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Original research

OUTCOME EVALUATION OF FLOW DIVERTER STENT PLACEMENT IN TREATMENT OF RUPTURED AND UNRUPTURED CEREBRAL ANEURYSMS

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ABSTRACT

Background: *Cerebral aneurysms affect about 5% of the population and are associated with high mortality rates and severe complications for families and society. Complex aneurysm types include giant aneurysms, wide - necked aneurysms, blister - like aneurysms, recurrent aneurysms, fusiform aneurysms, and multiple aneurysms, which are difficult to manage with conventional endovascular or surgical methods due to complications such as coil migration and high rates of re - rupture. The development of flow diverter stents has been a breakthrough in recent decades and has been demonstrated to be safe and effective in treating aneurysms. The aim of this study was to evaluate the outcomes of flow diverter stent placement in the treatment of ruptured and unruptured cerebral aneurysms.*

Methods: *This was a descriptive prospective study that followed up on 23 patients diagnosed and treated for cerebral aneurysms with flow - diverter stent intervention at the Stroke Department of Hue Central Hospital from 6/2020 to 6/2022. The follow - up data after 6 months and 12 months were recorded.*

Results: *There were 23 patients (9 males, 14 females) with 28 cerebral aneurysms, with a mean age of 51.7 ± 9.9 years. Aneurysms were predominantly located in the anterior circulation (85.7%) and 14.3% in the posterior circulation. The most common aneurysm type was fusiform (75%), followed by dissecting (17.9%) and blister - like (7.1%). Most aneurysms had wide necks, with a neck - to - dome ratio < 1.5, accounting for 82.1%. Flow diverter stent placement was successfully performed in 91.3% of patients, with 27 stents used. Stents were properly positioned, well - expanded in 88.9%. The complication rate after intervention was 4.3%. Complete aneurysm occlusion rates at 6 to 12 months were 92.9% and 96.4%, respectively. The rate of mild in - stent stenosis without clinical symptoms was 4.3%. The good outcome rate (mRS 0 - 2) was 91.3%.*

Conclusion: *Flow diverter stent is effective and safe with high rate of successful and low procedural complications in the treatment of complex cerebral aneurysms.*

Keywords: *Cerebral aneurysm, cerebral intervention, pipeline, flow diverter stent.*

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I. INTRODUCTION

Cerebral aneurysm is a relatively common disease (2, 3 - 5% of the population) and tends to increase with the average life expectancy in our country ta [1]. When ruptured, it causes a high mortality rate (40 - 45%) with severe sequelae for the individual, family, and society [2]. Endovascular treatment with metal coils for narrow-necked, small aneurysms and coils with a balloon or stent support for wide - necked aneurysms has been applied for many years. However, for complex aneurysms including giant aneurysms, wide - necked aneurysms, blister - like aneurysms,

recurrent aneurysms, fusiform aneurysms, and multiple aneurysms, these methods of treatment with coils and clipping surgery can easily fail or encounter many difficulties due to the risk of coil migration and high recurrence rate after treatment.

Since 2007, flow - diverter stents have been applied for treatment [3], and in 2011, it was approved by the FDA to treat wide - necked and large - sized aneurysms [4]. The special design of the stent, when placed horizontally across the aneurysm neck, restricts the outflow and inflow of blood into the aneurysm sac, causing stagnation of flow and creating conditions for the formation of a clot that fills the aneurysm sac while still ensuring blood flow through the stent placed in the vessel as well as blood flow into the branches and collateral vessels covered by the stent. The advent of flow - diverter stents is a breakthrough that has been proven to be safe and effective in the treatment of cerebral aneurysms. However, successful implementation of the technique remains a significant challenge in most interventional neurology units in Vietnam as well as around the world. At Hue Central Hospital, the Pipeline stent (Pipeline, ev3, USA) was used for the first case of cerebral aneurysm treatment in 2019. Until now, many patients have been treated with this advanced treatment method, and the evaluation of treatment efficacy is necessary. Therefore, we conducted this study to describe the clinical characteristics and morphological features of ruptured or unruptured cerebral aneurysms in patients who received flow - diverter stent placement; and evaluate the results of intervention within 6 months to 1 year.

II. MATEIRALS AND METHODS

2.1. Study subjects

The study included 23 patients who were treated at the Stroke Center, Hue Central Hospital from June 2020 to June 2022, diagnosed and treated for cerebral aneurysms by flow - diverter stent.

Selection criteria: (1) Adult patients (> 18 years old). (2) Ruptured or unruptured cerebral aneurysms with complex morphology such as blister - like, dissecting, fusiform, large - sized (largest diameter ≥ 10 mm), wide - necked (height/diameter ratio < 1.5 and/or neck diameter ≥ 4 mm), giant aneurysms (≥ 25 mm), symptomatic aneurysms, multiple aneurysms in 1 artery (≥ 2 aneurysms), recanalized aneurysm after treatment

Exclusion criteria: Patients with mRS > 2 before intervention; Patients unable to use dual antiplatelet therapy before and after intervention; Patients or their families do not agree with the treatment method

2.2. Research methods

Methods: Cross - sectional descriptive study with longitudinal follow - up.

