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New endovascular approaches in management ofintracranial complex bifurcation aneurysms not amenable to simple coiling

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***Abstract*---**Background: Aneurysmal neck remodeling with stents has recently emerged as an effective treatment option. Flow-diverter devices (FDDs), Silk flow diverter stent, the Woven EndoBridge (WEB) have been proven to be a valuable tool in the endovascular treatment of wide-necked bifurcation aneurysms. Aim: The purpose of this study was to assess the efficacy, safety and durability of new endovascular approaches in management of intracranial complex bifurcation aneurysms. Subjects and Methods: Between October 2017 and august 2019, we performed 37 endovascular procedures for 32 patients having intracranial complex bifurcation aneurysms. The procedures were performed in the "Vascular and Interventional Unit" of the Radiology Department, in Kasr-Al Ainy Hospital, and Sheikh Zayed specialized Hospital. Results: One out of 30 patients (3.3%) had a procedural related complication, which was a femoral puncture and scrotal hematoma. Two days later this patient died from MI, and this was the only mortality in our study. Eight out of 30 patients (26.6 %) still experienced mild degrees of morbidity and neurological deficits

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related to the natural history of the SAH and unrelated to the procedures. One out of 10 patients (10%) treated by balloon assisted coiling showed neck recanalization at 6 months angiographic follow up. Three out of 8 patients (37.5%) treated by simple coiling showed recanalization at 6 months angiographic follow up. 1 out of 7 patients (14.3 %) treated by FD stents showed residual patency of the aneurysm at 6 months angiographic follow up due to improper opening of the mid segment of the stent during deployment. All the patients treated with stent assisted coiling and WEB showed total occlusion of the aneurysms at 6 months angiographic follow up. Conclusion: If the complex aneurysm is ruptured and presenting in the acute stage, then we prefer to avoid using stent assisted coiling or flow diverter stents to avoid the antiplatelet therapy with its hemorrhagic complications. If the complex aneurysm is ruptured and presenting in the subacute stage, stent assisted coiling or FD stents can be used, if the complex aneurysm is unruptured, then the modality of choice will differ according to the size, location and morphology of the aneurysm, but the most preferable modalities would be the FD stent, stent assisted coiling and recently the WEB device, due to their very low rate of recanalization. The double microcatheter technique is preferably used in cases of complex aneurysms (whether ruptured or not) having a branch arising from the aneurysm neck or fundus and is difficult to be secured by balloon or stent.

***Keywords*---**Endovascular Approaches, Intracranial Complex Bifurcation Aneurysms, Simple Coiling.

Introduction

Intracranial saccular or berry aneurysms are common, occurring in about 1-2% of the population. Unruptured intracranial aneurysms are increasingly being detected as cross-sectional imaging techniques are used more frequently in clinical practice. Once an unruptured intracranial aneurysm is detected, decisions regarding optimum management are made on the basis of careful comparison of the short- term and long-term risks of aneurysmal rupture with the risk associated with the intervention, whether that be surgical clipping or endovascular management (Brown and Broderick, 2014).

Aneurysmal subarachnoid hemorrhage (SAH) is a worldwide health burden with high fatality and permanent disability rates. The estimated worldwide incidence of SAH is 9/100,000 persons/year. Ruptured cerebral aneurysms account for 75%-85% of non-traumatic SAH. The overall prognosis depends on the volume of the initial bleed, re-bleeding, and degree of delayed cerebral ischemia. The International Subarachnoid Aneurysm Trial (ISAT) reported a favorable neurological outcome with the endovascular coiling procedure (D'Souza, 2015).

Wide-neck (when the neck is >4 mm, or when the dome/neck ratio <1.5-2) intracranial aneurysms were originally thought to be either untreatable or very

challenging to treat by endovascular means because of the risk of coil protrusion into the parent vessel. The introduction of the balloon remodeling technique (BRT) and later stents specifically designed for intracranial use has progressively allowed these lesions to be endovascularly treated (Piotin and Blanc, 2014).

Aneurysmal neck remodeling with stents has recently emerged as an effective treatment option. This method is beneficial for treating aneurysms with wide necks or for situations in which coils unexpectedly herniate into the parent vessel, requiring rescue with a device that can reconstrain the coil within the lesion (Ryu et al, 2015).

Flow-diverter devices (FDDs) are new-generation stents placed in the parent artery at the level of the aneurysm neck to disrupt the intra-aneurysmal flow, providing significant rheological effects with potential changes in trans-mural pressure gradient. They progressively create intra-aneurysmal thrombosis, offering good support for the development of a neo-intima (Brignati et al, 2015).

Silk flow diverter stent has proven to be a valuable tool in the endovascular treatment of intracranial giant partially thrombosed aneurysms and aneurysms of the internal carotid artery cavernous segment presenting with mass effect (Leonardi et al, 2011).

