Original Research Article

Management of Complex Wide Neck Intracranial Aneurysms

Abstract

Background: About 5 % of the population has intracranial aneurysms, however the majority are asymptomatic and never discovered. Subarachnoid haemorrhage, the most frequent manifestation of aneurysm rupture, is a devastating medical disorder that frequently results in severe neurological impairment or death. The aim of this work was to evaluate the efficacy and safety of our procedures including microsurgical and endovascular techniques used for the management of complex wide neck intracranial aneurysms.

Methods: This prospective study was carried out on 50 patients with complex wide neck intra cranial aneurysms. All patients were subjected to neuroimaging (CT Brain, MRI brain, MRV, CT brain angiography and diagnostic angiography) and laboratory investigations (CBC, liver and kidney functions and complete coagulation profile).

Results: Remodelling technique was the most common technique used for ruptured aneurysms (14 %) followed by clipping (6%). Regarding 3months follow up, the group who had ruptured aneurysm had lower incidence of occlusion and higher incidence of recanalization. The relationship between technique used and outcome (mRS grade) was significant being better with Coilin + balloon technique followed by flow diversion then Coiling+ stent.

Conclusions: Endovascular techniques are better to deal with the complex anatomy of intracranial aneurysms. In case of ruptured aneurysm, the earlier the treatment, the better the outcome by preventing the hazards of rebleeding and safe management of vasospasm. CT

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Brain Angiography with 3D reconstruction proved to be a fast and reliable method for diagnosis and preoperative planning for cerebral aneurysms.

Keywords: Complex Wide Neck Intracranial Aneurysms, Remodelling Technique, Balloon Assisted Embolization, Stent-Assisted Coiling

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Introduction:

About 5 % of the population has intracranial aneurysms, however the majority are asymptomatic and never discovered. An aneurysm normally develops in adulthood, and its formation and growth are associated with risk factors including as age, hypertension, inherited diseases, and smoking. Subarachnoid haemorrhage, the most frequent manifestation of aneurysm rupture, is a devastating medical disorder that frequently results in severe neurological impairment or death. [1].

Cerebral aneurysms are accompanied with a 50% mortality rate after rupture and patients can suffer significant morbidity during subsequent treatment. The neurosurgical treatment of ruptured and unruptured aneurysms has developed over time. [2].

Endovascular therapies and microsurgery are often viewed as competing treatments but it is important to recognize their individual limitations [3].

Complex intra-cranial aneurysms include not only giant aneurysms but also smaller aneurysms in difficult sites of the human brain and cranial base. Many other features also play a significant role in defining an aneurysm complexity : the presence or absence of collateral circulation, previous treatments, intraluminal thrombus, and calcification of the aneurysmal wall [4].

The endovascular treatment of aneurysms the incorporated branch or with wide-neck can be technically very challenging. Various neck protecting devices, such as self-expanding stents or temporary balloons are effective for treatment of the wide-neck aneurysm. However, these devices are not amenable to successful management of aneurysms with unfavourable configurations [5].

The remodelling technique, also known as "balloon assisted embolization", was one of the first methods introduced in the routine practice for the treatment of wide-necked aneurysms or aneurysms with unfavourable morphology.

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The stent-assisted coiling (SAC) method was developed to manage wide neck intracranial aneurysms. Several intracranial self-expanding stents have been introduced throughout the past decade. [6].

Flow diverters have been developed to treat intracranial aneurysms. These endovascular devices are placed within the parent artery rather than the aneurysm sac [7].

Occasionally, a complex aneurysm cannot be entirely avoided with a single technique and its successful treatment needs a combination of endovascular and microsurgical techniques. Planning such an approach depends on understanding anatomy of aneurysm and thus should routinely involve 3D angiographic imaging [2].

The aim of this work was to assess the safety and efficacy of our procedures including microsurgical and endovascular techniques used for the management of complex wide neck intracranial aneurysms

Patients and Methods:

This prospective study was carried out on 50 patients (40 cases in the Central University Hospital at Limoges, 4 cases in Neurosurgery Department at Lariboissiére Hospital at Paris and 6 cases at Neurosurgery department at Tanta University Hospitals) with complex wide neck intra cranial aneurysms with evident CT Brain Angiography images [(neck size >4mm) or with a dome-to-neck ratio less than1:2] and morphological complexity of the aneurysms evident with 4 vessels DSA & 3D reconstruction also assessment of the parent artery and the perforators. It was carried out during the period from September 2016 till September 2018.