Study variables: Personal characteristics, clinical characteristics, characteristics of aneurysms, success rate of the procedure. Complications, clinical outcomes after intervention, 6 months, 12 months, degree of occlusion classified by Roy - Raymond

Diagnostic procedures: Cerebral aneurysms is diagnosed by CTA, MRI or DSA.

Interventional procedures:

Preparation before the procedure:

- For unruptured aneurysms: dual antiplatelet therapy with Plavix 75mg + Aspirin 81mg daily for at least 5 days before intervention.

- For ruptured aneurysms, divided into two cases:

Aneurysms that are not bleeding and the flow - diverter stent is placed as soon as possible: use Plavix 75mg x 4 tablets + Aspirin 81mg x 3 tablets pumped through the stomach tube at least 4 hours before the procedure.

In stable patients, the flow - diverter stent is placed after 1 - 2 weeks of bleeding, and Plavix 75mg + Aspirin 81mg are used daily for 5 days before the procedure.

Post - intervention follow - up:

- Evaluate the patient's clinical status before and after the intervention, take CT of the brain or MRI of the brain if necessary depending on the clinical progress.

- About treatment: Maintain dual antiplatelet therapy for at least 3 - 6 months with Plavix 75mg + Aspirin 81mg depending on the time of thrombosis of the aneurysm, then maintain Aspirin 81mg/day long term.

- Schedule re - examination and follow - up periodically 6 months after intervention by CTA or MRA to assess secondary stroke, take DSA to assess the degree of aneurysm thrombosis according to the Raymond - Roy scale.

- If the aneurysm is not completely thrombosed,

schedule a follow - up visit in 9 - 12 months with the same procedure.

2.3. Data analysis: Using SPSS 20.0 software to anylyze the data.

III. RESULTS

3.1. Clinical, paraclinical and imaging characteristics before intervention

The total number of patients in the study group was 23 with 28 ruptured and unruptured intracranial aneurysms. Among them, 60.9% (14) were female and 39.1% (9) were male, with a female - to - male ratio of 1.56. The mean age was 51.7 ± 9.9 years, with the youngest patient being 38 years old and the oldest being 78 years old. All 23 patients had clinical symptoms upon admission, with headache being the most common, as well as other symptoms such as trigeminal neuralgia and abducens nerve palsy. Upon admission, 1 patient was comatose (GCS 3 - 8), 1 patient was lethargic (GCS 9 - 12), and 21 patients were alert (GCS 13 - 15) according to the Glasgow Coma Scale. Regarding the characteristics of the computed tomography scan of the brain, 39.1% (9) of cases had subarachnoid hemorrhage due to aneurysm rupture, while 60.9% (14) of cases had unruptured aneurysms. Among the aneurysms, 75% (21) were saccular, 17.9% (5) were dissecting, and 7.1% (2) were blister - like. The distribution of aneurysms in the anterior circulation and the posterior circulation was 85.7% (24) and 14.3% (4), respectively. The mean diameter of the aneurysm was 13.3 ± 12.5 mm, and the mean width was 8.4 ± 7.6 mm. The mean neck size was 8.2 ± 6.5 mm, with a ratio of the aneurysm dome to neck less than 1.5 in 82.1% of cases.

Table 1: Clinical Presentation and Aneurysm Characteristics in 23 Patients with 28 Aneurysms Treated by Pipeline Stent Placement

Patient	Age/ Sex	Clinical Presentation			Aneurysm Characteristics			Stent Diameter/ Length
		GCS	Symptoms	SAH on CT	Diameter (mm)	Location	Type	
1	63/F	15	Headache, Trigeminal neuralgia Cranial nerve VI palsy		19	ICA - Cavernous segment	Wide neck, Saccular	4.25 x 25
2	78/F	15	Headache Multiple aneurysms		6	ICA - Posterior communicating segment	Wide neck, Saccular	4.75 x 25
3	52/F	15	Headache Trigeminal neuralgia		18	ICA - Cavernous segment	Wide neck, Saccular	4.25 x 25
4	55/F	15	Headache Trigeminal neuralgia		4,5	ICA - Para-ophthalmic segment	Wide neck, Saccular	4.25 x 20
5	57/F	15	Headache Cranial nerve VI palsy		28	ICA - Cavernous segment	Giant, Saccular	4.5 x 35

Patient	Age/ Sex	Clinical Presentation			Aneurysm Characteristics			Stent Diameter/ Length
		GCS	Symptoms	SAH on CT	Diameter (mm)	Location	Type	
6	45/M	6	Coma	+	8	V4 segment of VA	Dissection	3.5 x 25 3.5 x 25
7	56/F	15	Headache Multiple aneurysms	+	1,5 1,6	ICA - Para-ophthalmic segment	Blister-like	4.25 x 25
8	52/M	15	Headache		10,5	ICA - Posterior communicating segment	Wide neck, Saccular	4.25 x 25
9	67/F	15	Headache Cranial nerve VI palsy		32	ICA - Para-ophthalmic segment	Giant, Saccular	4.5 x 35
10	58/M	15	Headache	+	9,5	V4 segment of Vertebral Artery	Dissection	4.25 x 25
11	54/M	15	Headache		13,5	ICA - Posterior communicating segment	Wide neck, Saccular	3.75 x 30
12	52/F	15	Headache Multiple aneurysms	+	3 2,5	ICA - Posterior communicating segment	Wide neck, Saccular	4.25 x 25
13	60/M	15	Headache		8	Basilar artery	Dissection	5.0 x 20
14	49/F	15	Headache Multiple aneurysms		2,8	ICA - Posterior communicating segment	Wide neck, Saccular	3,75 x 18
					4	ICA - Para-ophthalmic segment	Wide neck, Saccular	4.25 x 20
15	43/F	15	Headache Multiple aneurysms	+	2 3	ICA - Posterior communicating segment	Wide neck, Saccular	4.25 x 25
16	43/M	12	Headache	+	50	From ICA - Posterior communicating segment to Middle cerebral artery	Dissection	3,75 x 35 4,25 x 35