The Woven EndoBridge (WEB) is an innovative new technique for securing cerebral aneurysms. It is designed particularly for wide-necked bifurcation aneurysms that otherwise would be difficult to treat. The WEB has shown itself to be a promising new device with the potential to increase the scope of treatment for difficult wide-necked bifurcation aneurysms. The technique is safe, and short-term results show effective occlusion of complex aneurysms with minimal complications associated with the procedure (Lawson et al, 2017). The purpose of this study was to assess the efficacy, safety and durability of new endovascular approaches in management of intracranial complex bifurcation aneurysms.

Subjects and Methods

Between October 2017 and august 2019, we performed 37 endovascular procedures for 32 patients having intracranial complex bifurcation aneurysms. The procedures were performed in the “Vascular and Interventional Unit” of the Radiology Department, in Kasr-Al Ainy Hospital, and Sheikh Zayed specialized Hospital.

Inclusion criteria:

- Patients with ruptured or unruptured complex bifurcation aneurysms (wide neck aneurysms with sac to neck ratio less than 1.2, or having a branch arising from the aneurysm, or partially thrombosed aneurysm)
- Patient’s age from 18 to 80

Exclusion criteria:

- Patients with simple aneurysms.
- Patient with non bifurcation aneurysms.
- Below 18 or above 80 years old.

Pre-procedure assessment & preparation:

- History (personal, detailed present, past and family history).
- Physical examination included an assessment of vital signs, the pulmonary and cardiac status, a complete neurological examination and documenting any pre-procedural deficits.
- Reviewing any CT, MRI and angiographic studies (including CTA or MRA) of the patients was done.
- The protocol of management was discussed & planned with the neurosurgeon.
- Explanation of the decided protocol of treatment and its possible risks for the patient was done. Informed consent was taken in all cases.
- **Blood work** was performed and revised (CBC, liver function tests, kidney function tests, PT, PC and INR)
- **Echocardiography** was recommended for those above 40 years.
- The patients were examined by the anesthesiologist who reviewed their blood work, ECG and/or echocardiography to assess their eligibility for general anesthesia.
- If stent-assisted coiling or flow diverter was planned, antiplatelet therapy was necessary:
  - Aspirin 150 mg PO for 7 days prior to the procedure and
  - Ticagrelor (Brilique) 90 mg PO twice daily for 7 days prior to the procedure.
- Patients with hypertension and diabetes should be medically controlled till the time of procedure.
- NPO for 6 hours prior to the procedure, except for medications.
- Two peripheral intravenous lines were placed.
- General anesthesia was done, followed by introduction of bladder catheter.

Technique

Femoral puncture was performed, with introduction of 6 F vascular sheath, which had to be continuously flushed with saline. Once intravascular access was achieved systemic anticoagulation was done using a loading dose of 70 IU/Kg units of heparin given as a bolus intravenous injection and maintenance dose of 20 IU/Kg units every hour if the procedure prolongs. Diagnostic cerebral angiography (four vessels angiography) was performed using a diagnostic catheter (braided Berenstein or Headhunter 5 F) over a guide wire (Terumo Gide wire® hydrophilic coated 0.035"). The angiogram was important for several reasons: Recheck for the presence of atherosclerosis and or fibromuscular dysplasia of the neck vessels. Check the presence of sufficient cross flow via patent anterior communicating or posterior communicating arteries. Intracranial images at the beginning of the case are necessary for comparison with the final control angiogram after endovascular treatment to assess for thromboembolic complications. Study of the morphology and hemodynamics of the aneurysm to choose the guiding catheter, microcatheter and devices to be used. 3D angiogram was performed to assess the exact morphology of the aneurysm, its neck and the branches arising from, In addition to finding out the best and ideal working view.
The diagnostic catheter was then withdrawn.The guiding catheter was connected to a rotating hemostatic valve (“Y- connector” and “three-ways”). The system had

to be continuously flushed with saline, which contains a dose of 10 cc, 2mg Nimotop.
Guiding catheters we used were one of the following:

a) Guider Soft tip™ XF guide catheter (Boston Scientific, Natick, MA)
b) Chaperon 6F (Microvention, USA)
c) Fargo Max 6F (Balt extrusion, France)

Road map technique was performed, to visualize the parent artery and the neck of the aneurysm. The guiding catheter was then advanced under roadmap guidance over a hydrophilic wire into the target artery. A 3 D reconstruction was performed to find out the best and ideal working view. The microcatheters used for coiling were one of the following:

a) Excelsior® SL-10 (Boston Scientific, Natick, MA)
b) Headway (Microvention, MA)

If Excelsior microcatheter was chosen and we needed a curved tip, we steamed its most distal 1.5 cm by inserting the mandrel in the catheter tip and bending the catheter in an angle greater than the degree of angle desired. Steaming the catheter tip for 10 seconds. After removing the mandrel, the curve was attained somewhat. Microcatheter over a guide wire was introduced into the guiding catheter through the haemostatic valve.
We used the following microguidewires:

a) Transcend™ EX 0.014 inch Platinum (Boston Scientific, Inc., Natick, MA)
b) Traxcess™ 0.014 inch (Microvention, USA).