Exclusion criteria were simple intra cranial aneurysms, coagulation profile disturbance and patients with bad prognosis not suitable for surgical or endovascular intervention.

All patients were subjected to: History taking (patient data, complaint, past and family history), general and neurological examination, neuroimaging (CT Brain, MRI brain, MRV,

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CT brain angiography and diagnostic angiography) and laboratory investigations (CBC, liver and kidney functions and complete coagulation profile).

Pre-operative evaluation

Type of intervention: CSF diversion was done in 4 cases.

Timing of intervention: We operated ruptured aneurysms on emergency basis either at the day of onset or next day just after doing CT.

Operative evaluation:

General strategy for ruptured aneurysms is very similar irrespective of the aneurysm location or size. When operating on a ruptured aneurysm in a patient with multiple aneurysms, the ruptured aneurysm is treated first.

Endovascular intervention (technique used like coiling assisted by stents or balloons, applications of devices like flow divertors, evaluation of the blood flow in the parent artery and the perforators and thrombo- embolic events) and surgical intervention (clipping and dissection of the parent artery and great care for the perforators).

Surgical technique:

We used the pterional approach for clipping in four of our cases. One case was an unruptured Acom A aneurysm with complex anatomy. This one was operated with endoscopic assisted techniques. We used mostly all types of clips straight, curved and fenestrated. The other three aneurysms were ruptured MCA aneurysms.

Endovascular techniques

Simple coiling: We used all types and shapes of coils. We used simple coiling in one case of our series. It was a basilar tip aneurysm with high risk of thromboembolic complications.

Remodeling technique with balloons: We used it in about 50% of our cases. We used different types of balloons compliant or non-compliant, single lumen or double lumen. Kissing balloons technique was used in bifurcation complex aneurysms.

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Balloon-Assisted Coiling Followed by Stenting: We used this technique in 6 cases of our series. Most of them were MCA bifurcation aneurysms related to important branches with complex anatomy. We used double balloon catheters like Eclipse double lumen followed by stenting. We used LEO and LEO baby stents in most of our cases.

Jailing technique (stent assisted coiling): Jailing technique was used in three cases of our series with basilar tip aneurysms. Y stenting was done first then we continued our procedure with coiling. We used Neuroform Atlas stent in our series.

Flow diversion: We used flow divertors stents in 11 patients of our study. They were one Acom A aneurysm, five ICA aneurysms and five MCA aneurysms. We used Fred, Pipeline, and SILK stents. We used balloons for good apposition of stents in some cases with intended overstretching to increase the flow diversion.

Flow diversion with coiling: In the cases with complex neck related to the parent vessel especially with ophthalmic aneurysms, we did coil for the aneurysms before stenting with flow divertors. This technique changes the velocity of blood stream in the vessels and maintain the blood flow in the related vessel after flow diversion. This could be explained by diminishing the aspiration effect of complex aneurysms.

Vessel occlusion: Vessel's occlusion was used in three cases of our study. Two dissecting aneurysms (one PICA aneurysms and one vertebral aneurysm) were treated by this technique. One giant cavernous ICA aneurysm was managed also in 77 years old man with past history of thromboembolic problems. Test of occlusion was done first to assure the collateral circulation. Coils deployment followed by onyx injection could occlude the vessel safely.

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Statistical analysis

Statistical analysis was done by SPSS v26 (IBM Inc., Chicago, IL, USA). Quantitative variables were presented as mean and standard deviation (SD) and compared between the two groups utilizing unpaired Student's t- test. Qualitative variables were presented as frequency and percentage (%) and were analysed utilizing the Chi-square test or Fisher's exact test when appropriate. A two tailed P value < 0.05 was considered statistically significant.

Results:

Table 1 shows the gender and age distribution as the age ranged between 31 and 86years. The mean age was 55 years, 68% of the patients were between 40 – 60 years. It also shows the risk factors for development of aneurysms, clinical presentation, clinical and radiological grading of patients with ruptured aneurysms and topographic distribution of the treated aneurysms.

