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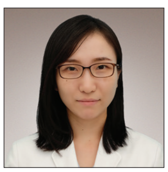
Case Report

Delayed rupture of a large intracranial internal carotid artery aneurysm after flow diverter placement

Marina Hirato, Tomoyuki Tsumoto, Yuta Kobayashi, Ryo Aiura, Eisuke Hirose, Arisa Umesaki, Sadayoshi Nakayama

Department of Neurosurgery, Fujigaoka Hospital of Showa University, Yokohama, Japan.

E-mail: *Marina Hirato - marihira@med.showa-u.ac.jp; Tomoyuki Tsumoto - tsumoto1029@gmail.com; Yuta Kobayashi - 11112041m@gmail.com; Ryo Aiura - ryo.aiura@med.showa-u.ac.jp; Eisuke Hirose - heisuke0327@gmail.com; Arisa Umesaki - aumesaki79@gmail.com; Sadayoshi Nakayama - sadanakayama@hotmail.co.jp



***Corresponding author:**
Marina Hirato,
Department of Neurosurgery,
Fujigaoka Hospital of Showa University, Yokohama, Japan.

marihira@med.showa-u.ac.jp

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ABSTRACT

Background: Delayed rupture after flow diverter (FD) placement is a serious complication, and often it leads to death; however, the exact mechanism leading to the rupture remains unclear. Therefore, in this case, study, we report a case of delayed rupture after FD placement and discuss its causes.

Case Description: This study presents the case of a 69-year-old female with multiple aneurysms who underwent FD placement with coil embolization for a large intracranial internal carotid artery aneurysm. Postoperatively, the patient had no significant symptoms, and angiography and magnetic resonance imaging revealed decreased intra-aneurysmal blood flow. However, on the 3rd postoperative day, she developed a sudden disturbance of consciousness. Computed tomography revealed a massive subarachnoid hemorrhage, diagnosed as a delayed rupture. We decided to withhold therapy due to her serious condition. Previous studies have suggested that hemodynamic mechanisms can cause delayed aneurysm rupture. Based on the computational fluid dynamics (CFD) of the aneurysm, we suggest that an increase in intra-aneurysmal pressure after FD placement may have caused the delayed rupture.

Conclusion: Preoperative CFD analysis may help evaluate the risk of delayed rupture for large aneurysms with a high inflow from the parent vessel.

Keywords: Computational fluid dynamics, Delayed rupture, Flow diverter, Internal carotid artery, Large internal aneurysm

INTRODUCTION

Large intracranial aneurysms, especially those >10 mm in size, have a high rate of spontaneous rupture. Interventions are needed for the management of such aneurysms; however, they are difficult to treat radically using conventional clipping or coil embolization. A flow diverter (FD) has been proposed as a treatment method for large aneurysms. It reduces blood flow to an aneurysm by placing a stent in the parent vessel to promote thrombosis. In Japan, FD received pharmaceutical approval in 2015. At present, multiple manufacturers have started providing FDs, increasing the number of cases with FD placement. Aneurysm rupture after FD placement, known as "delayed aneurysm rupture," is one of the most serious complications associated with FDs.[9] The previous studies have reported rupture incidence varying from 0% to 6.9% across different reports due to the lack of large-scale studies [1,4,12-14].

However, the clinical outcome of intracranial delayed aneurysm rupture has been reported to be poor in all these studies. Despite various studies, the mechanism of delayed aneurysm rupture remains unclear. Therefore, we report a case of delayed rupture after FD placement with coil embolization of a large internal carotid artery (ICA) aneurysm.

CASE PRESENTATION

A 69-year-old female was incidentally diagnosed with aneurysms of the right ICA and left anterior cerebral artery. She visited our hospital as the ICA aneurysm increased in size during follow-up. The ICA aneurysm measured 20 mm × 14 mm with a neck of 13 mm in the right C1 segment on digital subtraction angiography (DSA) [Figure 1]. The patient underwent FD implantation. Antiplatelet therapy (prasugrel 3.75 mg and aspirin 100 mg) was initiated 13 days before surgery. A platelet aggregation test (VerifyNow System) performed three days before surgery revealed aspirin reaction units of 373 and P2Y12 reaction units of 69 (inhibition 72%, base 244).