Patient	Age/ Sex	Clinical Presentation			Aneurysm Characteristics			Stent Diameter/ Length
		GCS	Symptoms	SAH on CT	Diameter (mm)	Location	Type	
17	55/M	14	Headache	+	22	Basilar artery	Dissection	4.5 x 35
18	39/F	15	Headache		23	MCA segment M1	Wide neck, Saccular	3,75 x 35
19	38/F	15	Headache	+	7.5	ICA - Para-ophthalmic segment	Wide neck, Saccular	4 x 25
20	44/F	15	Headache		9	ICA - Para-ophthalmic segment	Wide neck, Saccular	4 x 35
21	39/M	15	Headache	+	7	ICA - Para-ophthalmic segment	Wide neck, Saccular	4.25 x 20
22	50/F	15	Headache		6	ICA - Para-ophthalmic segment	Wide neck, Saccular	4 x 25
23	39/M	15	Headache		8	ICA - Para-ophthalmic segment	Wide neck, Saccular	4.25 x 25
					2	ICA - Para-ophthalmic segment	Wide neck, Saccular	4.25 x 18

3.2. Technical characteristics of flow - diverter stent placement and early results of the intervention

Most patients (60.9%) were under general anesthesia, while the remaining were under local anesthesia at the puncture site and received sedation during the procedure. A total of 27 stents were used in the intervention. Among them, 20 stents were used for 20 aneurysms, accounting for 74.1%, 01 stent for 02 aneurysms accounting for 11.1% (3), and 02 stents for 01 aneurysm accounting for 14.8% (4). Pipeline stent was used in all cases. The flow-diverter stent placement technique for cerebral aneurysm treatment was successfully performed in 91.3% (21) of patients in the study group. The stents were properly positioned, fully opened and closely approximated the vessel wall in 88.9% (24) of cases, and no stent had to be re - expanded using a balloon. There were 2 cases of incomplete coverage of the aneurysm neck (3 stents). DSA images immediately after the flow-diverter stent placement showed contrast stasis in the aneurysm sac in 53.6% of cases, ranging from mild to moderate degree, while 46.4% of cases did not show unchanged flow as well as no case of aneurysms completely occluded immediately after the intervention.

3.3. Clinical and imaging follow-up results

Table 2: Clinical and anatomic outcome in 23 Patients with 28 Treated Aneurysms

Patient	Immediate Flow Modification	Aneurysm Flow/ Occlusion		mRS		Complications	
		6 Months	12 Months	Discharge	6 months	Intra stent Stenosis	Stent Displacement
1	Significant flow reduction	Complete	Complete	1	0		
2	Unchanged	Complete	Complete	1	1		
3	Significant flow reduction	Complete	Complete	1	0		
4	Unchanged	Complete	Complete	1	0		
5	Significant flow reduction	Complete	Complete	1	0		
6	Slow flow	Complete	Complete	2	1	+	
7	Unchanged	Complete	Complete	2	1		
	Unchanged	Complete	Complete				
8	Significant flow reduction	Complete	Complete	1	1		
9	Significant flow reduction	Complete	Complete	1	0		
10	Slow flow	Complete	Complete	2	1		
11	Unchanged	Incomplete (unchanged)	Incomplete	1	1		+
12	Unchanged	Complete	Complete	2	1		
	Unchanged	Complete	Complete				
13	Slow flow	Complete	Complete	1	0		
14	Unchanged	Complete	Complete	1	5		
	Unchanged	Complete	Complete				
15	Unchanged	Complete	Complete	2	0		
	Unchanged	Complete	Complete				
16	Slow flow	Complete	Complete	4	3	+	+

Patient	Immediate Flow Modification	Aneurysm Flow/ Occlusion		mRS		Complications	
		6 Months	12 Months	Discharge	6 months	Intra stent Stenosis	Stent Displacement
17	Significant flow reduction	Complete	Complete	2	1		
18	Significant flow reduction	Incomplete	Complete	1	1		
19	Slow flow	Complete	Complete	2	1		
20	Significant flow reduction	Complete	Complete	1	0		
21	Slow flow	Complete	Complete	2	0		
22	Unchanged	Complete	Complete	1	1		
23	Slow flow	Complete	Complete	1	1		
	Unchanged	Complete	Complete				

Clinical follow - up after intervention showed that 39.1% (9/23) patients experienced mild hemisphere tension and discomfort after flow - diverter stent placement. However, these patients responded well to pain relief medication and their symptoms improved gradually after 2 to 3 days of treatment. 8.7% (2/23) patients had signs of localized nerve damage such as weakness of half of the body and difficulty speaking, of which 1 patient recovered well after increasing the heparin dosage and using the anti-spasmodic drug nimodipine with an infusion rate of 1mg/hour (case 6); 1 patient experienced severe left hemiplegia due to stent occlusion (case 16).