Table 1: Demographic data, risk factors, clinical presentation, clinical and radiological grading of patients with ruptured aneurysms and topographic distribution of the treated aneurysms

		N (%)
Sex	**Male**	21 (42%)
	Female	29 (58%)
Risk factors	**Hypertension**	35 (70%)
	Smoking	9 (18%)
	Family history	9 (18%)
	Diabetes mellitus	3 (6%)
Clinical presentation	**Headache**	42 (82 %)
	Vomiting	5 (10 %)
	Disturbed conscious level	5 (10 %)
	Neurological Deficit	6 (12%)
	Visual complaint	6 (12%)
Patients with ruptured aneurysms (n=14)		
WFNS grading	**I**	3 (21.4%)
	II	3 (21.4%)
	III	5 (35.8%)
	IV	3 (21.4%)
	V	0 (0%)
Fisher grading	**Grade 1**	3 (21.4%)
	Grade 2	3 (21.4%)
	Grade 3	3 (21.4%)
	Grade 4	5 (35.8%)
Topographic distribution of the treated aneurysms (n=60)		

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Aneurysm site	**A COM**	6 (10.0%)
	Basilar Tip	6 (10.0%)
	Basilar Trunk	1 (2.0%)
	PICA	4 (8.0%)
	Cavernous ICA	3 (6.0%)
	MCA Bifurcation	18 (24.0%)
	Ophthalmic	6 (12.0%)
	Pericallosal	1 (2.0%)
	Vertebral	6 (10.0%)
	ICA Bifurcation	3 (6.0%)
	P COM	6 (10.0%)
Aneurysm	**Single**	44 (88%)
	Multiple	6 (12%)

PICA: Posterior inferior cerebellar artery. ICA: Internal carotid artery. MCA: Middle cerebral artery. P COM: Posterior communicating artery

Table 2 shows the Different projection of aneurysms, techniques used for endovascular treatment and clipping and follow up (Aneurysm occlusion) results in the studied patients.

Table 2: Different projection of aneurysms, techniques used for endovascular treatment and clipping and follow up (Aneurysm occlusion) results in the studied patients

Variables		**The diagnosed aneurysms among the studied patients (n=60)**	
		N (%)	
Wall	**Irregular**	20 (33.3%)	
	Smooth	40 (66.3 %)	
Aneurysm size	**Neck**	**Range**	4.1-25.5 mm
	Dome		3-26.8 mm
Dome projection	**Superior**	21 (35%)	
	Inferior	3 (5%)	
	Medial	12 (205)	
	Lateral	24 (40%)	
Technique	**N = 50**		
	Clipping	4 (8.0 %)	
	Simple coiling	1 (2.0%)	
	Coiling + balloon	19 (38.0 %)	
	Coiling + stent after remodeling	6 (12.0%)	
	Coiling + flow diversion	3 (6.0 %)	
	Flow diversion	11 (22.0 %)	
	Jailing (stent +coiling)	3 (6.0 %)	
	Vessel occlusion	3 (6.0 %)	
Follow up 3 months	**Complete occlusion**	47 (94 %)	
	Recanalization	3 (6%)	
Follow up 1 year	**Complete occlusion**	50 (100%)	
Follow up 2 years	**Complete occlusion**	50 (100%)	

Data are presented as range and frequency (%).

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Diabetes mellitus and family history of aneurysms were significantly higher in the ruptured group compared to the unruptured group (P = 0.004). Smoking was significantly lower in the ruptured group compared to the unruptured group (P = 0.001) while age was insignificantly different between the two groups. Inside the raptured group, Headache, vomiting and disturbed conscious level were significantly higher (P 0.042, 0.006, 0.001 respectively) while there was an insignificant different neurological deficit. Surgical intervention was significantly higher and endovascular was significantly lower in the raptured group compared to the to the unruptured group (P = 0.029). Emergency intervention was significantly higher and elective was significantly lower in the raptured group compared to the to the unruptured group (P = 0.001). CSF diversion was significantly higher in in the raptured group compared to the to the unruptured group (P = 0.001). WFNS grading and Fisher grade also presented in Table 3.

Table 3: Relation between the patient data (gender) and risk factors for aneurysms presentation, correlation between aneurysms rupture and the clinical presentation and relation between aneurysms rupture, type of intervention, time and CSF diversion

