

Clipping versus Coiling in Ruptured Aneurysms of the Anterior Cerebral Circulation

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Abstract

Objective: To evaluate and compare the outcomes of microsurgical clipping and endovascular coiling of ruptured anterior cerebral circulation aneurysms. **Methods:** The current study retrospectively included 61 patients presented with subarachnoid hemorrhage (SAH), treated by clipping or coiling for ruptured aneurysms located in anterior circulation. Anatomic outcome and post-operative ischemic events were evaluated. The primary clinical outcomes were evaluated as operative complications while the secondary clinical outcome was evaluated by modified Rankin scale (mRS) at discharge. **Results:** Of 61 ruptured aneurysms, 47 and 14 were treated by surgery and coiling, respectively. The average follow-up duration was 19.1 ± 18.6 months for clipping and 21.7 ± 14.8 months for coiling. Complete occlusion was greater in surgery group (80.8%) than endovascular group (21.4%). Re-growth occurred in 2 cases of the coiling group only. Ischemic events were encountered in both groups; silent ones were higher in coiling group (21.4%) than in clipping group (6.3%), while symptomatic ones were higher in the clipping group (49%). Good outcome (mRS 0 - 2) was 51% and 71.4% after clipping and coiling respectively. Postoperative hospital period was longer after clipping ($P = 0.04$). **Conclusions:** For anterior circulation ruptured aneurysms, both treatments are feasible, coiling showed lower rate of morbidity while clipping results were better regarding durability and recurrence. Coil embolization may be preferred, which is the current point proved by the RCT like ISAT, but if you choose the patients carefully and find out the optimal candidate for the clipping, the clipping is still enough feasible as a mainstream.

Keywords

Anterior Circulation, SAH, Clipping, Coiling, Ruptured Aneurysms

1. Introduction

Ruptured cerebral aneurysms are considered the leading cause of non-traumatic subarachnoid hemorrhage (SAH) and represent 70% - 80% of all SAH cases [1]. Untreated ruptured intracranial aneurysms cause a high burden of morbidity and mortality with a high risk of rebleeding [2]. Treatment of ruptured aneurysms is difficult and different from treatment of unruptured ones. The difficulty comes from factors caused by the aneurysm rupture and SAH as brain swelling, presence of hematoma, the resulting intracranial hypertension, vasospasm, and fragility of the aneurysm at the site of rupture with increased risk of intraprocedural rupture [3].

Endovascular treatment (EVT) of intracranial aneurysms was initially introduced as a means of occluding inoperable aneurysms. Since the development of electrolytically detachable coils, the indications for EVT have widened to include surgically difficult ruptured, as well as non-ruptured, aneurysms [4]. Since then several advancements, including complex-shaped coils, balloon remodeling techniques, the use of stent-supported coiling, or flow diverter stents, have been introduced into the endovascular treatment options for more anatomically difficult and complex aneurysms leading to increased use of endovascular treatment in the management of cerebral aneurysms [5].

Endovascular coil embolization and surgical clipping are the main treatment options for ruptured and unruptured aneurysms. Which treatment modality is best in terms of aneurysm occlusion and durability with low recurrence rate and post-operative morbidity is, however, a widely debated topic. In this study we assess both modalities in the treatment of ruptured aneurysms in the anterior cerebral circulation.

2. Materials and Methods

The current study retrospectively included patients presented to Keio hospital by subarachnoid hemorrhage due to ruptured Saccular aneurysms located in anterior cerebral circulation from January 2012 to December 2017 with exclusion of patients with giant (>25 mm), fusiform or dissecting aneurysms, patients unfit for surgery or endovascular management were also excluded. All patients were initially admitted to intensive care unit. The management of SAH patients was performed according to the AHA/ASA latest guidelines [6]. All patients requiring external ventricular drainage were so treated, and all patients received appropriate vasospasm prophylaxis and treatment in the form of nimodipine 60 mg orally every 4 hours and maintenance of euvolemia.

The indication of surgical or interventional treatment was decided by evidence-based manner. The selection of treatment for each case was based on characteristics of individual patients and aneurysms offering both modalities of treatment taking into account patient preference. All clipping and coiling cases were performed on with monitoring of motor evoked potential (MEP) and somatosensory evoked potential (SEP). In clipping cases, the patency of parent artery, major branches, and visible perforators were confirmed with laser Doppler

flowmetry and indocyanine green angiography.