The microcatheter was then advanced beyond the tip of the guiding catheter under roadmap guidance.An angiogram through the guiding catheter is done to recheck the position of the microcatheter tip.

In simple coiling

The tip of the microcatheter was placed in the proximal half of the aneurysm and away from the dome. This avoids puncturing the dome with the catheter or coils. Once the microcatheter tip was in a stable and desired position, the framing coils were placed. The first 3-D coil was chosen to be equal or slightly larger than the diameter of the aneurysm dome. After each coil was deployed and prior to detachment, a guide catheter angiogram was done to check for:

- Coil position
- Thrombus within the parent vessel
- Perforation.
- Ensure flow in adjacent vessels and exclude drop-out.

Additional coils were deployed as necessary, to achieve tight packing of the sac.

In balloon assisted coiling:

Balloon remodeling of wide-necked aneurysms is based on the concept that framing coils placed in the aneurysm with the temporary support of a balloon across the neck. This creates a stable structure for coil packing. Two single headed rotating haemostatic valves were attached in series to the guide catheter, with continuous saline infusion to the haemostatic valves. A non-detachable

balloon Hyperglide (ev3, Irvine, CA) or Hyperform (ev3, Irvine, CA) or Eclipse (Balt Extrusion, France) was properly positioned, in the parent vessel adjacent to the aneurysm and across the neck while a microcatheter was placed into the aneurysm. The balloon was inflated intermittently with deployment of each coil. Under roadmap guidance, the first framing coil was deployed followed by other coils, as necessary, until satisfactory packing density was reached. The balloon was then deflated prior to detachment, and the stability of the coils was assessed by guide catheter control angiogram.

In stent assisted coiling:

Solitaire™ AB (ev3, Neurovascular Remodeling Device) as well as Leo stents (Balt, Montmorency, France), LVIS Jr (Microvention, USA) or Neuroform Atlas (Boston scientific, USA) were used. The stent was deployed (not detached) at least 2-3 mm past the neck of the aneurysm from either side, then the curve of the microcatheter was used to direct a soft-tip wire through the desired area of the stent and into the aneurysm (mesh technique) and finally coils were inserted until satisfactory packing density was achieved. In case of Y-stent we preferred to use open-cell laser cut stents (Neuroform Atlas).

Flow diverter cases:
In the cases in whom a flow diverter was deployed, we used Silk flow diverter (Balt Extrusion, Montmorency, France). It is a cylinder compromised of 48-braided nitinol strands and 35 µm platinum microfilaments with a high resultant metal surface coverage (approximately 35%). As a closed cell stent, it can be retrieved and/or repositioned at up to 90% deployment. The stent is very flexible. In other cases we used pipeline (PED) Flex embolization device (Medtronic, USA). The microcatheter was advanced at least 20 mm past the neck. Careful positioning of the stent was done so that it adequately and properly secures the neck of the aneurysm. The stent was then unsheathed from its own delivery microcatheter (Vasco; Balt) via pushing the delivery wire and retrieving the microcatheter (Push-Pull technique), allowing for expansion and compensation of foreshortening.
Final angiographic images were obtained:

- To insure good placement and apposition of the stent with the parent artery wall.
- Stasis inside the aneurysmal sac.
- In case of aneurysms exceeding 12 mm in diameter, coils were added in the sac of the aneurysm.
- Finally at the end of the procedure the whole system was withdrawn.
- The sheath was finally removed and hemostasis was obtained by manual compression before waking up the patient.
- Full neurological assessment after the procedure was carried out.

Endovascular treatment of vasospasm:

Once angiography documented a vasospasm and its degree and location, the guiding catheter was navigated proximal to the area of spasm. A dose of 1–3 mg of nimodipine (5–15 mL of Nimotop) per vessel was infused after it was diluted with physiologic saline (10–30 mL) to obtain a 50% dilution. Slow continuous infusion of the solution at a rate of 2 mL/min was achieved by manual injection. The total

dose of nimodipine injected intra-arterially for a given patient was maintained within 5 mg and was determined by judging the severity of initial spasm, the degree of vessel dilatation, and the initial systemic blood pressure. The anesthesiologist should be informed before the procedure to monitor any change in arterial blood pressure.