Variables		The study patients (n=50)		P
		Ruptured (n=14)	Unruptured (n=36)	
		N (%)	N (%)	
Age (years)		38 – 76	31 – 86	0.431
		53.64 ± 11.42	56.67 ± 12.31	
Sex	Males	6 (12%)	15 (30%)	0.939
	Females	8 (12%)	21 (42%)	
Hypertension	Yes	11 (78.6%)	24 (66.6%)	0.409
	No	3 (21.4%)	12 (33.4%)	
Diabetes mellitus	Yes	3 (21.4%)	(0%)	0.004*
	No	11 (78.6%)	0 (0%)	
Smoking	Yes	9 (64.2%)	36 (100%)	0.001*
	No	5 (35.8%)	(0%)	
Family history of aneurysms	Yes	3 (21.4%)	0 (0%)	0.004*
	No	11 (78.6%)	36 (100%)	
WFNS Grading	Grade I	3 (21.4%)	(0%)	-
	Grade II	3 (21.4%)	0 (0%)	
	Grade III	5 (35.8%)	36 (100%)	
	Grade IV	3 (21.4%)	(0%)	
	Grade V	0 (0%)	0 (0%)	
Fisher grade	Grade 1	3 (21.4%)	0 (0%)	-
	Grade 2	3 (21.4%)	0 (0%)	
	Grade 3	3 (21.4%)	0 (0%)	
	Grade 4	5 (35.8%)	0 (0%)	
	Ruptured			

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		Yes	No	
Headache		9 (18.0%)	32 (64.0%)	0.042*
Vomiting		4 (8.0%)	1 (2.0%)	0.006*
Disturbed conscious level		5 (10.0%)	0 0.0%	0.001*
Neurological Deficit		5 (10.0%)	1(2.0%)	0.491
		Ruptured	**Unruptured**	
Type of intervention	**Surgical**	3 (6.0%)	1 (2.0%)	0.029*
	Endovascular	11 (22.0%)	35 (70.0%)	
Time of intervention	**Emergency**	14 (28.0%)	0 (0.0%)	0.001*
	Elective	0 (0.0%)	36 (72.0%)	
CSF diversion		5 (10.0%)	0 (0.0%)	0.001*

Data are presented as mean ± SD or frequency (%). *: Significant as p value ≤0.05. CSF: Cerebrospinal fluid

Remodelling technique was the most common technique used for ruptured aneurysms (14 %) followed by clipping (6%). Regarding 3months follow up, the group who had ruptured aneurysm had lower incidence of occlusion and higher incidence of recanalization. Morbidity was reported in three patients with different endovascular techniques which is more likely to the presentation itself upon admission not the procedure while mortality was insignificantly different between both groups. It was noticed also with one year follow up. The relationship between technique used and outcome (mRS grade) was significant being better with Coilin + balloon technique followed by flow diversion then Coiling+ stent. Table 4

Table 4: Techniques used with rupture aneurysms, morbidity and mortality in relation to ruptured aneurysms with early follow up (aneurysms occlusion), morbidity in relation to techniques and techniques and outcomes correlation according to mRS

		Ruptured		P-value
		Yes	**No**	
Technique	**Clipping**	3 (6.0%)	1 (2.0%)	0.021*
	Simple coiling	1 (2.0%)	0(0.0%)	
	Coiling + balloon	7 (14.0%)	12 (24.0%)	
	Coiling + stent	0 (0.0%)	6 (12.0%)	
	Coiling + flow diversion	0 (0.0%)	3 (6.0%)	
	Flow diversion	1 (2.0%)	10 (20.0%)	
	Jailing	0 (0.0%)	3 (6.0%)	
	Vessel occlusion	2 (4.0%)	1 (2.0%)	
		Ruptured	**Unruptured**	

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Morbidity		3		0	0.004*
		6.0%		0.0%	
Mortality		0		0	0.479
		0.0%		0.0%	
Follow up 3 months	**Complete occlusion**	11		36	0.004*
		22.0%		72.0%	
	Recanalization	3		0	
		6.0%		0.0%	
		Morbidity			
Technique	**Clipping**	0 (0.0%)			0.002*
	Simple coiling	0 (2.0%)			
	Coiling + balloon	1(2.0%)			
	Coiling + stent	0 (0.0%)			
	Coiling + flow diversion	0 (0.0%)			
	Flow diversion	1(2.0%)			
	Jailing	0 (0.0%)			
	Vessel occlusion	1(2.0%)			
		Outcome mRS grade			
		0	**1**	**2**	**3**
Technique	**Clipping**	3(6.0%)	0 (0.0%)	1(2.0%)	0 (0.0%)
	Simple coiling	0 (0.0%)	1(2.0%)	0 (0.0%)	0 (0.0%)
	Coiling + balloon	19 (38.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Coiling + stent	6 (12.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Coiling + flow diversion	3 (6.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Flow diversion	11 (22.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Jailing	3 (6.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Vessel occlusion	2 (4.0%)	0 (0.0%)	0 (0.0%)	1(2.0%)

