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Case Report

Acute Distal Migration and Shortening of the Flow-Redirection Endoluminal Device: A Case Report

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Objective: The flow diverter (FD) is a promising device. Apart from two main complications, hemorrhagic and ischemic ones, stent migration is reportedly an unusual complication. In particular, distal migration of the FD has rarely been reported. We report a case of asymptomatic acute distal migration of the flow-redirection endoluminal device (FRED).
Case Presentation: A 50-year-old woman was incidentally diagnosed with an unruptured right internal carotid–ophthalmic artery aneurysm with a maximum diameter of 8.0 mm, and she subsequently underwent endovascular treatment with FRED. Based on the vessel diameter (3.8 mm proximal and 3.6 mm distal to the aneurysm), a 4.0-mm-diameter and 18-mm-long FRED was deployed without postoperative complications. However, on MRA 12 months after treatment, the aneurysm was not occluded; angiography showed distal migration of the FRED. The postoperative MRA and skull X-ray images were retrospectively reviewed to determine the period of the migration. The skull X-ray images and the signal loss area due to the FRED on MRA 1 day after the treatment had already demonstrated the migration of the FRED. In the second treatment, a 4.0-mm-diameter and 23-mm-long FRED was deployed in an overlapping fashion up to the proximal part of the carotid siphon. Prompt identification of distal migration of the FD without neurologic signs could be challenging.
Conclusion: It is important to follow up meticulously with MRA and skull X-ray images after FD treatment for detecting stent migrations as early as possible.

Keywords ▶ low-redirection endoluminal device, distal migration, case report

Introduction

Endoluminal vessel reconstruction with a flow diverter (FD) is a promising therapeutic device in the neuroendovascular field. They can be particularly advantageous for treating complex intracranial aneurysms, which are considered unsuitable for conventional coiling or lesions with high surgical risk or high risk of recurrence.[1)] The FD is a specific stent that decreases the velocity and pressure of intra-aneurysmal blood flow, and promotes delayed thrombosis with the reconstruction of the parent artery. It also provides a scaffold for long-term endothelialization across an aneurysm neck by diverting the blood flow away from the aneurysmal sac, resulting in clotting within the aneurysm.[2)] Several types of FDs have been used: the flow-redirection endoluminal device (FRED; MicroVention, Aliso Viejo, CA, USA), pipeline embolization device (PED; Covidien/ev3, Irvine, CA, USA), SILK (Balt Extrusion, Montmorency, France), p64MW HPC and p48MW HPC (Phenox, Bochum, Germany), and Surpass Streamline (Stryker, Neurovascular, Fremont, CA, USA). Many papers have demonstrated the effectiveness of the FDs.[3–9)] In a systematic review of the FDs, Briganti et al. reported that the rate of aneurysm occlusion progressively increased up to 81.5% over a mean follow-up period of 9-months. They also reported the neurologic morbidity within allowance (3.5%), rate of hemorrhagic complication (2.9%), and rate of non-negligible thromboembolic complications (4.1%).[9)] Apart from the two aforementioned main complications, FD stent migrations are reportedly unusual complications; compared with proximal migration,[10–13)] distal migration of