Post-procedural care & follow up:

- The patient was kept at strict bed rest in a flat position and instructed not to remove the bandage for 8 hours.
- Patients were observed in the neurointensive care unit for 24-48 hours then transferred to a regular room and usually discharged to home on the third post-procedural day.
- Neurological examination and checking the groin were performed every hour.
- Post-procedural medical management were prescribed according to the condition of the patient:
- Analgesics for headache.
- Steroids were prescribed for patients who were presenting my mass effect and edema of the surrounding brain parenchyma as follows: Dexamethasone 8 mg three times per day for one week.
- Aspirin PO 150 mg/ day for 6 months and Ticagrelor (Brilique) 90 mg PO twice daily for three months in case of laser-cut or braided stents and 6 months in case of flow diverter stent, followed by Aspirin alone for life.
- IV Nimotop and maintaining a state of euvolemia in subarachnoid hemorrhage patients.
- Clinical follow up was done at 1 & 3 weeks & 3 months post procedural, to detect any clinical complication related to the intervention.
- Any clinical event during or within 1 month after treatment, minor or major, transient or permanent, which might be even remotely associated with the procedure, was considered to be procedure related.
- If any complication occurred, the suitable imaging modality was done (either CT or MRI), aiming for exact explanation of its cause.
- Follow up angiography was done 6 months after the procedure to assess for recanalization of the aneurysm, if any. In the follow up angiography, it was classified according to Raymond's Roy classification into total occlusion (grade I), neck remnant (grade II) and aneurysm remnant (grade III).

Results

Age and sex:

Endovascular treatments were done for 32 patients with complex bifurcation aneurysms. There were 18 males (56.25 %) and 14 females (43.75 %), with a mean age of 48.1 years (range 20-67 years).

Table 1
Sex of patients

		Number of patients	%
Sex	Male	18	56.2 %
	Female	14	43.8 %

Cause of complexity of the aneurysm:

Twenty five patients had wide necked aneurysms, 6 other patients had wide neck aneurysms with a branch arising from the aneurysm either from its fundus, neck or sac. One patient had a partially thrombosed aneurysm.

Table 2
Cause of complexity of the aneurysm

	Number of patients	%
Wide neck	25	78.1 %
Wide neck with branch arising from the aneurysm	6	18.8 %
Partially thrombosed	1	3.1 %

Presenting symptoms:

Twenty three patients had ruptured aneurysms and presented with different symptoms related to SAH including headache, fatigue, lower limb weakness and drowsiness. Nine patients had unruptured aneurysms. Three of them were incidentally discovered without any clinical symptoms, while 6 patients presented with different forms of mass effect including: headache, gait disturbance and 3rd cranial nerve palsy.

Table 3
Presenting symptoms of patients

Symptoms		Number of patients	%
	Ruptured with symptomsrelated to SAH	23	71.9 %
	Unruptured with pressuremanifestations	5	15.6 %
	Unruptured with no symptoms (incidentally discovered)	4	12.5 %

In the balloon assisted coiling group, 11 patients presented with ruptured aneurysms; 4 of them presented with headache, another 4 patients presented

with DCL, 1 patient presented with aphasia, 1 patient presented with diminution of vision and the last patient presented with right sided hemiparesis.
In the simple coiling group, 4 patients had unruptured aneurysms, while 5 patients had ruptured aneurysms. Out of the 4 patients with unruptured aneurysms, 2 patients had 3rd cranial nerve palsy, while the other 2 patients had headache. Out of the five patients with ruptured aneurysms, 2 patients had DCL, 2 patients had headache and one patient had left lower limb weakness.
In the stent assisted coiling group, 4 patients had ruptured aneurysms, and 4 other patients had incidentally discovered unruptured aneurysms. Out of the 4 patients with ruptured aneurysms, 3 patients had headache and 1 patient with DCL.
In the FD group, 1 patient had a ruptured aneurysm and presented with headache. Six patients had unruptured aneurysms, 2 of them presented with headache, while 4 had no symptoms.
Two other patients has ruptured aneurysms, one of them presented by headache and was treated by double microcatheter technique. The other patient presented with DCL and was treated by WEB device.
In our study 32 patients underwent 37 procedures. Three patients underwent simple coiling at their 1st session, and angiographic follow up showed recanalization which required a 2nd session with FD deployment. Two other patients had multiple aneurysms on both sides which required to be treated on 2 sessions.
Balloon assisted coiling was performed in 11 patients. Stent assisted coiling was performed in 8 patients, 3 of them were done by Y stenting. Simple coiling was performed in 9 patients. One patient was treated using double microcatheter technique. Another patient was treated using WEB device.
Flow diverter stents were used in 7 patients. One patient was treated with FD and coiling at the same session. Two patients were treated with FD alone without coiling, while 4 patients were previously coiled in their 1st session, then showed recanalization in their angiographic follow up which required a 2nd session using FD stent.

Immediate angiographic outcome:

Apart from those patients treated by WEB and FD stents, total occlusion of the aneurysmal sac in the rest of the patients was achieved at the immediate final control angiogram except for 2 patients where part of the aneurysm was intentionally left uncoiled due to branches arising from these aneurysms, to be retreated in another session using stent after subsiding of the acute stage.