Data are presented as frequency (%). *: Significant as p value ≤0.05. mRS: Modified Rankin Scale

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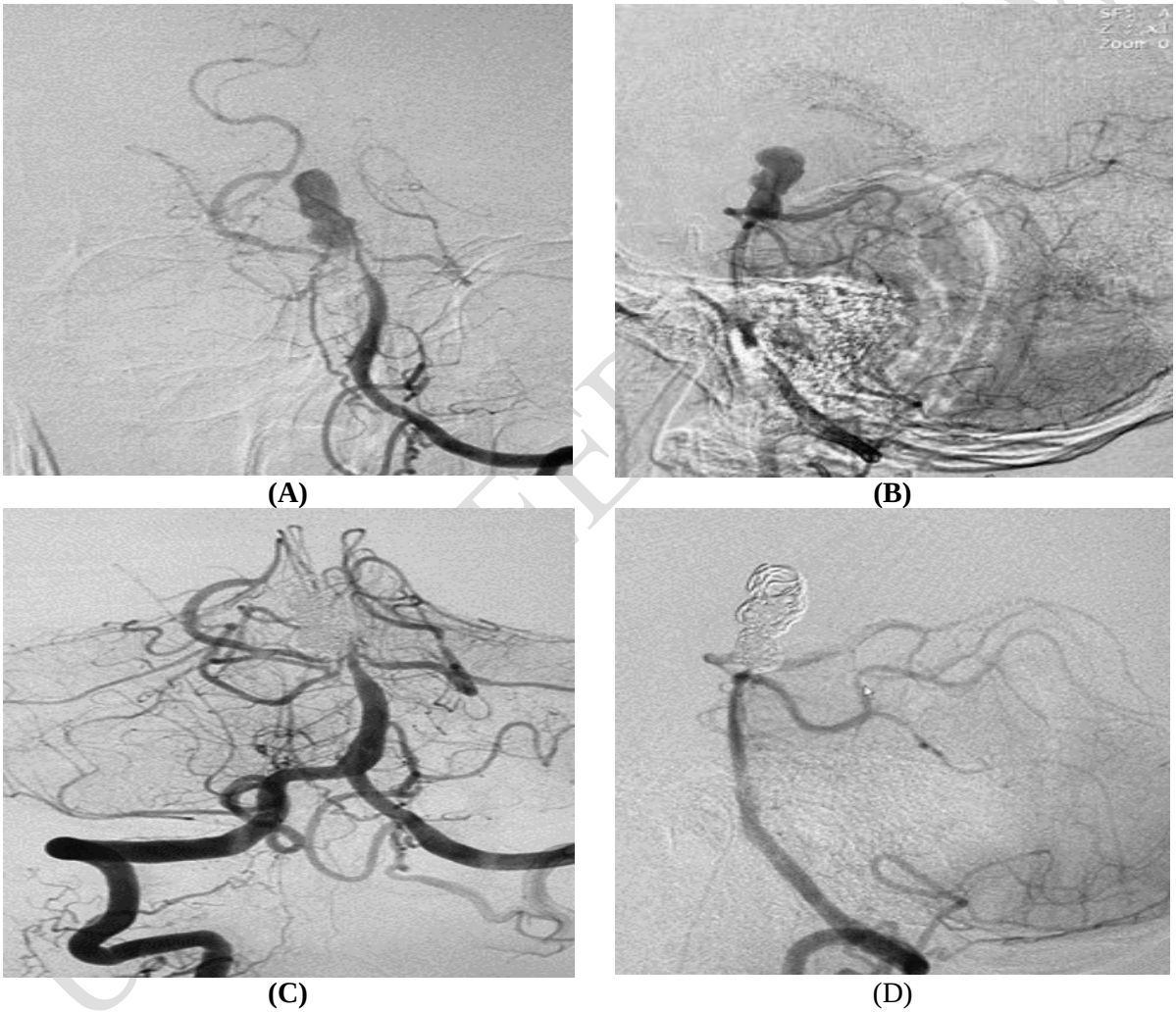
Male patient aged 68 years presented with chronic headache since two years, repeated attacks of TIA and ataxia. He had past medical history of hypertension and cardiac problems. EF was 49 % and cardiac hypokinesia by 60 %. The patient was prepared for staged cardiac stenting with anticoagulants prescription. The risk of bleeding was increased with these medications, so we chose to treat it with simple coiling to avoid any thromboembolic complications. Figure 1