2.1. Angiographic Outcome

Anatomic results were divided into complete occlusion, presence of postoperative neck remnant and re-growth on follow-up. Postoperative CT images were obtained in the first and seventh postoperative days after clipping. In coil embolization, CT was obtained in the first postoperative day and MRI in the fifth postoperative day, other follow up imaging was done at variable intervals depending on the case. Imaging included CT angiography (CTA), MRA and/or digital subtraction angiography (DSA).

2.2. Ischemic Events and Clinical Outcomes

The primary outcomes were evaluated as operative complications such as ischemic events, neurological morbidity (irrespective of duration), the presence of post-procedure hemorrhage (subdural, extradural, cerebral and subarachnoid hemorrhage), or infection (wound infection, meningitis, and pneumonia).

Ischemic events were defined by the presence of infarction on subsequent CT scan or MRI or angiographic occlusion of a blood vessel by the time of hospital discharge regardless of the presence of symptoms. In the current study early infarction (post-procedure in the first 3 days of SAH) is considered procedure-related complication while late infarction (4 days after the start of SAH) is considered due to vasospasm, some cases exhibited both types.

The secondary clinical outcome was evaluated by worsening of modified Rankin scale (mRS) at discharge, mRS was used for evaluation considering mRS 0 - 2 as good outcome and mRS 3 - 6 as poor outcome.

2.3. Independent Variables

Independent variables investigated as possible risk factors for outcomes included demographic data of patients (age, sex, preoperative WFNS grade, preoperative SAH grade, presence of diabetes mellitus, hyperlipidemia, hypertension and other co-morbidities), aneurysm data (dome size, aneurysm height, neck width, presence of daughter sac, incorporate artery and multiple aneurysms), procedure-related data (temporary arterial occlusion in surgery—the use of balloon and stent in coiling) and follow up duration.

2.4. Statistics

Categorical variables expressed as a percentile, continuous variables as mean \pm SD. Univariate analysis is done using chi-square test, Fisher exact test, and unpaired t-test as appropriate. Multivariate analysis is conducted by multivariate logistic regression.

2.5. Informed Consent

Informed consent is obtained from the patients by the way of the opt-out condi-

tion. The present study was approved by the ethics committee of Keio University School of Medicine and was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

3. Results

3.1. Characteristics of Patients and Aneurysms

Table 1 shows baseline characteristics of patients and aneurysms. Of 61 ruptured

Table 1. Demographic criteria of patients and aneurysms for ruptured cases.

Characteristics	Microsurgery (47)	Endovascular (14)	P value
Age (year)	58.8 ± 14	56 ± 16	0.57
Gender			
Female	28 (59.6%)	10 (71.4%)	0.53
Male	19 (40.4%)	4 (28.6%)	0.53
Hypertension	25 (53%)	5 (35.7%)	0.25
DM	3 (6.4%)	1 (7.1%)	0.91
Hyperlipidemia	4 (8.5%)	0	0.56
Other co morbidities	22 (46.8%)	6 (42.8%)	0.79
WFNS grade			
Grade 1	13 (27.6%)	4 (28.6%)	0.94
Grade 2	14 (29.8%)	3 (21.4%)	0.7
Grade 3	2 (4.2%)	0	0.99
Grade 4	12 (25.6%)	3 (21.4%)	0.75
Grade 5	6 (12.8%)	4 (28.6%)	0.2
Modified Fisher grade			
Grade 1	3 (6.4%)	2 (14.3%)	0.3
Grade 2	3 (6.4%)	2 (14.3%)	0.3
Grade 3	29 (61.7%)	6 (42.8%)	0.2
Grade 4	12 (25.5%)	4 (28.6%)	0.8
Aneurysm criteria			
Location of aneurysm			
ICA	11 (23.4%)	8 (57%)	0.016*
MCA	16 (34%)	1 (7%)	0.04*
ACA	20 (42.6%)	5 (36%)	0.64
Maximum diameter of dome (mm)	3.9 ± 2.2	5.4 ± 3.1	0.11
Maximum height of the sac (mm)	5 ± 2.4	5.2 ± 1.8	0.78
Neck width (mm)	2.8 ± 1.4	2.6 ± 0.8	0.56
Presence of daughter sac	28 (59.6%)	11 (78.6%)	0.22
Presence of Incorporate artery (IA)	6 (12.7%)	3 (21.4%)	0.41
ICA	6/11 (54.5%)	2/8 (25%)	0.35
MCA	0/16	1/1 (100%)	0.05
ACA	0/20	0/5	
Operative:			
Temporary arterial occlusion in surgery	34 (72.3%)		
Balloon-assisted coiling		8 (57%)	
Stent-assisted coiling		0	