For the FD placement, a Phenom 27 catheter (Medtronic, Minneapolis, MN, USA) and 5Fr SOFIASELECT (Terumo, Tokyo, Japan) were guided into the M1 segment of the right middle cerebral artery (MCA) and ICA using ASAHI CHIKAI 14 microguidewire (Asahi Intec) with the support of a 6Fr shuttle sheath (Cook Medical, Bloomington, IN, USA) inserted from the right femoral artery. Next, an Excelsior SL-10 pre-shaped J microcatheter (Stryker, Kalamazoo, MI, USA). A 3.2Fr Guidepost (Tokai Medical Products, Aichi, Japan) was placed into the aneurysm with ASAHI CHIKAI14 microguidewire with the support of a 4Fr ASAHI FUBUKI Dilator Kit (Asahi Intec, Aichi, Japan) inserted from the left femoral artery. The PIPELINE FLEX SHIELD (Medtronic) 5.0 mm/30 mm was selected and expanded from the proximal portion of the MCA through the Phenom 27 catheter. Next, coil embolization was performed from the jailed SL-10 using i-EDCOIL Infini (Kaneka Medix, Osaka) 20 mm/50 cm for the first and second coils and target detachable coil XL 360 soft (Stryker) 12 mm/45 cm for the third coil. Coil embolization was completed after confirming that the inflow of the contrast medium into the aneurysm was sluggish. Since the proximal portion of the stent was poorly adhered to the parent vessel, the SHOURYU HR 7.0 mm-7.0 mm (Kaneka Medix, Osaka) balloon catheter was advanced and expanded at the proximal end of the stent. There was shortening of the proximal side of FD after percutaneous transcatheter angioplasty, although the aneurysm was well covered. After the procedure, we confirmed the absence of intracranial hemorrhage using cone-beam computed tomography (CT) [Figure 2].

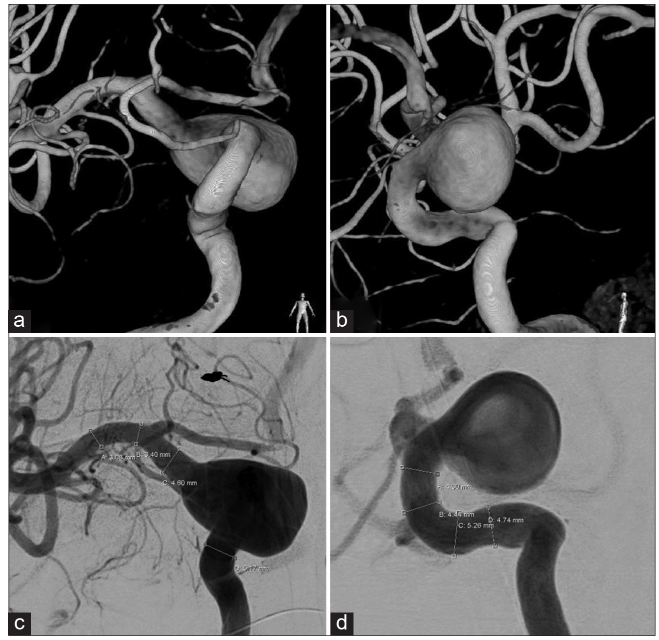


Figure 1: Preoperative DSA result (a and b) 3-dimensional (working angle) (c and d) 2-dimensional. Right ICA aneurysm, dome 20 mm × 14 mm, neck 13 mm. DSA: Digital subtraction angiography, ICA: Internal carotid artery.

No abnormal findings were observed on physical examination, and no new infarcts were detected by magnetic resonance imaging (MRI) on the 1st postoperative day. Moreover, the signal inside the aneurysm decreased on MRI. Antiplatelet medication was continued postoperatively. However, on the 3rd postoperative day, the patient was found in the hospital ward with an E1V1M1 consciousness level on the Glasgow Coma Scale. Resuscitation was initiated for cardiopulmonary arrest, and after her heartbeat resumed, CT revealed a subarachnoid hemorrhage. Based on the thick hematoma detected around the brainstem, the bleeding could have been caused by the aneurysm treated in this case. Therefore, delayed aneurysm rupture after FD placement was considered the cause of the hemorrhage [Figure 3]. No shape changes, including FD shortening, were detected using CT at that time. The patient's bilateral pupils were already dilated, and her circulatory system was unstable; therefore, surgical intervention was not considered feasible, and we decided to treat her conservatively. The patient died on postoperative day 11.