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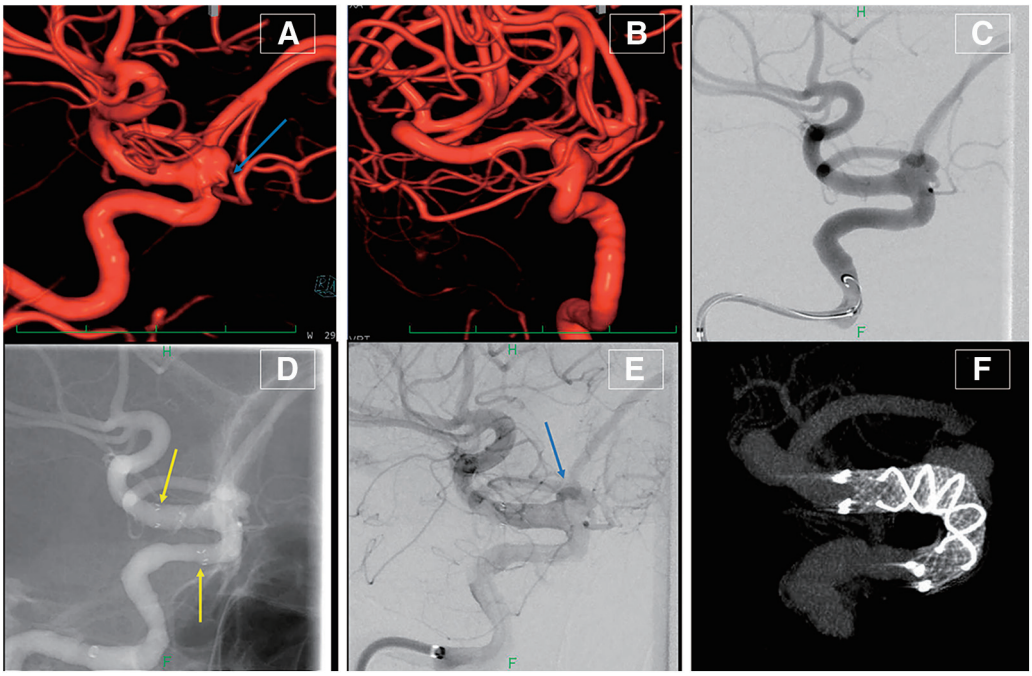

Fig. 1 A 50-year-old woman with an unruptured internal carotid–ophthalmic artery aneurysm. The maximum size and neck size of the aneurysm was 8.0 mm and 4.9 mm, respectively. The ophthalmic artery (blue arrow in **A**) branched from the dome of the aneurysm. (**A** and **B**) Initial 3D reconstruction of DSA and (**C**) DSA in the working angle. Based on the diameter of the ICA proximal (3.8 mm) and distal (3.6 mm) to the aneurysm, a 4.0-mm-diameter and 18-mm-long FRED was deployed across the neck of the aneurysm. The yellow arrows indicate the distal and proximal flared ends of the FRED, respectively (**D**). Post-deployment angiography revealed a little intra-aneurysm contrast stagnation (blue arrow) after the treatment. (**E**). Except for the proximal part (proximal flair) of the FRED, complete expansion of the FRED was confirmed using cone-beam CTA (**F**). FRED: flow-redirection endoluminal device; ICA: internal carotid artery

the FD has been rarely reported.[11,13–18] The possible cause of the FD stent migration, appropriate ways to identify the complications early with the exception of angiography, and its precautionary measures have not been studied sufficiently. We have previously reported a rare case of acute distal migration of the FRED, which is a representative of the FD, secondary to in-stent thrombi with symptomatic ischemic stroke.[19] In this study, we report a case of distal migration of the FRED without neurologic signs or symptoms and with an onset within 24 hours after treatment. The present case demonstrates the importance of follow-up with MRA and skull X-rays images following FD treatment.

Case Presentation

A 50-year-old woman was incidentally diagnosed with a right unruptured internal carotid–ophthalmic artery aneurysm with a maximum size of 8.0 mm and a neck size of 4.9 mm. The ophthalmic artery branched from the dome of the aneurysm (**Fig. 1A** and **1B**). Endovascular treatment with FRED was scheduled. Two weeks before the procedure, she received 100 mg aspirin and 75 mg clopidogrel daily. The day before the procedure, using the VerifyNow point-of-care platelet assay (Accumetrics, San Diego, CA, USA), the aspirin reaction unit and P2Y12 reaction unit were measured at 436 and 126, respectively. Both values were within adequate platelet inhibition, and no preoperative enhanced antiplatelet therapy was needed.[20] Measurement of the VerifyNow was approved by Dokkyo Medical University Saitama Medical Center Institutional Review Board (approval no. 1232), and the patient consented to this procedure.