DM: Diabetes mellitus; ICA: internal carotid artery; MCA: middle cerebral artery; ACA: anterior cerebral artery; IA: Incorporate artery; WFNS: World Federation of Neurosurgical Societies; *statistically significant.

aneurysms, 47 and 14 were treated by surgery and coiling, respectively. Between treatment groups, the location of aneurysm showed significant difference. In coiling group, 8 aneurysms (57%) were located at ICA. In contrast ruptured aneurysms located at MCA treated by coiling were only 1 (7%). There were no other significant differences between the two groups.

3.2. Angiographic Outcome

Complete obliteration of the ruptured aneurysms was greater in clipping group (80.8%) than in the coiling group (21.4%) ($P = 0.0005$), the frequency of post-operative neck remnant was greater in the coiling group (71.4%) than in the clipping group (19.2%) ($P = 0.0005$). Regrowth occurred in 2 cases after coiling (14.2%) both continued under follow up while no regrowth occurred after clipping ($P = 0.04$). In one case coiling was renounced and patient did not receive any further treatment (**Table 2**).

3.3. Clinical Outcomes

The average follow-up duration for ruptured aneurysms was 19.1 ± 18.6 months for the surgery group and 21.7 ± 14.8 months for the coiling group. Good outcome obtained in 24 cases in the surgery group (51%) and 10 cases in the endovascular

Table 2. Summary of results for ruptured cases.

Outcome	Microsurgery (47)	Endovascular (14)	P value
Complete occlusion	38 (80.8%)	3 (21.4%)	0.0005*
Neck remnant	9 (19.2%)	10 (71.4%)	0.0005*
Re growth	0	2 (14.2%)	0.04*
Retreatment for regrowth	0	0	
Failure	0	1 (7.2%)	0.22
Rebleeding	1 (2.1%)	1 (7.2%)	0.4
Asymptomatic thromboembolism	3 (6.3%)	3 (21.4%)	0.12
Symptomatic thromboembolism	23 (49%)	5 (35.7%)	0.38
SDH/EDH	6 + 7 (27.6%)	0	0.02*
Contusions/hemorrhage	3 + 2 (10.6%)	0	0.58
Hydrocephalus	13 (27.6%)	4 (28.6%)	0.94
Temporary morbidity	18 (38.3%)	3 (21.4%)	0.34
Permanent morbidity	16 (34%)	5 (35.7%)	0.9
Operations for complications	29 (61.7%)	4 (28.6%)	0.036*
wound infection/meningitis	5 (10.6%)	0	0.58
Pneumonia	16 (34%)	4 (28.6%)	0.7
Post-operative hospital period (day)	44 ± 25	31.4 ± 18	0.04*
Mortality	1 (2.1%)	2 (14.2%)	0.12

SDH: subdural hematoma; EDH: extradural hematoma; *statistically significant.

group (71.4%) with no significant statistical difference ($P = 0.22$). Nonetheless, as shown in **Table 3**, the outcome of endovascular treatment in severe cases (WFNS 4 - 5) was much better than surgery as good outcome was obtained in 57.1% of cases with coiling and 16.7% of cases with clipping but was not statistically significant ($P = 0.06$). Regarding mortality, one case (2.1%) in the surgery group and two cases in the endovascular group died (14.2%) ($P = 0.12$), all of them were WFNS grade 5 (**Table 4**).