Table 4
Immediate angiographic outcome

	Balloon assisted coiling		Stent assisted coiling		Simple coiling		Double microcatheter technique	
	Count	%	Count	%	Count	%	Count	%
Complete occlusion	11	100%	8	100%	8	88.8%	0	--

Incomplete occlusion	0	--	0	--	1	11.2%	1	100%

Procedural complications:
One patient (3.1 %) had a hematoma at the femoral puncture site which extended to the scrotum. He received blood and plasma transfusion and was controlled. Two days later he died in the ICU from myocardial infarction.

Procedural technical adverse events:
In one patient (3.1 %) the FD stent wasn't completely opened in its middle segment.

Post-procedural clinical results at 1 & 3 weeks:
In the balloon assisted coiling group, 1 patient didn't show up. One patient showed still noted diminution of vision with slight improvement (Modified Rankin score 2). One patient still showed right hemiparesis (MRS 3). One patient still showed mild headache and fatigue (MRS 1). Three patients still showed mild headache (MRS 1). Four patients showed no significant symptoms or neurological deficits (MRS 0).
In the simple coiling group, 1 patient didn't show up. Two other patients still showed 3rd cranial nerve palsy (MRS 2). Three other patients still showed headache (MRS 1). One patient still showed left lower limb weakness (MRS 3). Two other patients showed no significant symptoms or neurological deficits (MRS 0)
In the stent assisted coiling group, 1 patient died (MRS 6). Two patients still showed headache (MRS 1). Five patients showed no significant symptoms or neurological deficits (MRS 0).
In the FD group, 2 patients presented with headache (MRS 1), while 5 patients showed no significant symptoms or neurological deficits (MRS 0).
Another patient was treated by double microcatheter technique and still showed headache (MRS 1). Another patient was treated by WEB device and showed no significant symptoms or neurological deficits (MRS 0).

Table 5
Post procedural clinical results at 1 & 3 weeks

	Balloonassisted coiling		Stent assisted coiling		Simple coiling		FD		Double microcatheter technique		WEB	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Lost to follow up	1	--	--	--	1	--	--	--	--	--	--	--
Died	--	--	1	12.5%	--	--	--	--	--	--	--	--
Headache	4	40%	2	25%	3	37.5%	2	28.6%	1	100%	--	--
Pressure symptoms	1	10%	--	--	--	--	--	--	--	--	--	--
Neurological deficit	1	10%	--		3	37.5%	--	--	--	--	--	--
Clinicallyfree	4	40%	5	62.5%	2	25%	5	71.4%	--	--	1	100%

Post-procedural clinical results after 3 months:

In the balloon assisted coiling group, one patient (10%) still showed mild diminution of vision (MRS 2). One patient (10%) showed mild right hemiparesis

(MRS 2). One patient (10%) showed mild headache and fatigue (MRS 1). Seven patients (70%) showed no significant symptoms or neurological deficits (MRS 0).
In the simple coiling group, 2 patients (25%) still showed headache (MRS 1). One patient (12.5%) still had left lower limb weakness (MRS 3). Five other patients (62.5%) showed no symptoms with total recovery of their previous neurological deficits (MRS 0).

In the stent assisted coiling group, one patient (12.5 %) died (MRS 6). Two patients (25 %) still showed headache (MRS 1). Five patients (62.5 %) showed no significant symptoms or neurological deficits (MRS 0).
In the FD group, 1 patient (14.3%) presented with headache (MRS 1), while 6 patients (85.7%) showed no significant symptoms or neurological deficits (MRS 0).
Two other patients were treated by double microcatheter technique and WEB device respectively, and both were clinically free (MRS 0).

Table 6
Post procedural clinical results after 3 months

	Balloon assisted coiling		Stent assisted coiling		Simple coiling		FD		Double microcatheter technique		WEB	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Lost to follow up	1	--	--	--	1	--	--	--	--	--	--	--
Died	--	--	1	12.5%	--	--	--	--	--	--	--	--
Still noted headache	1	10%	2	25%	2	25%	1	14.3%				
Still noted pressure symptoms	1	10%	--	--	--	--	--	--	--	--	--	--
Still noted neurologicaldeficit	1	10%	--	--	1	12.5%	--	--	--	--	--	--
Clinicallyfree	7	70%	5	62.5%	5	62.5%	6	85.7%	1	100%	1	100%

Angiographic follow up after 6 months:

In the balloon assisted coiling group, 1 patient was lost to follow up, 1 patient showed neck recanalization. Nine patients showed total occlusion of the aneurysmal sac.
In the stent assisted coiling group, 7 patients showed total occlusion.
In the simple coiling group, 1 patient was lost to follow up, 5 patients showed stable total occlusion, 3 patients (37.5%) showed recanalization.
In the FD group, 1 patient showed residual patency of the aneurysm with intimal hyperplasia of the artery. Six patients showed total occlusion of their aneurysms.