At the time of hospital discharge, the patient status was assessed as 60.1% (14) patients with mRS = 1 and 34.8% (8) patients with mRS = 2 and 1 case with mRS = 4 (case 16: extensive cerebral infarction causing half-body paralysis, requiring the support of family members, but still conscious).

After a 6 - month follow - up post - intervention, 39.1% (9) patients had mRS = 0 (symptoms completely resolved), 52.2% (12) patients had mRS = 1, 1 patient with half-body paralysis had mRS = 3 (case 16), and 1 patient had mRS = 5 due to a converted subarachnoid hemorrhage (case 14).

There were no technical - related complications. During hospitalization, there were 2 cases of postoperative complications: 1 stent occlusion (case 16) and 1 stent stenosis (case 6). Follow - up complications at 6 months showed 1 case of tissue

hemorrhage (case 14). There were no incidents of distal branch occlusion, cross-branch occlusion or mortality due to technical complications.

All patients underwent CTA or MRA imaging after 6 months to evaluate tissue damage after stent placement and to preliminarily assess the degree of aneurysm occlusion. Among them, 23 patients with 28 aneurysm sacs underwent DSA imaging again, and the degree of aneurysm occlusion according to the Roy - Raymond classification was as follows [5]: Complete occlusion accounted for 92.8% (26/28), while residual flow at the neck accounted for 7.1% (2/28).

IV. DISCUSSION

4.1. Characteristics of cerebral aneurysm morphology

According to Vu Dang Luu, the distribution of cerebral aneurysms in the anterior circulation accounts for 88.6% [6], while according to Tran Xuan Thuy, it is 95.6% [7]. In our study, this ratio was 82.6%.

For the anterior circulation, the number of aneurysms at the location of the carotid artery was significantly higher than that at the middle cerebral artery, with 23 aneurysms in the study group compared to only 1 aneurysm at the middle cerebral artery. This was due to the standard selection of patients for flow - diverter stent placement, which requires minimizing the placement of stents across important arterial branches. The dominant shape of cerebral aneurysms was saccular, accounting for 75%, which is similar to the results of other authors [6, 7].

The majority of patients in the study group had a single aneurysm, accounting for 78.3% (18). There were 5 cases with 2 aneurysms, especially 3 patients with 2 consecutive aneurysms (multiple, tandem intracranial aneurysms) (cases 7, 12, 15) were treated with a single flow-diverter stent with an appropriate length to cover all aneurysm necks in one treatment session. All of these aneurysms were completely thrombosed upon re - evaluation at 6 - 12 months. Although there were not many patients in this group, treating multiple aneurysms with a single stent without the need for additional coil embolization or complex technical procedures was a significant advantage of flow - diverter stents with good aneurysm thrombosis results [8].

The majority of aneurysms in the study group had a large or giant size with a diameter ≥ 5mm, accounting for 64.3% of all patients. There was one patient with a dissecting aneurysm with a length of up to 50 mm, requiring 2 stents in series to cover the entire aneurysm.

The study included 9 cases of subarachnoid hemorrhage due to ruptured aneurysms. Most of these cases were dissecting, blister - like, wide - necked aneurysms with small sac size that were not suitable for conventional surgical or endovascular interventions. Therefore, these patients were treated with flow - diverter stent placement and had good outcomes, with no rebleeding during the 6 - 12 months of follow - up. A study by author José E. Cohen and colleagues on early flow - diverter stent placement within 4 days in patients with ruptured aneurysms resulted in no rebleeding after the intervention and a good outcome with mRS 0 - 2 after 90 days in 81.6% of cases [9].

4.2. Intervention outcomes of treating cerebral aneurysms with Pipeline stent

Patient sedation for intervention was performed in the initial stage of the study to ensure maximum concentration during the procedure. Later, we found that local anesthesia and analgesia combined with stent deployment achieved similar results, allowing patients to communicate with the physician during the procedure without the need for post-sedation recovery time.

The technique of placing flow - diverter stents for the treatment of cerebral aneurysms was successful in 91.3% (21) of patients in the study group. This result is similar to other authors worldwide [10 - 12]. Most stents were placed in good position, expanded well, and apposed the vessel wall in 88.9% (24) of cases. No instances of incomplete expansion required balloon-assisted dilation, and this ratio is also low in other studies, such as Simon Chun - Ho Yu and colleagues, who reported 1.4% [10], and Celal Cinar and colleagues, who reported 4.4% [13].