3.4. Ischemic Events and Morbidity

Ischemic events were encountered in both groups; the rate of asymptomatic ones is higher in coiling group (21.4%) than in clipping group (6.3%) In contrast, the occurrence rate of symptomatic ischemic complication is higher in clipping group (49%) than in coiling group (35.7%) but there was no statistical significance of either of them.

After clipping there was 8 cases with early infarction (17%) and 21 cases with late infarction (44.6%) while in the coiling group 3 cases with early infarction (21.4%) and 5 cases with late infarction (35.7%). Procedure related ischemic events showed no statistical difference ($P = 0.7$)

The occurrence rate of temporary morbidity including limb paralysis, dysphasia, cognitive dysfunction, cranial nerve affection, CSF leak, urinary dysfunction and frontal lobe symptoms was higher in the surgery group. The other independent complications and occurrence rate in each group were also shown in **Table 2**.

Table 3. Clinical outcome in both groups of ruptured aneurysms.

WFNS scale	Outcome		P-value
	mRS 0 - 2	mRS 3 - 6	
WFNS grade 1 - 3			
Clipping (29)	21 (72.4%)	8 (27.6%)	0.65
Coiling (7)	6 (85.7)	1 (14.3)	
WFNS grade 4 - 5			
Clipping (18)	3 (16.7%)	15 (83.3%)	0.06
Coiling (7)	4 (57.1%)	3 (42.9%)	

WFNS: World Federation of Neurosurgical Societies; mRS: modified Rankin Scale.

Table 4. Mortality cases in ruptured aneurysms.

	Sex	Age	Location	Dome Size	Neck Size	WFNS	Fisher	Modality	condition
1	M	73	Lt. IC-AchA	16.4	9.68	5	4	Clipping	Massive infarction with edema and midline shift due to vasospasm
2	F	44	Lt. ICA	12.47	3.8	5	4	Coiling	Massive infarction with edema and midline shift due to vasospasm
3	F	85	Lt. ICPC	11.3	4.2	5	3	Coiling	Failure of coiling, rebleeding, multiple strokes and hydrocephalus

Lt: left, Rt: right, ICA: internal carotid artery; AchA: anterior choroidal artery; PC: posterior communicating; F: female; M: male; WFNS: World Federation of Neurosurgical Societies.

Postoperative second intervention for complications was statistically higher in the surgery group as 17 cases underwent second surgeries, in some cases more than one surgery with total of 29 surgeries (61.7%) while in the coiling group, 4 cases subjected to second surgeries (28.6%) ($P = 0.036$), nature of the second intervention and its frequency is shown in **Table 5**. postoperative hospital period was significantly longer in clipping 44 days \pm 25 than in coiling 31.4 days \pm 18 ($P = 0.04$) (**Table 2**).

3.5. Predictors for Neck Remnant

Univariate analysis of risk factors for neck remnant in the clipping group presented neck width ($P = 0.03$) and the presence of incorporate artery (IA) ($P = 0.008$) to be significant independent variables. The presence of IA is significant in multivariate analysis (**Table 6**). Regarding coiling group, analysis of neck remnant and regrowth was not possible due to small number.

3.6. Predictors for Ischemic Events and Functional Outcome

On analysis of cases with ischemic events (symptomatic and asymptomatic) in the surgery group, age of the patient ($P = 0.038$), size of the aneurysm dome ($P = 0.008$), neck width ($P = 0.005$), WFNS grade 4 - 5 ($P = 0.0001$) and SAH with modified Fisher grade 4 in preoperative imaging ($P = 0.0004$) were found to be

Table 5. Operations for complications in both groups of ruptured aneurysms.

Modality	Intervention	Frequency
Surgical clipping	Ventriculoperitoneal shunt	13
	Cranioplasty	7
	Decompressive craniectomy	3
	Wound debridement	2
	Evacuation of EDH	1
	Dural repair for CSF leak	1
	Trapping of Acom A. (post-operative pseudoaneurysm)	1
	Ophthalmological surgery for Terson syndrome	1
	Endovascular coiling	Ventriculoperitoneal shunt
	Ophthalmological surgery for Terson syndrome	1

EDH: extradural hematoma; CSF: cerebrospinal fluid; Acom A.: anterior communicating artery.

Table 6. Predictors of neck remnant after clipping in ruptured aneurysms.