Table 7
Angiographic follow up after 6 months

	Balloon assisted coiling		Stent assisted coiling		Simple coiling		FD		Double microcatheter technique		WEB	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Lostto follow up	1	--	1		1	--	--	--	--	--	--	--
Stable total occlusion	9	90%	7	100%	5	62.5%	6	85.7 %	0	--	1	100%
recan alizati on	1	10%	0	--	3	37.5%	0	--	1 (intentionall yleft)	100%	--	--
Othercomplicati ons	0	--	0	--	--	--	1 (intimal hyperplasi a& residual patency of the aneurysm)	14.3 %	--	--	--	--

The patient treated with WEB device showed total occlusion of the aneurysm.
The patient treated with double microcatheter showed no increase in size of the previously intentionally left uncoiled part of the aneurysm.

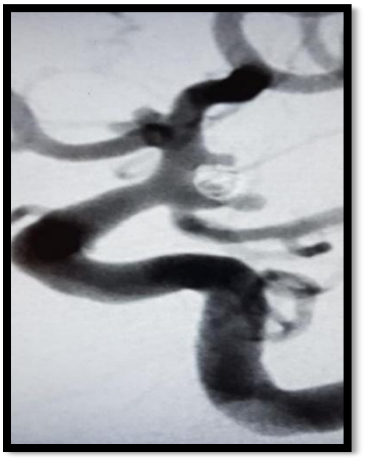

Photo 1: (A) DSA (oblique view) of the Rt ICA showing 3 aneurysms arising at the ICA bifurcation, anterior choroidal and a previously coiled one at the P. com artery

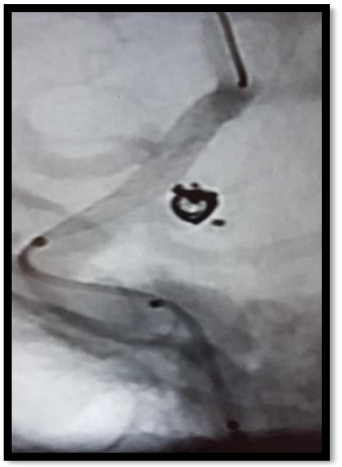

Photo 1: (B) During deployment of the pipeline stent. Microcatheter tip within the Pcom aneurysm

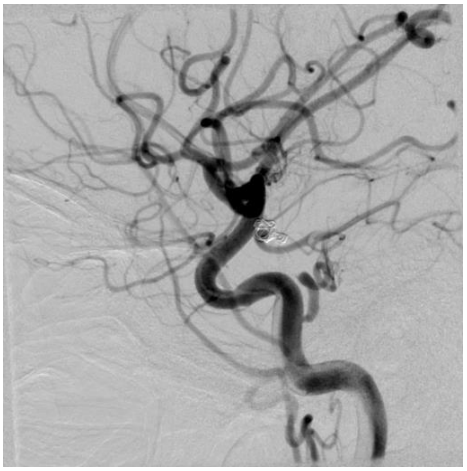

Photo 1: (C) Follow up angiography 6 months after FD deployment showed total occlusion of all the Rt ICA aneurysms

Photo 1: Female patient 53 years old, heavy smoker, with history of a previously ruptured right P.com aneurysm which was coiled 10 years ago. She came for follow up, and angiography showed partial recanalization of the previously coiled right P.com aneurysm with development of a small blister at the aneurysm fundus, together with development of 2 new aneurysms, namely at the right ICA terminus (bilobed wide neck measuring 4 x 2.5 mm) and (25 x 4 mm) the anterior choroidal artery (wide neck measuring 3 x 3 mm). A pipeline flex stent was deployed at the right ICA supraclinoid portion and extending to the M1 segment of the right MCA, covering the 3 aneurysms in addition to few coils that were added in the previously ruptured Pcom aneurysm. Follow up showed total occlusion of the 3 aneurysms

Discussion

In our study the mean age of patients was about 41.8 years. This corresponds in general to the mean age of aneurysm patients published in literature, where it is stated by Bonneville and his co workers (2006) that they are essentially lesions of adulthood, with a peak presentation between the fourth and sixth decades.

There was a male predominance in our study. We performed the endovascular treatments on 18 men and 14 women, that is to say that males represented 56.2% and females represented 43.8%. In the International Study of Unruptured Intracranial Aneurysms (ISUIA), it has been stated that females represents about 75% of the cases. (Bonneville et al. 2006)

Our choice of the type of endovascular treatment depended on different factors such as clinical presentation, aneurysm location, timing of treatment after SAH, aneurysm morphology including the sac: neck ratio and the branches arising from the aneurysm in addition to the presence of intraluminal thrombus if any

Nine patients with complex aneurysms were treated in the acute stage using simple coiling. Eight of these patients were fully packed with coils, while in only 1 patient subtotal occlusion was achieved and part of the aneurysm neck was intentionally left uncoiled as a branch was seen arising from it.

