; CI – Confidence interval

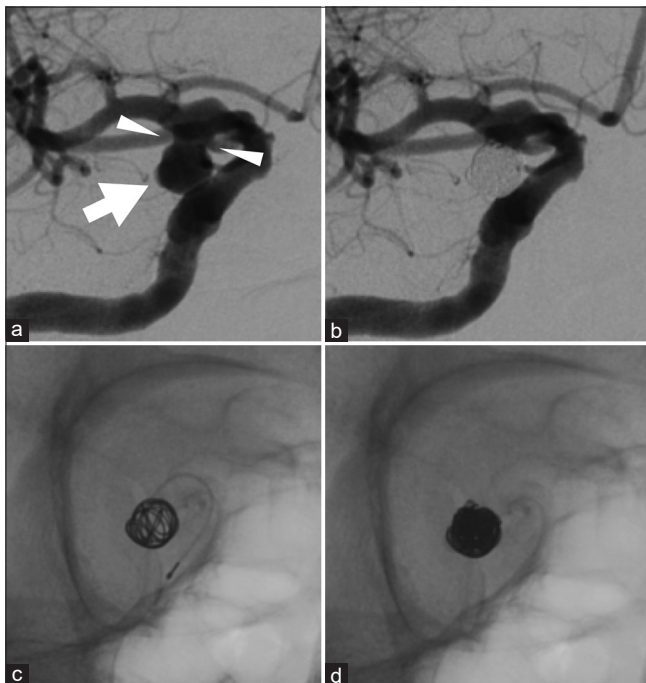


Figure 5: Example of wide-necked aneurysm with two-sided shoulder that was successfully treated by simple coiling technique. (a and b) Working projection from angiogram of right internal carotid artery showed right posterior communicating artery aneurysm (white arrow) which has two-sided shoulder (two white arrow heads) before and after embolization. (c and d) Non-subtraction images of coil mesh during and after embolization

than 1. Many studies suggest that dome width to neck width ratio is associated with achievement of simple coil embolization. For instance, Brinjikji *et al.* said that cases with dome-to-neck ratios <1.2, adjunctive techniques were used in most of them, whereas for cases with dome-to-neck ratios more than 1.6, aneurysms were treated without adjunctive techniques in most of them. We consider this ratio is somehow close but not the same as shoulder of aneurysm. The differences are that shoulder of aneurysm is the separation of measurement of aneurysm in each side and do not include neck width in consideration.

The advantage of this measurement is ease of use, because in our study, we do not use quantitative measurement of the distance of shoulder of aneurysm. We only identify that the shoulder of aneurysm is present or absent by visual assessment on working projection of the angiogram. It is very simple method. In order to make a quick decision for treatment of WIA. However, there are many drawbacks of this study, for example, we do not have quantitative value of shoulder of aneurysm to show because our data were not available for quantitative measurement in all cases from our PAC system. Nevertheless, the quantitative measurement can be collected in future study.

Even, simple coil embolization is the easiest way for endovascular treatment of intracranial aneurysm. Regrowth rate and retreatment rate show no statistic difference when compares with device-assisted technique. However, neurointerventionist has to make sure that coil position