Variable	Univariate analysis		Multivariate analysis	
	P value	P value	Odd ratio	Confidence interval 95%
Neck width				
continuous	0.14	0.18	1.6	0.85 - 3.49
Categorical (>4 mm)	0.03*			
Presence of IA	0.008*	0.04*	8.5	1.13 - 80.9

*statistically significant.

statistically significant in univariate analysis. On multivariate analysis, WFNS grade 4 - 5 was significant ($P = 0.01$) (**Table 7**). In the coiling group analysis did not reveal significant predictors, yet it showed higher percentage of ischemic infarct with modified fisher grade 4.

Analysis of the predictors of poor functional outcome ($mRS > 2$) of all ruptured aneurysms revealed age ($P = 0.0006$), dome size > 10 mm ($P = 0.03$), WFNS grade 4 - 5 ($P = 0.0002$), modified Fisher grade 4 ($P = 0.007$), occurrence of peri-operative ischemic events ($P = 0.00003$) and occurrence of hydrocephalus ($P = 0.0004$) to be important risk factors for poor outcome with no effect of the modality of treatment itself. On multivariate analysis age ($P = 0.04$), WFNS grade 4 - 5 ($P = 0.01$), ischemic events ($P = 0.04$) and hydrocephalus ($P = 0.02$) were all significant (**Table 8**).

4. Discussion

The current study was conducted in one institute but in which both treatments

Table 7. Predictors of ischemic events after clipping in ruptured aneurysms.

Variable	Univariate analysis		Multivariate analysis	
	P value	P value	Odd ratio	Confidence interval 95%
Age	0.038*	0.2	1.04	0.98 - 1.12
Neck width				
continuous	0.01*	0.65	1.4	0.32 - 7.65
Categorical (>4 mm)	0.005*			
Size of dome				
continuous	0.008*	0.28	1.68	0.67 - 4.85
Categorical (>10 mm)	0.049			
WFNS grade 4 - 5	0.0001*	0.01*	124	1.9 - 130
Modified Fisher grade 4	0.0004*	0.27	2.35	0.63 - 16.3

WFNS: World Federation of Neurosurgical Societies; * statistically significant.

Table 8. Predictors of poor functional outcome in ruptured aneurysms.

Variable	Univariate analysis		Multivariate analysis	
	P value	P value	Odd ratio	Confidence interval 95%
Age	0.0006*	0.04*	1.07	1.007 - 1.15
Size of dome				
continuous	0.15	0.78	0.94	0.64 - 1.35
Categorical (>10 mm)	0.03*			
WFNS grade 4 - 5	0.0002*	0.01*	10.2	1.86 - 79.3
Modified Fisher grade 4	0.007*	0.7	0.69	0.08 - 4.51
Ischemic events	0.00003*	0.04*	5.81	1.11 - 37.3
hydrocephalus	0.0004*	0.02*	7.95	1.39 - 62.7

WFNS: World Federation of Neurosurgical Societies; *statistically significant.

have been always available, we demonstrated that ruptured aneurysms located in anterior circulation were possible to be treated safely by clipping or coiling. The durability was greater in clipping group than in coiling group. Although the functional outcome did not show statistical difference between the two modalities, coiling was associated with better outcome than clipping especially in severe cases with preoperative WFNS 4 - 5 and shorter postoperative hospital period.

4.1. Durability

Regarding efficacy of treatment, previous reports show superiority of clipping over coiling in ruptured aneurysms in aneurysm obliteration, presence of residual aneurysm, recurrence and retreatment. In Barrow Ruptured Aneurysm Trial (BRAT) study, They achieved complete obstruction of aneurysms after 6 years follow up in 96% after clipping and 48% after coiling ($P < 0.0001$) with 4.6% retreatment rate in the clipping group and 16.4% retreatment rate in the coiling group ($P < 0.0001$) [7]. H. Li *et al.* conducted a metanalysis for studies comparing clipping and coiling in ruptured aneurysm, in this analysis they included Five studies [8] [9] [10] [11] [12] with 1749 patients, the results of the analysis supported the superiority of clipping over coiling regarding complete aneurysm occlusion (84.0% versus 66.5%) [13].