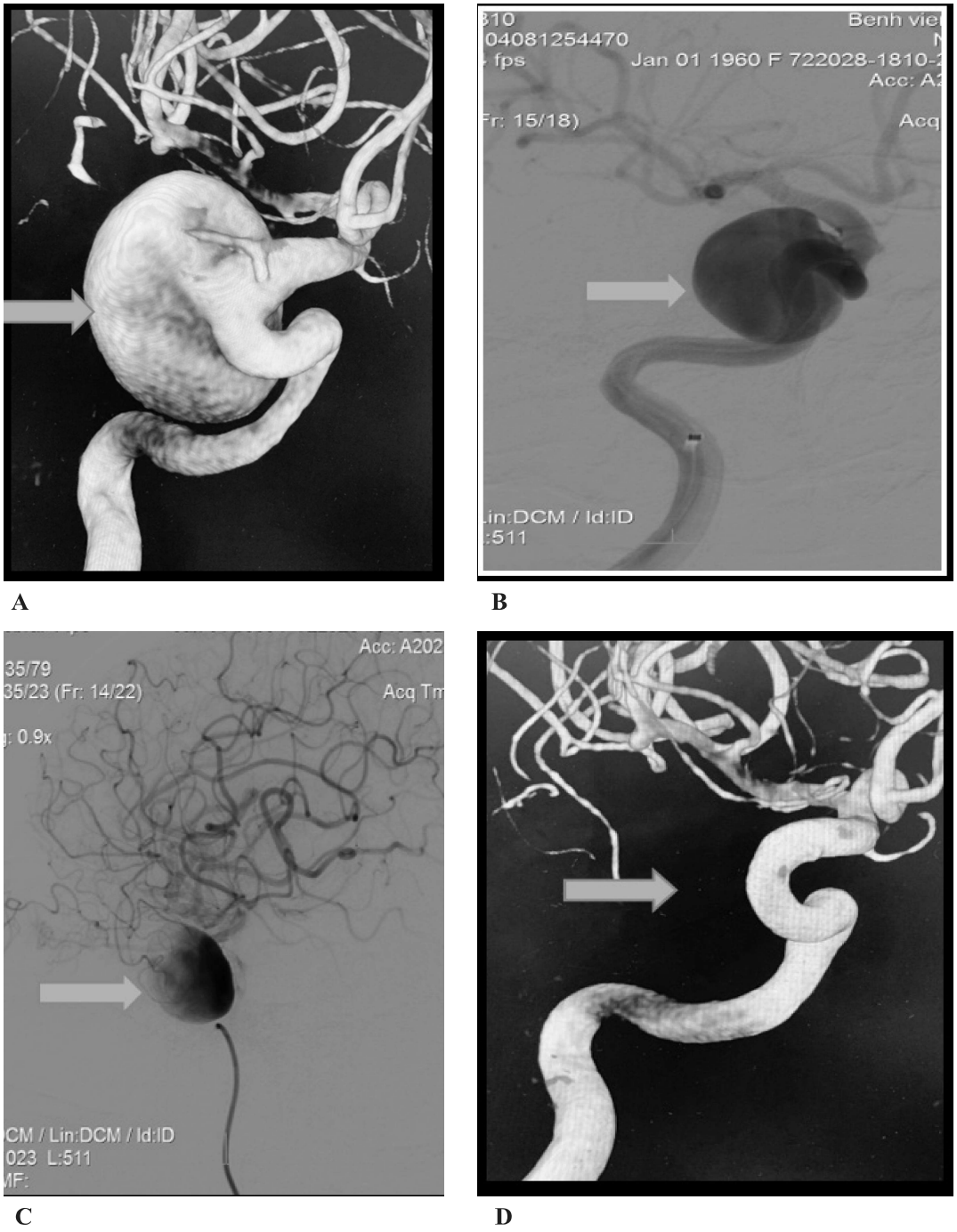


Figure 1: Case 5: A 57 **-** year **-** old female patient with a giant aneurysm located at ICA **-** the cavernous segment, measuring 7.8mm in neck size and 28mm in diameter, was admitted to the hospital with headache (A, B). A decision was made to intervene by placing a Pipeline stent, which significantly reduced the flow of the aneurysm (C). Twelve months after the intervention, the aneurysm regressed and improved completely (D) on the follow **-** up DSA.