Under general anesthesia, a 7-French shuttle sheath (Cook Medical, Bloomington, IN, USA) was placed with a coaxial system at the cervical portion of the left internal carotid artery (ICA) via the right femoral site. A Headway27 microcatheter (MicroVention) was navigated using a microguidewire (ASAHI CHIKAI 14; Asahi Intecc, Aichi, Japan) (**Fig. 1C**). The 5-French SOFIA SELECT EX (MicroVention) was also used as a distal access catheter. The size of the FRED was determined according to the diameter of the ICA proximal (3.8 mm) and distal (3.6 mm) to the aneurysm. A 4.0-mm-diameter and 18-mm-long FRED was adequately deployed through the microcatheter across the neck of the aneurysm under appropriate therapeutic

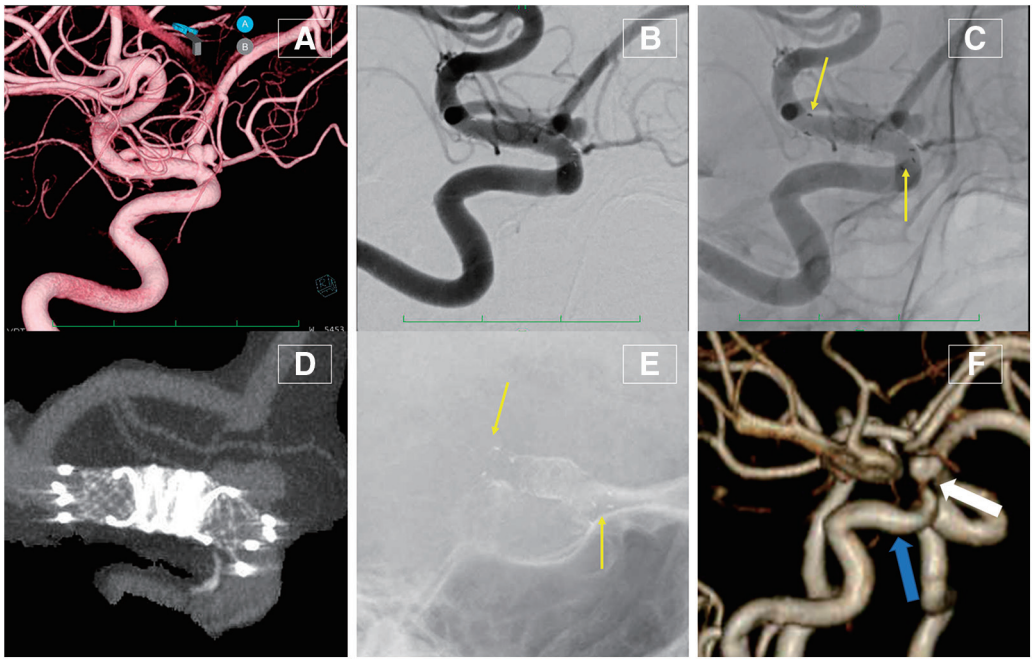

Fig. 2 Angiogram obtained 12 months after the treatment demonstrated a complete aneurysm. (**A**) 3D reconstruction of DSA and (**B**) DSA. Distal migration and shortening of the FRED stent were revealed, resulting in incomplete coverage of the aneurysm neck. The yellow arrows indicate the distal and proximal flared ends of the FRED, respectively. (**C**) Digital angiogram and (**D**) 3D reconstruction of cone-beam CTA. Lateral skull X-ray taken 1 day after the treatment demonstrated that the migration of the stent had already occurred. The yellow arrows indicate the distal and proximal flared ends of the FRED, respectively (**E**). Signal loss due to the stent artifact in MRA 1 day after the treatment did not span the portion where it was originally deployed (blue arrow) but began at the proximal neck of the aneurysm (white arrow), indicating that the migration of the stent had already occurred (**F**). FRED: flow-redirection endoluminal device

heparinization (**Fig. 1D**). Post-deployment angiography revealed little intra-aneurysm contrast stagnation following FRED deployment (**Fig. 1E**). Except for the proximal part (proximal flair) of the FRED, complete expansion was confirmed using cone-beam CTA. Percutaneous transluminal angioplasty (PTA) was not performed because PTA towards the proximal part of the FRED could result in shortening of the stent leading to unstable positioning of the stent (**Fig. 1F**). The patient awoke without any neurologic symptoms.