Our results have similar trends to the previous studies showing high occlusion rate in clipping over coiling. Post-operative neck remnant after clipping occurred in 9 cases (19.2%) in our study, Intentional incomplete clipping is necessary with a certain probability to avoid the complications. We demonstrated that aneurysms with neck width > 4 mm and presence of incorporate artery are risk factor of incomplete clipping which is in line with previous reports [14]. The significant predictor factor in multivariate analysis in the current study is the presence of incorporate artery, which is explainable as in attempt to keep the incorporate artery patent, part of the neck is not clipped, Ahn and Kim did not show the statistical significance but they pointed out that it is one of the unavoidable causes of neck remnant [15].

Size of the aneurysmal sac is a strong predictor for neck remnant after clipping in previous studies [14], we did not find this association in the current study because most of the ruptured aneurysm in this study are small in size with 95.7% of ruptured cases are less than 10 mm.

Regrowth and retreatment after coiling is higher than after clipping [7] [13]. Gallas *et al.* demonstrated regrowth rate 14.8% retreatment 4.7% after coiling in her study [3], while recurrent aneurysms needed retreatment was 11.9% in Sluzewski *et al.* [16]. In our study 2 cases (14.2%) showed coil compaction, one after 4 months and the second after 16 months. both cases showed residual dome filling immediately after coiling. they are under follow up with no retreatment required yet.

Recurrence and recanalization after coiling usually results from coil compaction either due to increased blood flow at the aneurysm site or continued growth

of the aneurysm due to vessel disease [3]. In many reports coiling of ruptured aneurysm yields better functional outcome, nonetheless the risk of recurrence, retreatment and rebleeding is higher after coil embolization [17], even the results of the Cerebral Aneurysm Rerupture After Treatment (CARAT) study, Which demonstrated similar results between clipping and coiling in regard to rehemorrhage rates, it indicated the presence of strong association between rebleeding risk and the size of residual aneurysm [7].

O'Kelly *et al.* in his administrative analysis suggested that hemorrhage free survival is worse after coiling of ruptured aneurysms and that the ISAT results although it shows superiority of coiling over clipping regarding mortality after 1 year follow up, yet in the patients with longer follow up (mean 9 years) mortality became similar between the two groups, this indicates that initial better outcome of coiling is diminished by time as a result of rehaemorrhage caused by increased recurrence rate [18], which makes durability more and more important aspect due to its effect on the long-term functional outcome.

In the light of these results, it is recommended to use the maximum possible number of platinum coils in the treatment of aneurysms to achieve good aneurysm packing and avoid recurrence and rehemorrhage. It is demonstrated by several histologic studies that coil compaction is increased when the initial packing attenuation is less than 20% and coil packing attenuation more than 25% is protective against recanalization [3] [19]. Regarding durability, Ruptured aneurysms in very young patients especially those who are difficult to perform regular follow up are better treated by clipping than coiling to avoid the risk of rebleeding and retreatment on the long run.

4.2. Ischemic Events

In our study, ischemic events occurred in 26 cases (55.3%) after clipping (3 silent + 23 symptomatic) and in 8 cases (57.1%) after coiling (3 silent + 5 symptomatic) which is almost similar ($P = 0.38$), also procedure related ischemic events showed no statistical difference between clipping and coiling (17% versus 21.4%, $P = 0.7$) which is in line with previous reports [13] [20].

The incidence of ischemic infarcts after SAH varies in comparative studies of clipping and coiling for ruptured aneurysm occlusion [13]. In the current study vasospasm related infarction was 44.6% and 35.7% in clipping and coiling respectively with no statistical difference between the two modalities ($P = 0.5$).

Although many studies found total vasospasm (asymptomatic & symptomatic) to be more after clipping, most of them reported no difference between the two modalities of treatment regarding the actual occurrence of cerebral infarction which validate our results.

It is a matter of speculation as to why the type of treatment of the ruptured aneurysm might affect vasospasm. There are arguments in favor of clipping to decrease vasospasm as a result to removal of cisternal blood during surgery, an argument against this is the lack of removal of cisternal blood and clots during

coiling yet it shows lower rates of vasospasm in previous reports [13] [21], however other factors may be involved with increased vasospasm after clipping as craniotomy, brain retraction and manipulation of the blood vessels during surgery [22]. Previous studies reported an association between vasospasm and cerebral infarction [21] [22]. Therefore, an increase in angiographic vasospasm attributable to surgical clipping also should be associated with increased cerebral infarction. This was not the case in this analysis as our results and previous reports show no difference between clipping and coiling in that matter.