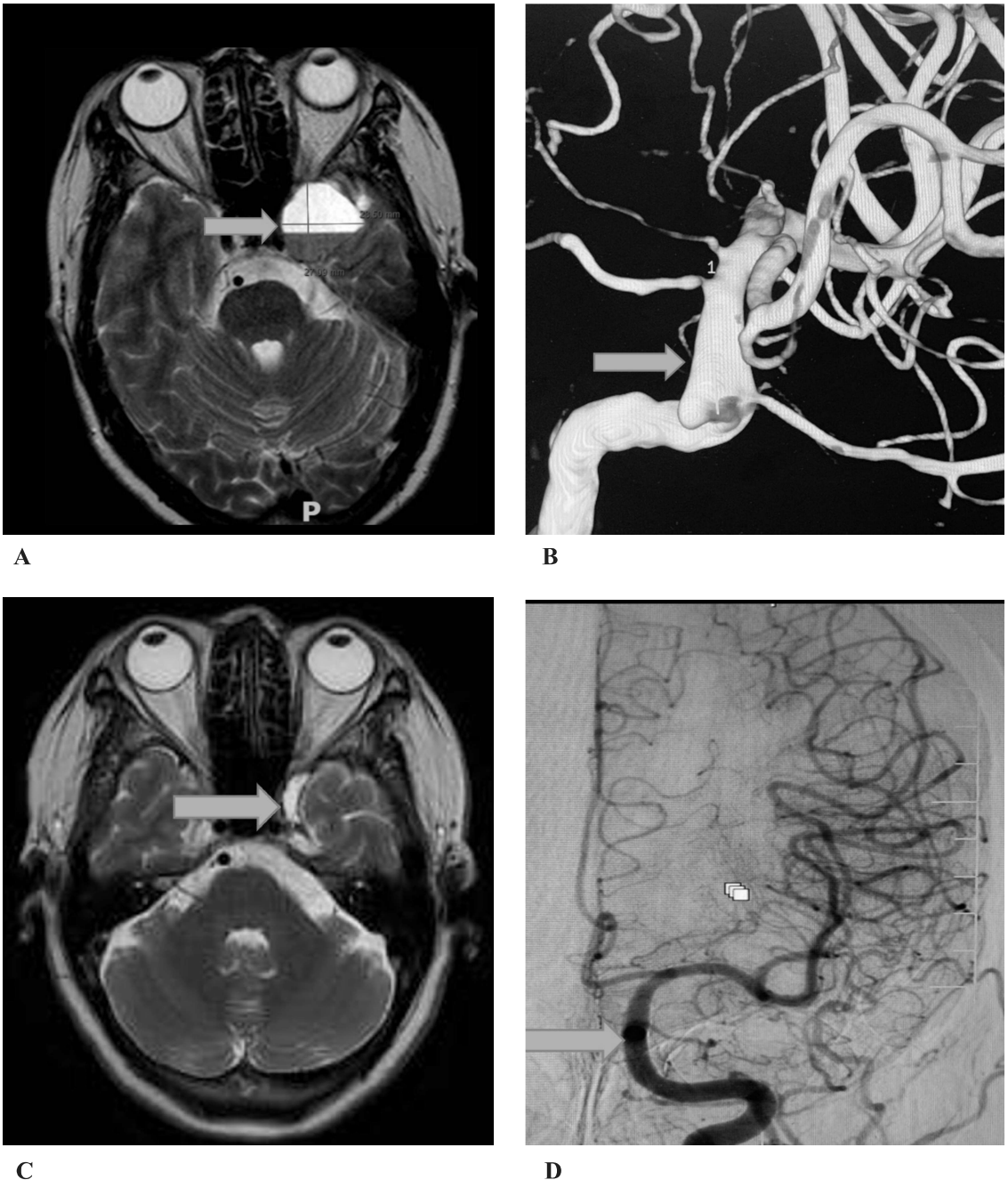


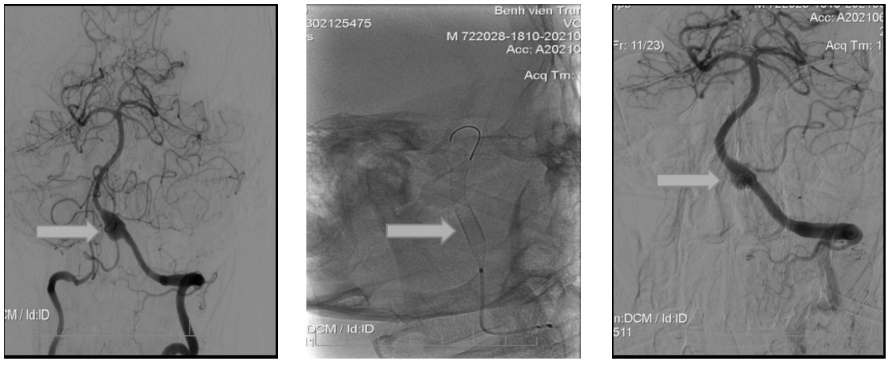
Figure 2: Case 9: A 67 - year - old female patient was admitted to the hospital due to mild and persistent headaches with ptosis. Clinical examination showed a Glasgow Coma Scale of 15, mild headache, ptosis, exotropia, and blurred vision. MRA images revealed a giant aneurysm in left ICA - para - ophthalmic segment that was almost completely occluded by a thrombus, with a maximum diameter of approximately 32mm, compressing the III, VI nerves, and the ipsilateral p - com artery, causing severe symptoms (A). DSA did not clearly show the aneurysm, only a small filling defect (B). The decision was made to perform a Pipeline stent intervention. After 6 months, the aneurysm had regressed and reduced in size on MRA (C) and DSA (D), and the patient's symptoms completely improved, with no more blurred vision.

For stent selection, a stent diameter of 0.25 - 0.5 mm larger than the parent artery diameter and a length greater than 10mm compared to the aneurysm sac size were chosen to ensure good stability. If the stent is too large for the artery, it will not fully expand as designed, leading to early clot formation in the aneurysm sac. If the stent is smaller than the artery diameter, there is a risk of stent migration. However, there were still 2 cases (cases 11 and 16) in which the flow - diverter stent was displaced and collapsed after deployment, while the neck was not completely covered, leading to failure.

Case 11: A 54 - year - old male patient presented with a wide - necked aneurysm located at ICA - the p - com artery segment, with a maximum diameter of 13.5mm. A flow - diverter stent was chosen to cover from the proximal segment of the middle cerebral artery to the aneurysm in the cavernous segment. However, immediately after deployment, the distal end of the stent displaced into the aneurysm. The patient was explained the option of placing a second stent, but due to financial constraints, we continued to monitor the patient.