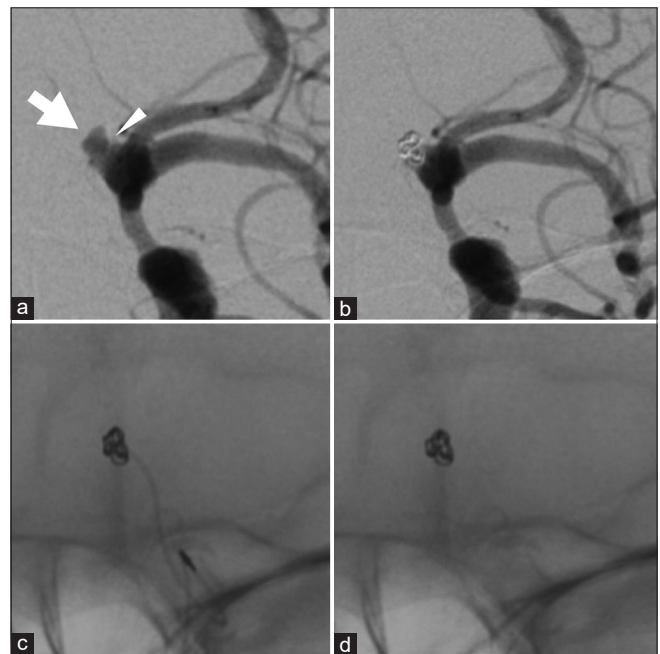


Figure 6: The example of wide-necked aneurysm with one-sided shoulder that was successfully treated by simple coiling technique. (a and b) Working projection from angiogram of left internal carotid artery showed left posterior communicating artery aneurysm (white arrow) which has one-sided shoulder (white arrow head) before and after embolization. (c and d) Nonsubtraction images of coil mesh during and after embolization

is good enough, within aneurysmal sac, and before detachment. If not sure, the operator can retrieve coil back and change to more advanced technique to support coil, depend on individual expertise.

According to large meta-analysis of endovascular treatment of WIA in 2016 by Zhao *et al.*, complete and

nearly complete occlusion is 57.4%.^[12] The study is 82.6% (Complete obliteration + Subtotal obliteration), better than this meta-analysis. Moreover, meta-analysis shows 80.1% for coiling alone, which comparable to 90% in our study.

Regrowth and retreatment rate in this meta-analysis = 9.4% and 5.8%.^[12] Even using stent, McLaughlin *et al.* showed recanalization rate in WIA up to 13%.^[13] These results are quite contrary to our study that shows 20% and 15.7%, respectively. The explanation is that our cases are mainly ruptured aneurysm; we try to secure the aneurysm without tight coil packing or using too many devices. Together with problem of reimbursement system and low number of neuro-interventionist in our country, our endovascular cases are mainly aneurysm in difficult location for surgery, such as posterior circulation, paraclinoid aneurysm, and also difficult posterior communicating artery aneurysm (91/115, 79.1%). These aneurysms are more favorable in terms of regrowth rate or retreatment during the follow-up.^[14,15] Some anterior circulation aneurysms, such as middle cerebral artery aneurysm, are usually sent for surgical treatment. Then, only one case of middle cerebral artery bifurcation aneurysm in our series, this patient was treated by coil embolization in the same setting of ruptured another posterior communicating artery aneurysm.

The most common complication for embolization of WIA in our study is intraprocedural rupture, 4 from 115 cases (3.5%). However, we can secure them all. All four cases presented with acute subarachnoid hemorrhage, so clinical did not change much. Many literatures pointed out rate of the intraprocedural rupture of the aneurysm from

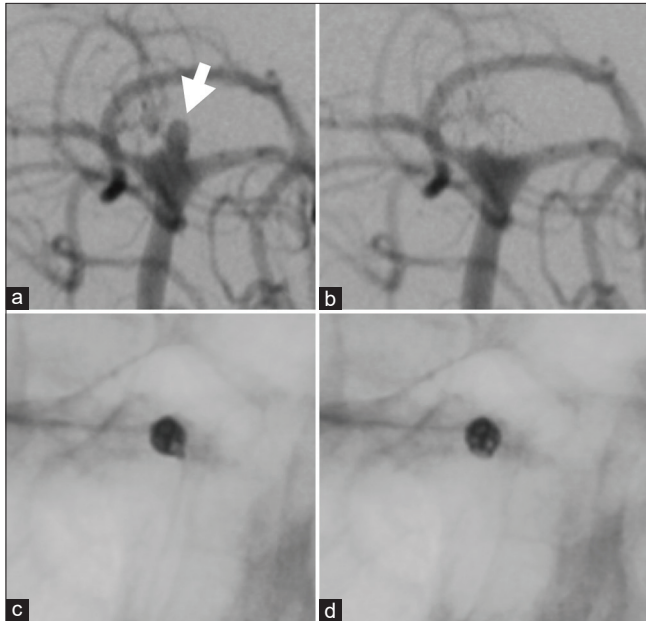


Figure 7: Example of wide-necked aneurysm without aneurysmal shoulder that was successfully treated by simple coiling technique. (a and b) Working projection from angiogram of basilar artery showed basilar tip aneurysm (white arrow) which has no aneurysmal shoulder before and embolization. (c and d) Non-subtraction images of coil mesh during and after embolization