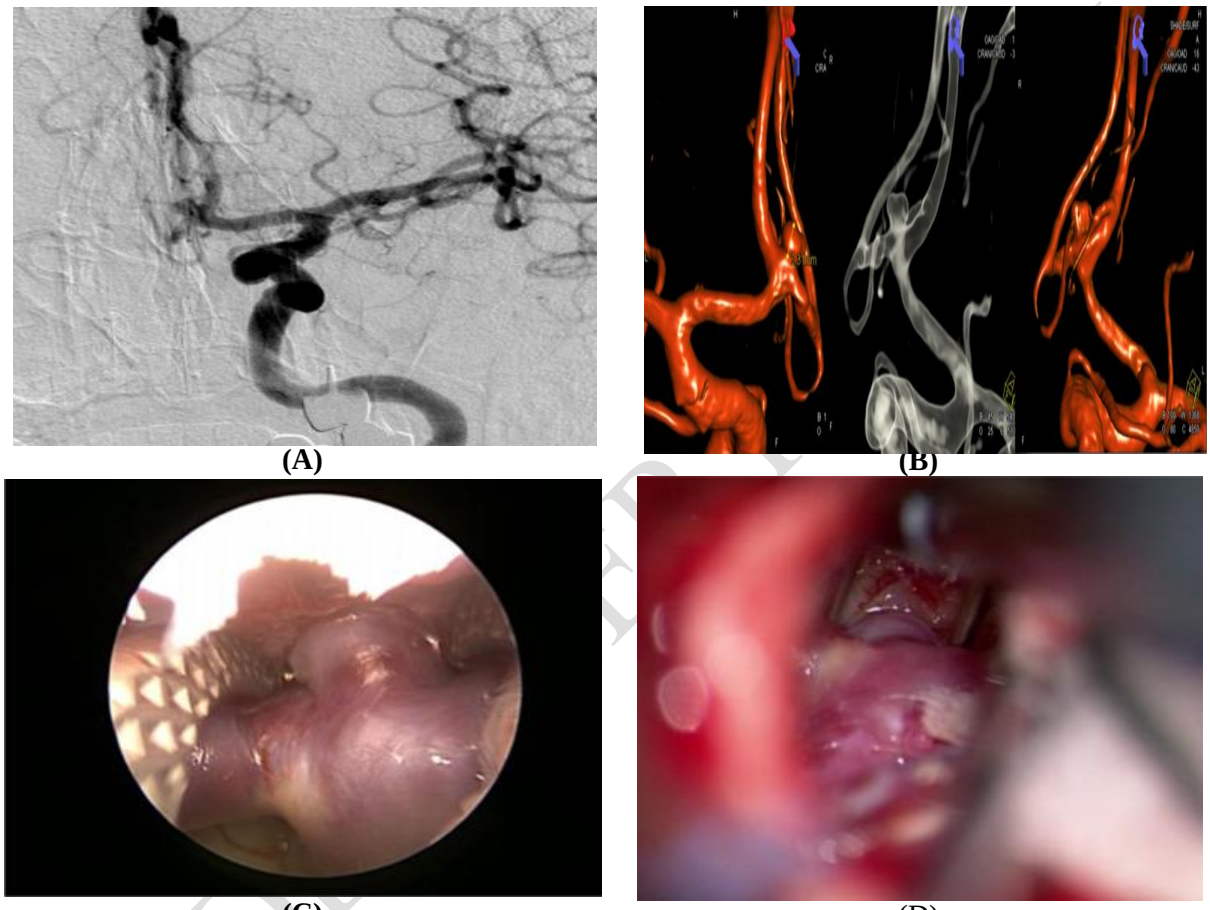


(A) **(B)**

(C) (D)

Figure 1: (A) DSA AP view (B) profile view revealed basilar tip aneurysm, (C) DSA AP view (D) profile view revealed postoperative complete occlusion of the aneurysm

Female patient aged 60 years presented with headache for one year. A com aneurysm was incidentally discovered. DSA showed marked fibromuscular dysplasia. Surgical clipping was chosen for this patient due to the increased risk of vessel dissection with endovascular treatment. Endoscopic assisted clipping was used for better visualization in this area of complexity. Figure 2



(A) **(B)**

(C) (D)

Figure 2: A) DSA AP view showing Acom aneurysm: Arrow left carotid artery 2D angiogram: anterior communication aneurysm. B) Left carotid artery 3D angiogram showing an anterior communicating aneurysm with wide neck. C & D) Comparative views of AComA aneurysm with endoscope (C) and microscope (D). Endoscope technic offers better visualization and illumination of the surgical field than the microscope.