Case 16: A 43 - year - old male patient experienced subarachnoid hemorrhage due to a dissection injury of right ICA - the p - com artery following a head trauma. The dissection extended from the ophthalmic artery segment to the distal segment. CTA and DSA revealed a 50mm - long dissection segment with a pseudoaneurysm diameter of approximately 25mm and a thrombus thickness adhering to the wall of about 15mm. The treatment strategy involved reconstructing the dissection segment and preserving flow through endovascular intervention using a flow - diverter stent. The initial procedure went smoothly, with two stents overlapping and covering the entire dissection segment. However, during the retrieval of the delivery wire of the second stent, the two stents separated. The distal stent remained in the middle cerebral artery, extending to the dissection segment, while the proximal stent remained in the ophthalmic artery, extending to the dissection segment. The procedure was halted as it was not possible to reconnect the two stents. The patient developed extensive right hemisphere cerebral infarction due to occlusion of the distal stent and ipsilateral middle cerebral artery. The patient underwent a repeat intervention to completely occlude the dissection segment with coils before undergoing decompressive craniectomy.

After DSA, 53.6% of the aneurysm lesions intervened had a moderate to low contrast stasis level. There were 46.4% of aneurysms without contrast stasis, and we observed that all these cases were in the small - sized aneurysm group < 6mm. The direct technical complications commonly encountered were wire perforation of the vessel wall and thrombus migration during procedures were not encountered in our study. There were two cases of complications after intervention during hospitalization, including 1 stent occlusion (case 16) and 1 stent stenosis (case 6). There were no cases of complications such as distant branch occlusion, cross - branch occlusion, or death due to technical complications. In many cases, the aneurysms had some branches arising from the wall, which made it difficult to preserve these branches with coils. The stent structure was designed as a mesh to ensure that it did not slow down the flow of these branches [14, 15].



A **B** **C**

Figure 3: Case 6: A 45 - year - old male patient was admitted to the hospital due to sudden severe headache followed by unconsciousness, with a Glasgow Coma Scale (GCS) score of 6, caused by a

subarachnoid hemorrhage from a ruptured dissecting aneurysm of the left vertebral artery segment V4 (8 mm in length, maximum diameter 6 mm, with a thin adherent clot) and a hypoplastic contralateral V4 segment (A). Therefore, the treatment strategy was to preserve the dissecting segment. Because of the high risk of rebleeding, two flow-diverter stents were used to enhance the reconstructive ability of the blood vessel, reduce the flow into the dissected segment, and preserve the ipsilateral posterior inferior cerebellar artery (PICA), which arises just before the dissected segment. Two stents were deployed across the dissected segment (B). The two stents covered the dissected segment well, significantly reducing the flow and promoting thrombosis of the dissected segment, while preserving the PICA (C). After the intervention, the patient was treated with intensive care and had a good recovery. However, in the sixth week, the patient developed symptoms of dizziness, dysarthria, hemiparesis, and a DSA showed stent stenosis. The patient was treated with intravenous heparin for 5 days (APTT 60 - 80 seconds) in combination with dual antiplatelet therapy (aspirin and Plavix). The patient's symptoms improved almost completely, and he was discharged after 2 weeks (8 weeks in total from the time of the subarachnoid hemorrhage) with an mRS of 1, and after 1 year, the mRS was 0.

The rate of mild stent restenosis due to endothelial cell proliferation exceeding the stent mesh on DSA images after 6 - 12 months was 1 case (4.3%). Murthy's study reported a complication rate of approximately 5% for Silk stents [16] and approximately 3.2% for Pipeline stents with stroke/TIA and 3.5% for stent stenosis, however, these patients had no localized neurological symptoms [17].

All patients were examined with CTA or MRA after 6 months to evaluate tissue damage after the intervention of reverse flow stent placement and to preliminarily assess the degree of stenosis and aneurysm damage. The rate of complete stenosis on DSA at 6 months according to the Roy-Raymond classification [5]: Complete stenosis accounted for 92.9% (26/28), which was higher than other authors in the world [3, 10], possibly due to our small sample size, which was also a limitation of this study. After 12 months, the rate of complete stenosis increased to 96.4% (27/28). Murthy's study showed that the rate of complete aneurysm occlusion was 79.7% after 6 months, and this rate increased over time [17].

Clinical evaluation of patients after intervention during hospitalization showed that most patients recovered well, with only 2 cases of cerebral infarction and ipsilateral aneurysm damage with symptoms of hemiplegia and difficulty speaking, of which 1 patient recovered well after increasing heparin dosage and using nimodipine to prevent vasospasm at a dose of 1mg/hour (case 6); 1 patient developed severe hemiplegia due to stent occlusion (case 16). Therefore, the overall complication rate after intervention was 4.3% with 1 case of wide cerebral infarction due to stent occlusion, similar to other authors with complication rates ranging from 3 - 6% [8, 10].

At the 6-month follow - up, one patient became severely disabled with an mRS score of 5 due to a change in hemorrhagic stroke (case 14), caused by hypertension - induced intracranial hemorrhage and dual antiplatelet therapy being a contributing factor. This was a case of a giant aneurysm that was successfully treated with stent placement. However, at the third month, a CT scan showed extensive hemorrhage in the left frontal lobe, and a DSA revealed complete regression of two previously treated aneurysms, with no re - rupture and no new aneurysms detected. The remaining patients had favorable outcomes, with 39.1% (9) patients achieving an mRS score of 0 (symptom - free), 52.2% (12) patients achieving an mRS score of 1, and 1 patient with half - body paralysis having an mRS score of 3 (case 16). This result was similar to the study by Adam M. Brouilard and colleagues, who treated large and wide - necked aneurysms with flow - diverter stents and achieved good clinical outcomes, with an mRS score of 0 - 2 in 95% of cases [2].