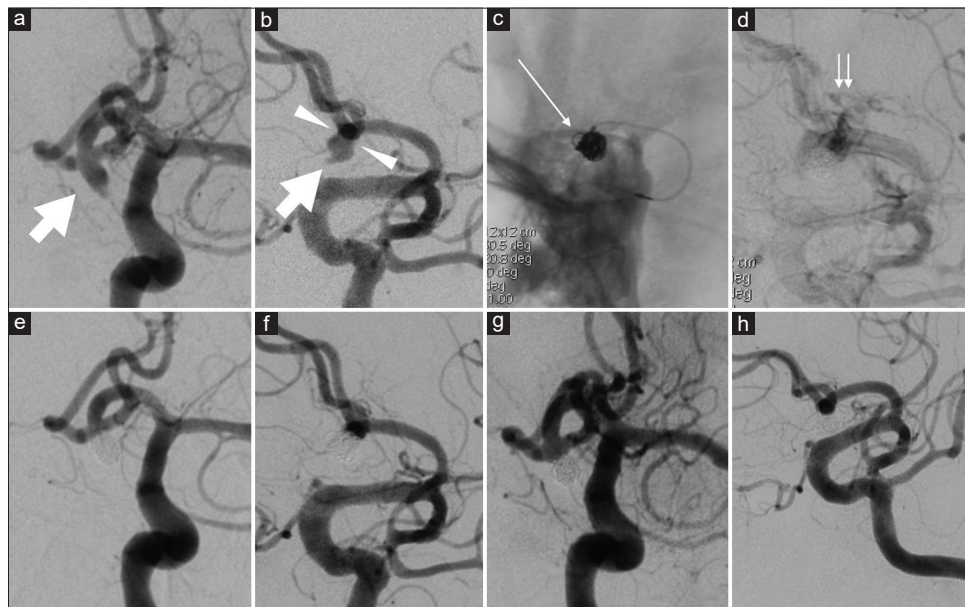


Figure 8: Example of peri-procedural rupture during simple coil embolization. (a and b) Working projection from angiogram of left internal carotid artery showed anterior communicating artery wide-necked aneurysm (white thick arrow) which has two-sided shoulder (two white arrow heads). (c) Coil loop of second coil protrude out of aneurysmal contour (Thin white arrow). (d) Contrast extravasation from the aneurysm (Double thin white arrow). (e and f) Control angiogram showed no residual aneurysmal neck. (g and h) Follow-up angiogram 2 years after showed no aneurysmal regrowth

endovascular treatment ranging between 1% and 5%.^[9,16] This is one of the disadvantages of simple coiling when compare to balloon-assisted coiling, that using balloon can control hemorrhage after the incidence. Some studies also showed that balloon-assisted coiling do not increase rate of intra-procedural rupture.^[16]

Limitations of this study are single-center retrospective study, limit number of cases. There may be selection bias or operator dependent of our staff in choosing which case can be successful simple coil embolization or not. Measurement error due to different machine or 3D reconstruction image setting is also possible.

Conclusion

Although we have many devices such as balloon, stent, or flow diverter to cope with complex aneurysm such as WIA. However, complex technique come with more risk of complication and also risk of using double antiplatelet therapy in stenting. Simple coil embolization is still useful, economical friendly and it is the simplest technique for neuro-interventionist to deal with aneurysm, especially when aneurysmal morphology is suitable. WIA which have neck width <3.6 mm and two-sided shoulder are significantly associated with success rate of simple coil embolization in our institute.

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Conflicts of interest

There are no conflicts of interest.

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