Discussion

Wide-necked intracranial aneurysms located at arterial bifurcations (wide-necked bifurcation aneurysms, WNBAs) are an especially difficult subset of intracranial aneurysms to treat, with increased risks of poor outcome, stroke, morbidity, and mortality [8, 9].

In our study MCA aneurysms with complex anatomy represented in 24 % of our series followed by ophthalmic artery aneurysms by 12%. A com aneurysm, P com aneurysms and basilar tip aneurysms represented by 10 % for each group. The most complex size in our study was 6X9 represented in 24 % of our study. The second ones were 7X10 & 8X10 with 18 % for each group. In the present study, three months follow up revealed complete occlusion of the aneurysms in 94 % of our study and recanalization in 3 cases which required second sessions later. These cases were ruptured aneurysms, one was treated by simple coiling and the other two were treated by remodelling technique.

In line with our results, Lin et al., [10] reported a series of 28 anterior circulation aneurysms treated with flow diversion. Clinical follow-up was available for an average of 10.7 months. 21 aneurysms had complete occlusion (78%).

On the other hand, series reported the use of flow diverters in the treatment of middle cerebral artery bifurcation aneurysms with ischemic complications, as confirmed by MR imaging, occurring in 43% of the patients and leading to a procedure-related morbidity of 21%. Angiographic follow-up (mean 16 months) demonstrated complete occlusion in 62% of the aneurysms [11].

In the present study, morbidity was reported in 3 cases of the ruptured aneurysms. 3 cases of ruptured aneurysms showed recanalization in the 3 months follow up with second sessions later. 11 cases of ruptured aneurysms were grade ZERO according to mRS after one year follow up. Morbidity was reported in 3 patients with different endovascular techniques which

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is more likely to the presentation itself upon admission not the procedure. It was noticed also with one year follow up. No mortality is reported in our study.

Compatible with our results, overall procedure-related morbidity and mortality were 6% and 3%, respectively at the last clinical follow-up, only one patient had a worse mRS score changed from 0 to 6, two patients had mRS of 3 (stable from a prior procedure), and all others had mRS 0 or 1 [12].

In our study, we reported 2 cases of vasospasm which were noticed during the procedures and one of them treated later by mechanical angioplasty. Also, we found that patients with ruptured aneurysms had worse preoperative status compared to those with unruptured aneurysms. These factors likely lead to a lower good outcome rate, but not to a higher mortality rate.

To improve occlusion rate and to overcome the faintness of coil compaction, aneurysm recurrence, and rebleeding after coiling, a paradigm shift in interventions from an endo saccular to an endoluminal reconstruction was promoted by the design of the FD [13].

Remodelling technique (coils and balloon) represent the most successful technique in our series of complex aneurysms by 38 % of our study. Remodelling technique was the most common technique used for ruptured aneurysms (14 %) followed by clipping (6%). No intraoperative rupture or thromboembolic events were reported. Similarly, the remodelling technique was more frequently used in unruptured aneurysms than in ruptured aneurysms according to the analyses conducted in the ATENA and CLARITY series [14, 15].

We found that the staged strategy is valuable for complex ruptured aneurysms as it allows for transitioning of the patient from the acute phase to a more subacute phase where the patient and aneurysm are stabilized.

Similar to our strategy, Nossek et al., [16] reported the use of staged coiling followed by flow diversion treatment of ruptured aneurysms with good results.

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Finally, it is clear that the sole use of microsurgical techniques would have involved actions associated with elevated risk of morbidity and mortality, such as revascularization of the area distal to the aneurysm to maintain brain blood flow [17]. Therefore, in our opinion, the endovascular and microsurgical techniques are complementary rather than competing strategies for the treatment of complex neurovascular lesions.

Conclusions:

Endovascular techniques are better to deal with the complex anatomy of intracranial aneurysms. In case of ruptured aneurysm, the earlier the treatment, the better the outcome by preventing the hazards of rebleeding and safe management of vasospasm. CT Brain Angiography with 3D reconstruction proved to be a fast and reliable method for diagnosis and preoperative planning for cerebral aneurysms. The age of the patient, the initial clinical and radiological grading, and associated comorbidities can greatly affect the outcome. Optimal management requires effective collaboration between neurosurgeon, endovascular interventionist, neuroradiologist, neuro-anesthesiologist, and intensivist.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

Ethical Approval and Consent:

An informed written consent was obtained from the patient or relatives of the patients. The study was done after approval from the Ethical Committee Tanta, Limoges and Lariboissiére University Hospitals.