DISCUSSION

As per previous reports, the risk factors for delayed rupture include giant aneurysms, symptomatic aneurysms, saccular aneurysms with an aspect ratio of ≥1.6, aberrant FD placement in aneurysms, and mechanical damage to FDs.[3,6,10,11] A systematic review[8] published in 2020 described the characteristics of delayed rupture cases after

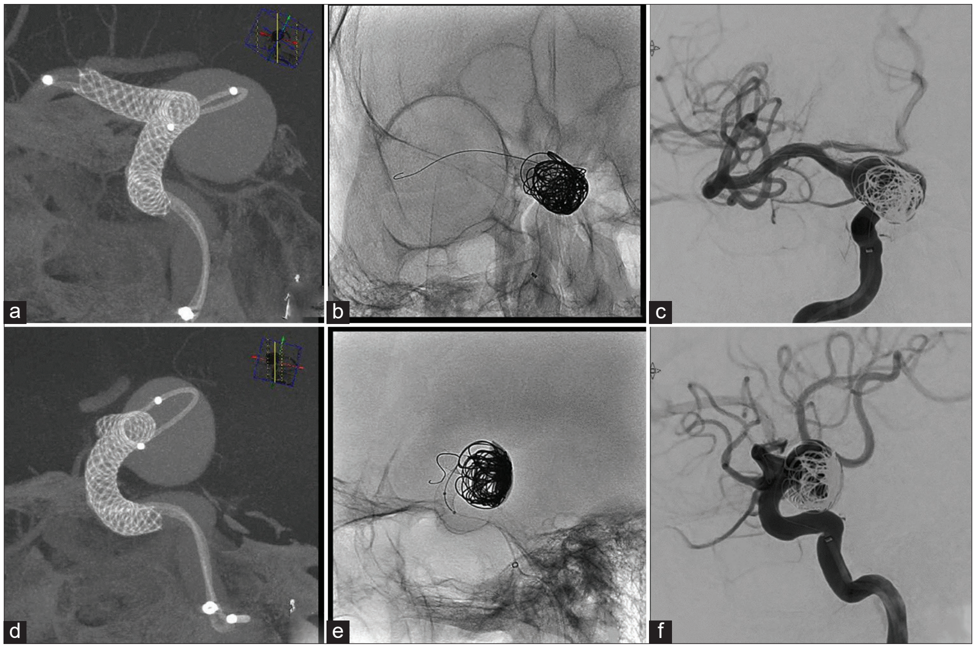


Figure 2: Operative image (a and d) VasoCT. (b and e) after the coil embolization (There was a shortening of the proximal side of FD after PTA). (c and f) Postoperative DSA result (working angle). FD: Flow diverter, CT: Computed tomography, PTA: Percutaneous transcatheter angioplasty, DSA: Digital subtraction angiography.

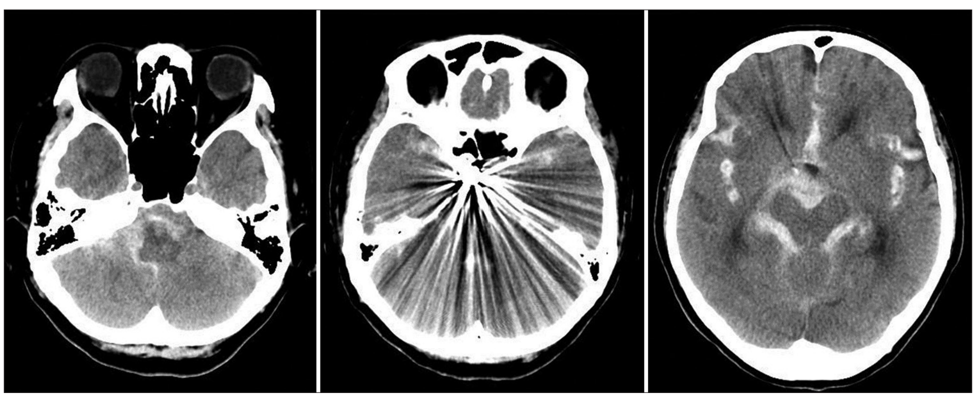


Figure 3: Computed tomography images of the sudden disturbance.