No postoperative complication developed, and gradual thrombotic change within the aneurysm by the FRED was expected. However, MRA performed 12 months after the treatment showed neither occlusion nor contraction of the aneurysm. Angiography revealed that the aneurysm was not occluded (**Fig. 2A** and **2B**). Distal migration and shortening of the FRED were confirmed, resulting in incomplete coverage of the aneurysm neck (**Fig. 2C** and **2D**). Postoperative head MRA and skull X-ray images were retrospectively reviewed to determine the period of migration and shortening of the FRED stent. Skull X-rays 1 day after the treatment already demonstrated the migration of the FRED, although we did not recognize this complication (**Fig. 2E**). The MRA 1 day after the treatment also demonstrated the phenomenon: the signal loss area attributed to the stent artifact in MRA began from the proximal neck of the aneurysm, which revealed that the proximal edge of the FRED had already migrated from the original portion (**Fig. 2F**). The patient underwent a second treatment using FRED. A 4.0-mm-diameter and 23-mm-long FRED was deployed in an overlapping fashion up to the proximal part of the carotid siphon using the same device systems as the first treatment (**Fig. 3A**–**3C**). Complete expansion of the FRED was again confirmed using cone-beam CTA (**Fig. 3D**). Skull X-ray images taken 1 day after the treatment did not show any obvious migration or shortening of the FRED stents (**Fig. 3E**). MRA 1 day after the treatment also demonstrated signal loss spanning the proximal part of the carotid siphon, indicating no obvious migration of the stents (**Fig. 3F**).

The patient has consented to the submission of this case report to the journal.

Discussion

This case report demonstrates a rare complication of FD: distal migration and shortening of the FD stent. Neurosurgeons should recognize the possibility of this complication, even

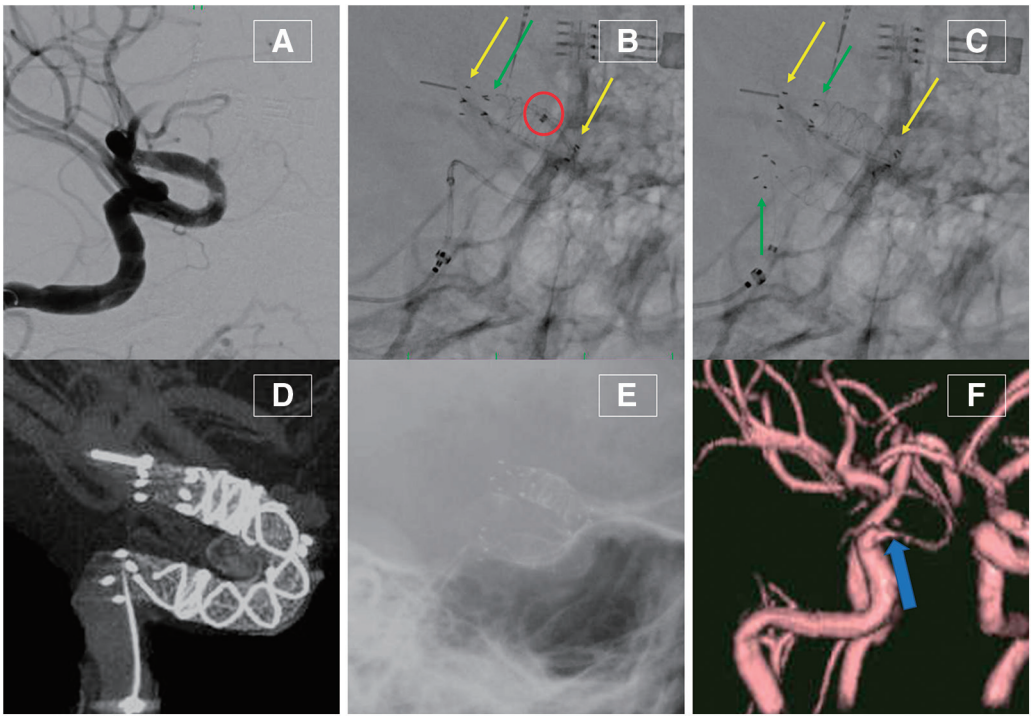

Fig. 3 Second treatment using FRED. Angiogram in the working angle image before the second treatment (**A**). A 4.0-mm-diameter and 23-mm-long FRED was deployed in an overlapping fashion from the part (green arrow) just proximal to the distal edge of the first FRED stent. The yellow arrows show the distal and proximal flared ends of the first FRED, respectively. The red circle shows the tip of the microcatheter for the second FRED deployment (**B**). Lastly, the second FRED was deployed up to the proximal part of the carotid siphon. The yellow arrows show the distal and proximal flared ends of the first FRED, respectively. The green arrows show the distal and proximal flared ends of the second FRED, respectively (**C**). Full expansion of the FRED stents was confirmed using cone-beam CTA (**D**). Skull X-ray images 1 day after the treatment did not show any obvious migration or shortening of the FRED stents (**E**). The MRA 1 day after the treatment also demonstrated signal loss spanning the proximal part of the carotid siphon (blue arrow), indicating no obvious migration of the stents (**F**). FRED: flow-redirection endoluminal device