V. CONCLUSION

This study of 23 cases showed that flow-diverter stents are highly effective and relatively safe for the treatment of cerebral aneurysms (with a complete occlusion rate of 96.4%), with low rates of

procedural complications and adverse events. It is a promising treatment strategy for complex aneurysm lesions. In particular, flow - diverter stents are an effective treatment for acute ruptured aneurysms, with no cases of re - bleeding in our study or in other studies around the world. However, the number of patients in our study was small, and further studies are needed to evaluate long - term effectiveness.

REFERENCES

1. Molyneux AJ, Kerr RSC, Yu L-M, Clarke M, Sneade M, Yarnold JA, et al. International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. The Lancet. 2005; 366(9488): 809-817.
2. Steiner T, Juvela S, Unterberg A, Jung C, Forsting M, Rinkel G. European Stroke Organization guidelines for the management of intracranial aneurysms and subarachnoid haemorrhage. Cerebrovascular diseases. 2013; 35(2): 93-112.
3. Fiorella D, Woo HH, Albuquerque FC, Nelson PK. Definitive reconstruction of circumferential, fusiform intracranial aneurysms with the pipeline embolization device. Neurosurgery. 2008; 62(5): 1115-1121.
4. Fischer S, Vajda Z, Aguilar Perez M, Schmid E, Hopf N, Bäzner H, et al. Pipeline embolization device (PED) for neurovascular reconstruction: initial experience in the treatment of 101 intracranial aneurysms and dissections. Neuroradiology. 2012; 54: 369-382.
5. Mascitelli JR, Moyle H, Oermann EK, Polykarpou MF, Patel AA, Doshi AH, et al. An update to the Raymond–Roy occlusion classification of intracranial aneurysms treated with coil embolization. Journal of neurointerventional surgery. 2015; 7(7): 496-502.
6. Binh NT, Luu VD, Thong PM, Cuong NN, Anh NQ, Tuan TA, et al. Flow diverter stent for treatment of cerebral aneurysms: a report of 130 patients with 134 aneurysms. Heliyon. 2020; 6(2): e03356.
7. Thủy TX, Tuyển NT, Linh NH. Nghiên cứu đặc điểm hình thái phình mạch máu não và đánh giá kết quả ngắn hạn can thiệp đặt stent chuyển hướng dòng chảy điều trị phình mạch máu não. Journal of 108-Clinical Medicine and Phamarcy. 2020.
8. John S, Bain M, Cerejo R, Bauer A, Masaryk T, Hussain MS, et al. Flow diverter treatment of tandem intracranial aneurysms. World Neurosurgery. 2017; 107: 142-147.
9. Cohen JE, Gomori JM, Moscovici S, Kaye AH, Shoshan Y, Spektor S, et al. Flow-diverter stents in the early management of acutely ruptured brain aneurysms: effective rebleeding protection with low thromboembolic complications. Journal of Neurosurgery. 2021; 135(5): 1394-1401.
10. Yu SC-H, Kwok C-K, Cheng P-W, Chan K-Y, Lau SS, Lui W-M, et al. Intracranial aneurysms: midterm outcome of pipeline embolization devicea prospective study in 143 patients with 178 aneurysms. Radiology. 2012; 265(3): 893-901.
11. Lubicz B, Collignon L, Raphaeli G, De Witte O. Pipeline flow-diverter stent for endovascular treatment of intracranial aneurysms: preliminary experience in 20 patients with 27 aneurysms. World neurosurgery. 2011; 76(1-2): 114-119.
12. Nelson PK, Lylyk P, Szikora I, Wetzel SG, Wanke I, Fiorella D. The pipeline embolization device for the intracranial treatment of aneurysms trial. American Journal of Neuroradiology. 2011; 32(1): 34-40.
13. Çinar C, Bozkaya H, Oran İ. Endovascular treatment of cranial aneurysms with the pipeline flow - diverting stent: preliminary mid - term results. Diagnostic and interventional radiology. 2013; 19(2): 154.
14. Kan P, Wakhloo AK, Mokin M, Puri A. Techniques in distal access of wide - necked giant intracranial aneurysms during treatment with flow diversion. Surgical Neurology International. 2015; 6(Suppl 7): S284.
15. Kallmes DF, Ding YH, Dai D, Kadirvel R, Lewis DA, Cloft HJ. A new endoluminal, flow-disrupting device for treatment of saccular aneurysms. Stroke. 2007; 38(8): 2346-2352.
16. Murthy SB, Shah S, Shastri A, Rao CPV, Bershad EM, Suarez JI. The SILK flow diverter in the treatment of intracranial aneurysms. Journal of Clinical Neuroscience. 2014; 21(2): 203-206.
17. Murthy SB, Shah S, Rao CPV, Bershad EM, Suarez JI. Treatment of unruptured intracranial aneurysms with the pipeline embolization device. Journal of Clinical Neuroscience. 2014; 21(1): 6-11.