FD placement. This review included cases with multiple FDs and/or additional coil embolization. However, no significant differences were observed concerning delayed rupture compared to the single FD cases. The most ruptured aneurysms were saccular (71.3%), followed by dissecting and spindle-shaped aneurysms (21.7%). The rupture timing ranged from 2 days to 1 month postoperation (68.3%). However, a few cases were in the acute and chronic phases. Most aneurysms were >10 mm in diameter (88.3%).

The cause of rupture in this case remains unclear; however, two major hypotheses have been proposed in the previous studies, including an increase in intra-aneurysmal pressure and inflammation induced during thrombus formation.

A study with computational hemodynamics analysis[2,4] revealed an increase in aneurysmal pressure in cases with aneurysm rupture by investigating aneurysmal computational fluid dynamics (CFDs) analysis before and after surgery in cases with and without aneurysm rupture after FD treatment. There can be two possible causes for the increase in the internal pressure in that study. First, in aneurysms with stenosis of the proximal parent artery, FD would change the parent artery configuration, improving the blood flow and resulting in an increase in the aneurysmal internal pressure. Second, an increase in peripheral arterial resistance due to FD placement triggers autoregulation, increasing systolic pressure in the body's circulation, thereby increasing aneurysm pressure. This study used a ruptured aneurysm model to calculate the vascular resistance, blood pressure, and blood flow in the proximal and distal portions of the aneurysm.

Consequently, FD increased the resistance of the aneurysm and decreased blood flow toward the aneurysm. Aneurysms with a wide neck shape allow more blood flow from the parent vessel to the aneurysm, provide higher resistance, and are more likely to induce autoregulation. Another possible cause based on past histological analyses is autolysis of the aneurysmal wall due to inflammation induced by thrombus formation in the aneurysm. In many previous case reports,[10] pathology revealed wall cell necrosis with the loss of fibroblasts and infiltration of acute inflammatory cells near the rupture point. Comparing these two theories, the rupture of aneurysms caused by elevated internal pressure is often reported in the early postoperative period (approximately one week), while inflammatory cell infiltration occurs from 1 week to 1 month after surgery.

In this case, the aneurysm had no proximal stenosis; however, the neck was wide and originated at the bend of the parent vessel, suggesting that most of the parent vessel's blood flow entered the aneurysm. We conducted CFD analysis on this patient's preoperative aneurysm model. A computational unstructured grid was generated using ANSYS ICEM CFD 2020R1 (ANSYS, Canonsburg, Pennsylvania, USA) based on the geometry data from digital imaging and communication in medicine data acquired from DSA data before the FD deployment. The blood flow was analyzed using ANSYS CFX 2020R1 (ANSYS, Inc.). The inlet boundary condition was 0.003465 kg/s, which is the diastolic value in healthy adults.[5] At the outlet, the static pressure was fixed to 0 Pa. The preoperative CFD analysis [Figure 4] revealed that the blood flow collided with the aneurysm wall on the inflow side and flowed along the wall, forming a large vortex-like flow within the aneurysm. These hydrodynamic characteristics fit the aneurysm shape, which was prone to autoregulation after FD implantation in a previous study.[2] Moreover, in this study, a simulation analysis revealed that autoregulation increased systolic blood pressure from 120 mmHg preoperatively to 145 mmHg after FD implantation, and an increase of intra-aneurysmal pressure changed from 2 mmHg preoperatively to 25 mmHg after FD implantation. This suggests that a small change in systolic blood pressure has a large impact on intra-aneurysmal pressure during autoregulation. The perioperative blood pressure in this case [Table 1] increased to 146 mmHg on the morning of the 3rd postoperative day and remained unchanged until immediately before the sudden change. This suggests that the mechanism of delayed rupture, in this case, may have involved an increase in the intra-aneurysmal pressure due to autoregulation after FD implantation.