if the patient presents with no obvious postoperative neurologic symptoms.

Several possible mechanisms and factors are associated with FD migration. First, stretching of the device during deployment could lead to spontaneous foreshortening.[15,21] Second, significant diameter discrepancy (>1 mm) between the distal and proximal parent vessels could be attributed to FD migration.[10,18] In that case, the smaller vessel end of the stent cannot be completely opened to enhance the apposition of the stent, leading to a constant squeezing force at the end of the stent.[11] Third, large neck or fusiform-type aneurysms could decrease the surface area of the stent landing zone and increase the risk of stent migration.[13] Fourth, poor wall apposition of the FD stents could also reduce the surface area of the stent landing zone.[18] Fifth, in-stent microthrombus formation could affect the stable position of the stent and ultimately cause distal migration.[13–15] In the present case, the aneurysm was not large and no significant discrepancy existed between the distal and proximal parts of the parent artery. Obvious concurrent thromboembolic stroke indicative of in-stent microthrombus formation was not confirmed. In addition to the large anatomical curve of the carotid siphon, there are two possibilities, one being insufficient wall apposition of the proximal part of the FRED. PTA for the proximal part of the FRED could have been considered in response to this problem. However, eventually, PTA was not performed owing to fear of shortening of the FRED, which could result in incomplete aneurysm neck coverage or unstable positioning of the stent. The other possible reason could be the stretching of the device during deployment, that is, proximal stretching of the device during implantation with distal device fixation. To solve this problem, especially for aneurysms located at the ICA paraclinoid or ophthalmic segment, longer FDs and avoiding excessive stretching of the device may be preferred; hence, they are deployed up to the proximal part of the carotid siphon.[10,11] In addition, appropriate sizing of the stent is also important because the undersized FD stents could possess a radial force toward the target vessel wall falls below the force of

Table 1 Cases of distal migration of FD in anterior circulation in the literature including the present case

Study	Age (year)/ sex	Location	Maximum size (mm)	Parent artery diameter (D/P) (mm)	Type of FD	FD size (mm)	When confirmed (after treatment)	Thromboembolic stroke
Present case report	50/F	ICA ophthalmic	8.0	3.8/3.6	FRED	4.0 × 18	Within 24 hours	No
Cohen et al.[14]	11/F	ICA ophthalmic	Not reported	Not reported	SILK	Not reported	1.5 months	No
Tsai et al.[13]	74/F	ICA cavernous	19.0	4.6/3.6	PED	4.75 × 20	3 months	No
Gawlitza et al.[16]	76/F	ICA cavernous	38.0	Not reported	p64MW (D), FRED (P)	5.0 × 24, 5.0 × 26	6 days	No
Petrov et al.[18]	Not reported	ICA ophthalmic	Not reported	Not reported	p64MW	Not reported	Not reported	No
Petrov et al.[18]	Not reported	ICA paraclinoid	Not reported	Not reported	p64MW	Not reported	115 days	No
Petrov et al.[18]	Not reported	ICA paraclinoid	Not reported	Not reported	p64MW	Not reported	Not reported	No
Nariai et al.[19]	35/F	ICA ophthalmic	6.1	3.3/3.2	FRED	3.5 × 17	1 hour	Yes
Chalouhi et al.[10]	50/M	MCA	12.7	3.2/2.5	PED	3.0 × 16	5 months	Yes
Dornbos et al.[15]	24/F	ICA paraclinoid	5.0	Not reported	PED	3.5 × 12	Immediately after waking up from general anesthesia	Yes
Tsai et al.[13]	42/F	ICA-Pcom	13	3.0/2.6	PED	3.0 × 18	3 months	Yes