Concerning the 8 patients that were fully packed with coils, 1 of them had a branch arising from the aneurysm, and despite this fact we decided to fully pack this aneurysm with coils. The explanation of this was that the branch arising from the aneurysm sac was a long anterior choroidal artery, and *Yu and his co workers (2018)* reported that the long-course AChA has anastomoses with the lateral posterior choroidal artery, the posterior cerebral artery and the posterior communicating artery. Even when the proximal AChA or internal carotid artery (ICA) are occluded, retrograde filling of the AChA from the posterior circulation has been observed on a vertebral angiogram

No procedural related complications or technical adverse events occurred in patients treated with simple coiling. In the follow up angiography, it was classified according to Raymond's Roy classification into total occlusion (grade I), neck remnant (grade II) and aneurysm remnant (grade III).

Eight out of 9 patients were available for angiographic follow up, as 1 patient didn't show up again. Five out of 8 patients showed no recanalization of their aneurysms (62.5%), while 3 patients showed grade II recanalization (37.5%). This may be due to coil impaction, coil migration into intraluminal thrombus or dissolution of intraluminal thrombus resulting in luminal enlargement. This recanalization rate (37.5%) was almost similar to what *Rautio and his co workers (2018)* reported, as he stated that angiographic recurrence after endovascular aneurysm coiling is 34%. But our results were a bit higher than what is reported in the literature, as *Hwang and his co workers (2011)* reported that the recanalization rate in his patients with complex aneurysms was 21%.

The 3 patients that showed grade II recanalizations of their aneurysms were planned for a 2nd session with FD stent deployment and this was done after preparing the patient with antiplatelet therapy. Six months later they came for angiographic follow up, which showed total occlusion of the aneurysm.

Despite the relatively higher recanalization rate compared to other modalities, yet simple coiling is still a valuable modality in securing some wide neck aneurysms during the acute stage of SAH by manipulating microcatheter/coils, till a 2nd session can be planned later on for definite treatment using a stent, as coiling the complex aneurysm alone without deployment of a stent will eventually result in recanalization later on.

Eleven patients with complex aneurysms were treated using balloon assisted coiling. Later on 1 patient was lost to follow up. In the immediate angiography, all of the patients showed total occlusion of their aneurysms. No procedural related complications or technical adverse events occurred in patients treated with balloon assisted coiling.

In the follow up angiography, one patient with an aneurysm arising from the left P.com artery showed neck recanalization (10%). This patient was initially presenting by gradual diminution of vision and a recent attack of severe headache. Although his cross sectional imaging was free of SAH, we suspected a sentinel SAH because of his complaint of a recent attack of severe headache. This shifted our plan of treatment from stent assisted coiling to balloon assisted coiling, as stent assisted coiling wasn't preferred in this stage to avoid antiplatelet therapy which carries the risk of rebleeding, so we preferred to secure the fundus of the aneurysm at first then retreat the aneurysm with a FD stent few months later in another session. He was planned for a 2nd session with FD stent deployment, but he refused treatment. *Wallace and his co workers (2019)* reported that 35.6% of his patients showed Raymond Roy II occlusion, and this was higher than our results. *Cekirge and his co workers (2011)* reported that they had recanalization rate of 18 %, and this was close to our results.

Stent assisted coiling was performed in 8 patients, 2 patients presented to us in the acute stage and 6 in the subacute stage. Three of them were treated by Y stenting, as those 3 patients had aneurysms at the MCA bifurcation and the basilar tip, which required the placement of 2 Neuroform atlas stents to secure both branches. In the immediate angiography, all patients showed total occlusion of their aneurysms.

No technical adverse events occurred. We didn't have any hemorrhagic complications despite using antiplatelet therapy before and after the procedure, and this was because most of the patients presented to us in the subacute stage which allowed us to use antiplatelet therapy with relative safety.

One patient (3.1%) who was known to be a cardiac patient had a post procedural femoral puncture hematoma, which extended to the scrotum. He received blood and plasma transfusion, and 2 days later he died in the ICU from MI. This was the only procedural related complication and the only mortality in our study. This was close to the rates of procedural related complications reported in the

literature, as *Goertz and his co workers (2019)* reported that only 2.7% of their cases showed procedural related complications. Also *Pierot and his co workers (2016)* reported that 6.6% of their cases showed periprocedural complications.

In the angiographic follow up, after exclusion of the patient who died, 7 patients remained, and all of them showed total occlusion of their aneurysms (100%). This didn't go far away from what is reported in the literature, where *Cagnazzo and his co workers (2018)* reported that complete/near complete occlusion was achieved in 95% of aneurysms. Also *Goertz and his co workers (2019)* reported that 92.3% favorable occlusion was achieved in their patients

Seven patients have been selected for flow diversion in our study. One patient was treated with FD and coiling at the same session as the aneurysm size was 14 x 8 mm. Two other patients were treated with FD alone without coiling, while 4 patients were previously coiled in their 1st session, then showed recanalization in their angiographic follow up which required a 2nd session using FD stent.