In the present case, no change in the position of the FD and coils was observed on imaging, although it is impossible to confirm this as an autopsy was not performed. Although previous studies have reported that delayed rupture can be prevented by coil assistance or in conjunction with multiple FDs,[15] delayed rupture occurred in our case

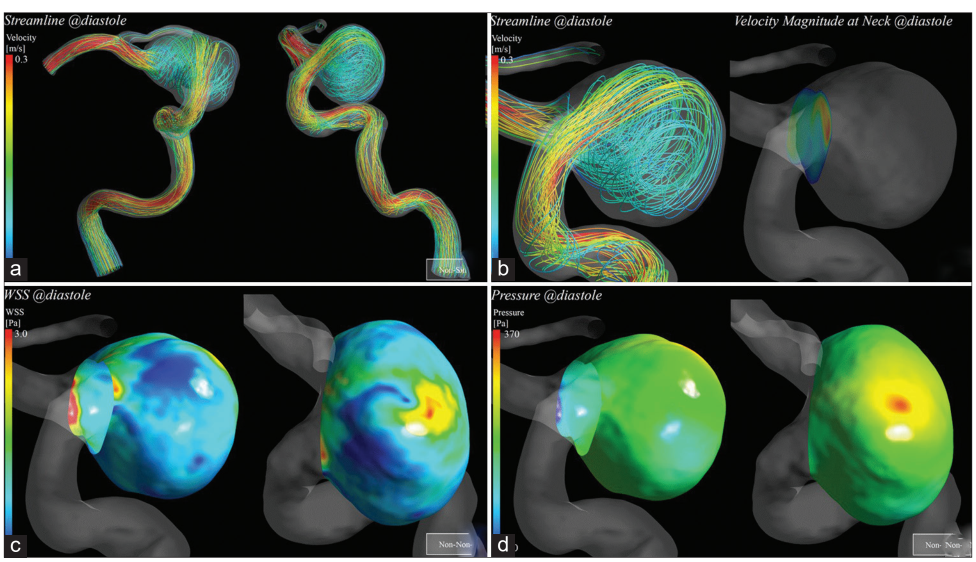
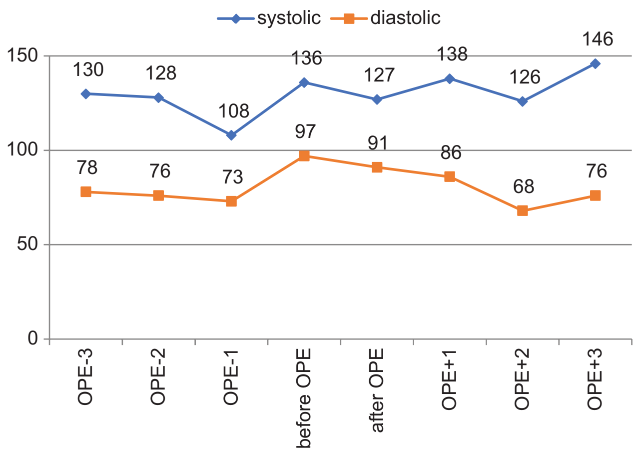


Figure 4: Results of CFD analysis (a and b) Streamline, (c) WSS, and (d) Pressure. CFD: Computational fluid dynamics, WSS: Wall shear stress.

Table 1: Perioperative variation of blood pressure.



despite concurrent coil embolization. Furthermore, 13% of ruptures occurred with coils, and 38% of ruptures occurred with multiple stents in a systematic review.[8] In our case, coil embolization was intended to assist thrombosis by FD to prevent completely blocked blood flow in the mass due to the extremely large size of the mass. Therefore, we used only three coils, but this reduced the coil filling on the inflow side. Thus, the coil filling ratio and coil distribution in the previous rupture cases after FD coil placement should be investigated in the future.

Steroids have been reported to be effective in preventing inflammatory cell infiltration.[7] In our hospital, all patients with large aneurysms are treated with steroids in the perioperative period unless there are contraindications or precautions. This case was no exception, and 6.6 mg dexamethasone was administered perioperatively. Although its preventive effect has not yet been understood; however, the occurrence of the rupture in the early postoperative period suggests increased aneurysmal pressure rather than inflammatory cell infiltration as the mechanism of rupture. Moreover, because no pathological analysis was performed, assessing the advantages and disadvantages of steroid administration was difficult.

CONCLUSION

We encountered a case of delayed rupture of FD placement. Although the cause of rupture is unknown, previous studies have suggested the involvement of hydrodynamic and histological factors. In this case, we believe that hydrodynamic factors may have been involved in the delayed rupture based on CFD analysis. Preoperative CFD analysis may help evaluate the risk of delayed rupture for large aneurysms with a high inflow from the parent vessel, such as the aneurysm in this case.

Ethical approval

The author(s) declare that they have taken the ethical approval from IRB CR2023024-A, September 25th, 2023.

Declaration of patient consent

Patient's consent not required as patient's identity is not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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