BA-SCA: basilar artery-superior cerebellar artery; D: distal; F: female; FD: flow diverter; FRED: flow-redirection endoluminal device; ICA: internal carotid artery; M: male; MCA: middle cerebral artery; P: proximal; Pcom: posterior communicating artery; PED: pipeline embolization device

its shortening or migration.[18] In the present case, the parent vessel diameters proximal and distal to the aneurysm were 3.8 mm and 3.6 mm, respectively. Appropriate device diameter sizing of the FDs is reportedly 0.25–0.5 mm larger than the larger parent vessel.[11,13] Thus, instead of a 4.0-mm-diameter FRED, a 4.5-mm-diameter FRED should have been considered in the present case.

Studies have described cases of FD migration detected as early as immediately after treatment to as late as 14 months after the procedure.[11,13,15,16,19,21] Proximal migration of the FD during the treatment or shortly after the treatment is a frequent intraoperative complication and rarely results in neurologic symptoms.[10] Compared with proximal migration, distal migration of an FD is rare.[14,22] Besides our case, 11 cases of distal FD migration have been identified in the literature (**Table 1**).[11,13–19]

To date, the types of FDs with the reported complication of distal migration are PED,[11,13,15,17] SILK,[14] p64 HPC,[18] and FRED.[16,19] Limited to distal migration of the FD, causes may be classified as in-stent microthrombus formation (the presence of thromboembolic stroke) or others. Among the four distal migration cases with thromboembolic stroke, all presented with symptomatic neurologic deficits.[11,13,15,19] Thus, in cases of distal migration owing to in-stent microthrombus formation, the clinical appearance of the neurologic symptoms could enable early detection of stent migration. Conversely, in cases of distal migration owing to causes other than in-stent microthrombus formation, MRA or skull X-ray images should be reviewed to detect this complication, as in our present case owing to the absence of neurologic signs. In general, the signal loss in MRA is reportedly caused by magnetic susceptibility and radiofrequency shielding effect.[23] De Cobelli et al. reported that the length of the signal loss in MRA corresponded to the length of the stents in their assessment of patients with coronary stenosis and control after stent positioning.[24] Thus, the signal loss by the FD stent artifact can be useful for detecting the position of the stent. In addition, the time when the distal migrations were detected was reportedly 6 to 115 days after the treatment.[13,14,16–18] For this patient, the complication was demonstrated on MRA and skull X-ray imaging within 24 h after the treatment, although we did not recognize it then. This case shows that the distal migration of the FD caused by factors other than in-stent microthrombus formation can also occur extremely early after the treatment and determining the onset could be challenging due to the absence of neurologic deficits.

Conclusion

Prompt identification of distal migration of FD without neurologic deficits could be challenging. Signal loss due to FD stent artifact on postoperative MRA and the position of the FD stent on skull X-ray images should be meticulously checked to detect migration because this phenomenon can arise early in the posttreatment period without symptoms. Further prospective studies are needed to clarify the causes of distal migration of the FD and possible solutions.

Disclosure Statement

The authors declare that they have no conflicts of interest.

References

1) Brinjikji W, Murad MH, Lanzino G, et al. Endovascular treatment of intracranial aneurysms with flow diverters: a meta-analysis. *Stroke* 2013; 44: 442–447.
2) Leung GK, Tsang AC, Lui WM. Pipeline embolization device for intracranial aneurysm: a systematic review. *Clin Neuroradiol* 2012; 22: 295–303.
3) Waqas M, Dossani RH, Alkhaldi M, et al. Flow redirection endoluminal device (FRED) for treatment of intracranial aneurysms: a systematic review. *Interv Neuroradiol* 2022; 28: 347–357.
4) Issa R, Al-Homedi Z, Syed DH, et al. Surpass evolve flow diverter for the treatment of intracranial aneurysm: a systematic review. *Brain Sci* 2022; 12: 810.
5) Pierot L, Soize S, Cappucci M, et al. Surface-modified flow diverter p48-MW-HPC: preliminary clinical experience in 28 patients treated in two centers. *J Neuroradiol* 2021; 48: 195–199.
6) Manzato LB, Santos RB, Filho PMM, et al. Brazilian FRED registry: a prospective multicenter study for brain aneurysm treatment-the BRED study. *AJNR Am J Neuroradiol* 2021; 42: 1822–1826.
7) Florez WA, Garcia-Ballestas E, Quiñones-Ossa GA, et al. Silk® flow diverter device for intracranial aneurysm treatment: a systematic review and meta-analysis. *Neurointervention* 2021; 16: 222–231.
8) Aguilar Pérez M, Henkes E, Hellstern V, et al. Endovascular treatment of anterior circulation aneurysms with the p64 flow modulation device: mid- and long-term results in 617 aneurysms from a single center. *Oper Neurosurg (Hagerstown)* 2021; 20: 355–363.
9) Briganti F, Leone G, Marseglia M, et al. Endovascular treatment of cerebral aneurysms using flow-diverter devices: a systematic review. *Neuroradiol J* 2015; 28: 365–375.