The current study presented the size of aneurysm dome and neck, age, WFNS grade 4 - 5 and Modified fisher Grade 4 as independent factors for ischemic events after clipping. This is in line with other reports [22] [23]. In the multivariate analysis WFNS grade 4 - 5 was significant and this actually explains the high incidence of ischemic events in the current study as 41% of the patients had poor preoperative grade (WFNS grade 4 - 5).

4.3. Functional Outcomes and Morbidity

Since the publication of the results of the ISAT study in 2002 and the management of ruptured intracranial aneurysms changed dramatically in favor of endovascular coiling. Along with this change, the debate increased in the scientific community regarding clipping and coiling and which modality is more superior regarding functional outcomes. The ISAT study at one year follow up showed Good outcome (mRS 0 - 2) 74.6% and 63.6% in coiling and clipping respectively [24]. But the ISAT study population showed 88% of patients with WFNS grade 1 - 2, also as we mentioned before at 6 years follow up the mortality between the two groups did not show much difference due to increased rate of rebleeding and retreatment in the coiling group [18].

Three years after the ISAT, Kato *et al.* demonstrated that clipping is more superior to coiling with 64.4% good outcome after clipping and 38.2% good outcome after coiling, with so much criticism to the ISAT study results [25]. In 2013, H. Li *et al.* conducted a meta-analysis for studies comparing clipping and coiling in ruptured aneurysms, in this meta-analysis RCTs demonstrated better outcomes with coiling than clipping ($P < 0.00001$), while the observational studies showed no difference between the two modalities in outcomes ($P = 0.17$). In patients with poor preoperative grade (WFNS/Hunt & Hess grade 4 - 5), there was no significant difference in outcome between clipping and coiling. Both observational studies and RCTs found no statistical difference between the two modalities regarding mortality [13].

In 2015, the 6-year results of the Barrow Ruptured Aneurysm Trial (BRAT) was published, they noted that there was no significant difference in the functional outcome between the two modalities in the treatment of ruptured anterior circulation aneurysms at almost all time points in BRAT. The results of the 6 year follow up showed 34% and 39% poor outcome in the coil-assigned group and clip-assigned group respectively ($P = 0.33$) [7].

The current study shows poor outcome in 23 patients (49%) after clipping and 4 patients (28.6%) after coiling with no statistical difference between the two groups ($P = 0.22$). Although statistically insignificant our results showed a better percent of good outcome in the coiling group especially in cases with WFNS grade 4 - 5. However, whether these results and the difference between the two modalities will hold and exist on the long run or not is a matter of debate, as there is a trend in the reports with long follow up for the results of functional outcome to become more similar with time due to the effect of durability of each modality. Another aspect in our results that poor outcome for both modalities is higher than in previous reports, this is because patients with WFNS grade 4 - 5 constituted $< 5\%$ and 16% in ISAT and BRAT respectively [7], while in our study they constitute 41% .

Our data presented age, size of the aneurysm dome, WFNS grade 4 - 5, Modified Fisher grade 4, Ischemic events and hydrocephalus as important predictors for poor outcome in univariate analysis. In multivariate analysis age, WFNS grade 4 - 5, ischemic events and hydrocephalus were significant. The type of treatment modality did not significantly affect outcome in this study ($P = 0.2$). these results are consistent with previous reports [16] [18] [20] [23].

The PRESAT group found many significant predictors for poor outcomes, On multivariate analyses, poor outcomes were associated with increasing age, WFNS grade IV-V on admission, preadmission aneurysmal rerupture, vasospasm-induced cerebral infarct, infection (pneumonia and sepsis), shunt-dependent hydrocephalus, seizure, postclipping hemorrhagic complications, and postcoiling ischemic complications [20], but the type of treatment modality was not significant in either univariate or multivariate analyses which support our results.