In the immediate angiography, all of the aneurysms showed gradual stagnation of contrast within.No procedural related complications were noted during using the FD stents. There was a technical adverse event in only 1 patient (3.1%), where the mid segment of the FD stent didn't open completely. This had its effect in the angiographic follow up after 6 months.

In the follow up angiography, 6 out of 7 patients (85.7%) showed total occlusion of their aneurysms. This matched most of the results reported in the literature. *Rautio and his co workers (2019)* reported that 87% of the aneurysms studied showed total occlusion upon angiographic follow up. Also *Kulcsár & Szikora (2012)* showed a high rate (93%) of complete angiographic occlusion at 6 months in a population of the most challenging anatomic subtypes of cerebral aneurysms.

Conclusion

If the complex aneurysm is ruptured and presenting in the acute stage, then we prefer to avoid using stent assisted coiling or flow diverter stents to avoid the antiplatelet therapy with its hemorrhagic complications (unless we don't have any other options, eg: in case of a very wide neck aneurysm), and balloon assisted coiling or WEB would be a better modality.

If the complex aneurysm is ruptured and presenting in the subacute stage, stent assisted coiling or FD stents can be used, and the patient can be prepared with antiplatelet therapy with a relatively low risk of hemorrhagic complications compared to the acute stage.

If the complex aneurysm is unruptured, then the modality of choice will differ according to the size, location and morphology of the aneurysm, but the most preferable modalities would be the FD stent stent assisted coiling and recently the WEB device, due to their very low rate of recanalization.

The double microcatheter technique is preferably used in cases of complex aneurysms (whether ruptured or not) having a branch arising from the aneurysm neck or fundus and is difficult to be secured by balloon or stent.

Conflict of Interest: None

References

Bonneville F, Sourour N & Biondi A (2006): Intracranial aneurysms, an overview. Neuroimaging clinics of North America 16 (2006), 371-382.

Briganti, F., Leone, G., Marseglia, M., Mariniello, G., Caranci, F., Brunetti, A., & Maiuri, F. (2015). Endovascular treatment of cerebral aneurysms using flow-diverter devices: A systematic review. *The neuroradiology journal*, *28*(4), 365–375.

Brown J and Broderick J (2014): Unruptured intracranial aneurysms: epidemiology, natural history, management options, and familial screening. The Lancet Neurology, 13(4), pp.393-404.

Cagnazzo F, Limbucci N, Nappini S, et al. (2019): Y-Stent-Assisted Coiling of Wide-Neck Bifurcation Intracranial Aneurysms: A Meta- Analysis. American Journal of Neuroradiology January 2019, 40 (1) 122- 128.

Cekirge HS, Saatci I.A new aneurysm occlusion classification after the impact of flow modification. *Am J Neuroradiol* 2016; 37: 19–24.

D'souza, S (2015): Aneurysmal subarachnoid hemorrhage. *Journal of neurosurgical anesthesiology*, *27*(3), p.222.

Goertz L, Liebeg T, Siebert E et al, et al. (2019): Risk Factors of Procedural Complications Related to Woven EndoBridge (WEB) Embolization of Intracranial Aneurysms. Springer-Clinical Neuroradiology, pp 1-8.

Hwang G, Park H, Bang JS, et al. (2011): Comparison of 2-Year Angiographic Outcomes of Stent- and Non stent-Assisted Coil Embolization in Unruptured Aneurysms with an Unfavorable Configuration for Coiling. American Journal of Neuroradiology October 2011, 32 (9) 1707-1710.

Lawson A, Goddard T, Ross S, et al. (2017): Endovascular treatment of cerebral aneurysms using the Woven EndoBridge technique in a single center: preliminary results. *Journal of neurosurgery*, *126*(1), pp.17-28.

Piotin M, Spelle L and Moret J (2008): Stent-jack technique in stent- assisted coiling of wide-neck aneurysms. *Neurosurgery* (2008) 62:ONS414–6.

Rautio R, Rahi M, Katila A and Rinne J (2018): Single-center experience with six-month follow-up of FRED Jr® flow diverters for intracranial aneurysms in small arteries. Acta Radiologica Volume: 60 issue: 7, page(s): 917-924.

Ryu C.W., Park S., Shin H.S. and Koh, J.S. (2015): Complications in stent-assisted endovascular therapy of ruptured intracranial aneurysms and relevance to antiplatelet administration: a systematic review. *American Journal of Neuroradiology*. 36 (9) pp 1682-1688.

Wallace A , Samaniego E, Kayan Y, et al. (2019): Balloon-assisted coiling of cerebral aneurysms with the dual-lumen Scepter XC balloon catheter: Experience at two high-volume centers.

Yu J, Xu N, Zhao Y, and Yu J (2018): Clinical importance of the anterior choroidal artery: a review of the literature. International journal of medical sciences. 15(4): 368–375.