10) Chalouhi N, Satti SR, Tjoumakaris S, et al. Delayed migration of a pipeline embolization device. *Neurosurgery* 2013; 72(Suppl Operative): ons229–ons234; discussion, ons234.
11) Chalouhi N, Tjoumakaris SI, Gonzalez LF, et al. Spontaneous delayed migration/shortening of the pipeline embolization device: report of 5 cases. *AJNR Am J Neuroradiol* 2013; 34: 2326–2330.
12) Takong W, Kobkitsuksakul C. Delayed proximal flow diverting stent migration in a ruptured intracranial aneurysm: a case report. *Neurointervention* 2020; 15: 154–157.
13) Tsai YH, Wong HF, Hsu SW. Endovascular management of spontaneous delayed migration of the flow-diverter stent. *J Neuroradiol* 2020; 47: 38–45.
14) Cohen JE, Gomori JM, Moscovici S, et al. Delayed complications after flow-diverter stenting: reactive in-stent stenosis and creeping stents. *J Clin Neurosci* 2014; 21: 1116–1122.
15) Dornbos D 3rd, Powers CJ. Acute distal migration of a flow diverting stent. *J Clin Neurosci* 2017; 44: 223–225.
16) Gawlitza M, Soize S, Manceau PF, et al. Delayed intraaneurysmal migration of a flow diverter construct after treatment of a giant aneurysm of the cavernous internal carotid artery. *J Neuroradiol* 2020; 47: 233–236.
17) Navarro RN, Cano EJ, Brasiliense LBC, et al. Fatal outcome after delayed pipeline embolization device migration for the treatment of a giant superior cerebellar artery aneurysm: technical note for complication avoidance. *OJMN* 2014; 4: 163–168.
18) Petrov A, Rentsenkhuu G, Nota B, et al. Initial experience with the novel p64MW HPC flow diverter from a cohort study in unruptured anterior circulation aneurysms under dual antiplatelet medication. *Interv Neuroradiol* 2021; 27: 42–50.
19) Nariai Y, Takigawa T, Hyodo A, et al. Distal migration of the flow-redirection endoluminal device immediately after treatment: a case report and literature review. *Surg Neurol Int* 2022; 13: 81.
20) Ajadi E, Kabir S, Cook A, et al. Predictive value of platelet reactivity unit (PRU) value for thrombotic and hemorrhagic events during flow diversion procedures: a meta-analysis. *J Neurointerv Surg* 2019; 11: 1123–1128.
21) Jabbour P, Atallah E, Chalouhi N, et al. A case of pipeline migration in the cervical carotid. *J Clin Neurosci* 2019; 59: 344–346.
22) El Ouadih Y, Coll G, Jean B, et al. A rare complication of flow diverter: delayed migration causing aneurysm expansion and brainstem compression. *Br J Neurosurg* 2019 May 27. [Epub ahead of print]
23) Teitelbaum GP, Bradley WG Jr., Klein BD. MR imaging artifacts, ferromagnetism, and magnetic torque of intravascular filters, stents, and coils. *Radiology* 1988; 166: 657–664.
24) De Cobelli F, Guidetti D, Vanzulli A, et al. Magnetic resonance angiography of coronary arteries: assessment in patients with coronary stenosis and control after stent positioning. *Radiol Med (Torino)* 1998; 95: 54–61. (in Italian)