Hydrocephalus is a well-known sequelae of aneurysmal SAH and an important predictor for poor outcome in this study, has been reported to range from 6% to 67% [9]. It occurred in 13 cases (27.6%) after clipping and 4 cases (28.6%) after coiling in the current study ($P = 1$). There is an argument that clipping decreases the frequency of hydrocephalus by removing blood clots from the subarachnoid space and lamina terminalis fenestration [25], that was not the case in our study with no effect of the modality of treatment on the frequency of hydrocephalus, our results are supported by previous results as Seven studies [9] [26]-[31] (1981 patients) demonstrated no difference between clipping and coiling regarding shunt depending hydrocephalus (16.4% versus 19.3% ; $P = 0.16$) [13].

Hemorrhagic complications in the current study occurred mainly with clipping as a result of craniotomy, most of them were asymptomatic and did not require treatment and did not affect the patient outcome, only one case of extradural hematoma needed surgical intervention. The rest of surgical interventions required after craniotomy were mainly for hydrocephalus (which had similar rate between clipping and coiling), followed by decompressive craniotomy and cranioplasty which were done mainly in 5 out of 7 cases in patients with WFNS grade 4 - 5, in 4 cases of them the decision to perform decompressive

craniectomy was taken during the aneurysm surgery due to brain swelling inevitably leading to a second intervention for cranioplasty.

Our data showed that clipping as compared to coiling was associated with an average of 1.4-times more days in hospitalization for ruptured patients. Hoh *et al.* demonstrated similar trend regarding hospitalization period [32], we believe the invasiveness of the procedure and the need for second intervention played a role in this difference.

4.4. Mortality

Three patients died during this study, one case after clipping and two after coiling ($P = 0.2$) with no difference between the two modalities in that matter and this is consistent with previous reports [7] [13] [17]. All the patients were WFNS grade 5 and died from cerebral infarctions related to vasospasm. Mortality in this study was evaluated at 4.9%, because of poor preoperative conditions. High mortality rate after severe SAH is expected, Bracard *et al.* reported results involving severe hemorrhage, with a global mortality rate of 29% [33]. The actual rates of morbidity and mortality of clipping and coiling in ruptured aneurysms are difficult to be evaluated as a result of SAH and its complications, they are best evaluated in unruptured aneurysms [3].

5. Conclusion

In the treatment of ruptured aneurysms, both clipping and coiling are feasible options. Clipping has the advantage of durability and less recurrence which makes it more suitable for very young patients or patients whose commitment to follow up is not certain. coiling is associated with better functional outcome especially in the more severe cases, so whenever it is available it should be used for the treatment but with precautions, good coil packing is essential to avoid recurrence of the aneurysm and good follow up to detect the recurrence when it happens to avoid rebleeding complications. Nowadays, for anterior circulation aneurysm, if both treatments are feasible, coil embolization may be preferred, which is the current point proved by the RCT like ISAT. But if you choose the patients carefully and find out the optimal candidate for the clipping, the clipping is still enough feasible as a mainstream.

Limitations

This study has some limitations, first it is a retrospective study reviewed from only medical record. Surgical indication and treating method were determined by neurosurgeon individually. Secondary, it has small number of patients especially for the endovascular group. Third, the follow up period was short to evaluate the regrowth and rebleeding in the future.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

ACA, Anterior Cerebral Artery
AHA/ASA, American Heart Association/American Stroke Association
BRAT, Barrow Ruptured Aneurysm Trial
CARAT, The Cerebral Aneurysm Rerupture after Treatment Study
CT, Computed Tomography
CTA, Computed Tomography Angiography
CSF, Cerebrospinal Fluid
DSA, Digital Subtraction Angiography
EVT, Endovascular Treatment
IA, Incorporate Artery
ICA, Internal Carotid Artery
ISAT, International Subarachnoid Aneurysm Trial
MCA, Middle Cerebral Artery
MRA, Magnetic Resonance Angiography
MRI, Magnetic Resonance Imaging
mRS, Modified Rankin Scale
PRESAT, The Prospective Registry of Subarachnoid Aneurysms Treatment Study
RCT, Randomized Controlled Trials
SAH, Subarachnoid Hemorrhage
SD, Standard Deviation
WFNS, World Federation of Neurological Surgeons