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References:

1. Seibert B, Tummala RP, Chow R, Faridar A, Mousavi SA, Divani AA. Intracranial aneurysms: review of current treatment options and outcomes. Front Neurol. 2011;2:45-65.

2. Choudhri O, Mukerji N, Steinberg GK. Combined endovascular and microsurgical management of complex cerebral aneurysms. Front Neurol. 2013;4:108-25.

3. Meilán Martínez A, Murias Quintana E, Gil García A, Vega Valdés P, Saiz Ayala A. [Assisted techniques for the endovascular treatment of complex or atypical cerebral aneurysms]. Radiologia. 2013;55:118-29.

4. Andaluz N, Zuccarello M. Treatment strategies for complex intracranial aneurysms: review of a 12-year experience at the university of cincinnati. Skull Base. 2011;21:233-42.

5. Ryu C-W, Koh J-S, Lee CY, Kim E-J. Endovascular management of the wide-neck aneurysms: The applications of the coils and catheter. Neurointervention. 2010;5:71-8.

6. Aydin K, Arat A, Sencer S, Barburoglu M, Men S. Stent-assisted coiling of wide-neck intracranial aneurysms using low-profile LEO baby stents: initial and midterm results. AJNR Am J Neuroradiol. 2015;36:1934-41.

7. Alderazi YJ, Shastri D, Kass-Hout T, Prestigiacomo CJ, Gandhi CD. Flow diverters for intracranial aneurysms. Stroke Res Treat. 2014;2014:415-65.

8. Spetzler RF, McDougall CG, Albuquerque FC, Zabramski JM, Hills NK, Partovi S, et al. The barrow ruptured aneurysm trial: 3-year results. J Neurosurg. 2013;119:146-57.

9. Spetzler RF, McDougall CG, Zabramski JM, Albuquerque FC, Hills NK, Russin JJ, et al. The barrow ruptured aneurysm trial: 6-year results. J Neurosurg. 2015;123:609-17.

10. Lin N, Lanzino G, Lopes DK, Arthur AS, Ogilvy CS, Ecker RD, et al. Treatment of distal anterior circulation aneurysms with the pipeline embolization device: A us multicenter experience. Neurosurgery. 2016;79:14-22.

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11. Caroff J, Neki H, Mihalea C, D'Argento F, Abdel Khalek H, Ikka L, et al. Flow-diverter stents for the treatment of saccular middle cerebral artery bifurcation aneurysms. AJNR Am J Neuroradiol. 2016;37:279-84.

12. Fang S, Brinjikji W, Murad MH, Kallmes DF, Cloft HJ, Lanzino G. Endovascular treatment of anterior communicating artery aneurysms: a systematic review and meta-analysis. AJNR Am J Neuroradiol. 2014;35:943-7.

13. Molyneux AJ, Birks J, Clarke A, Sneade M, Kerr RS. The durability of endovascular coiling versus neurosurgical clipping of ruptured cerebral aneurysms: 18 year follow-up of the UK cohort of the International Subarachnoid Aneurysm Trial (ISAT). Lancet. 2015;385:691-7.

14. Pierot L, Spelle L, Vitry F. Immediate clinical outcome of patients harboring unruptured intracranial aneurysms treated by endovascular approach: results of the ATENA study. Stroke. 2008;39:2497-504.

15. Pierot L, Cognard C, Anxionnat R, Ricolfi F. Remodeling technique for endovascular treatment of ruptured intracranial aneurysms had a higher rate of adequate postoperative occlusion than did conventional coil embolization with comparable safety. Radiology. 2011;258:546-53.

16. Nossek E, Chalif DJ, Chakraborty S, Lombardo K, Black KS, Setton A. Concurrent use of the pipeline embolization device and coils for intracranial aneurysms: Technique, safety, and efficacy. J Neurosurg. 2015;122:904-11.

17. Abdulrauf S, Cantando J, Mohan Y, Olivera R, Lebovitz J. EC-IC bypass for giant ICA aneurysms. In: Saleem I A, editor. Cerebral revascularization Techniques in extracranial-to-intracranial bypass surgery: Elsevier Saunders; 2011. p. 231-45.

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