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INR INTERVENTIONAL NEURORADIOLOGY

Interventional Neuroradiology
1–9
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Flow diverter stents in the treatment of recanalized intracranial aneurysms

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Abstract

Background: We assessed the safety and efficacy of flow diverter stents (FDSs) in the treatment of recanalized or residual intracranial aneurysms treated endovascularly.

Materials & Methods: Patients whose recanalized or residual aneurysms were treated with FDSs in five tertiary hospitals were reviewed retrospectively. The patients' demographic data, aneurysm characteristics, types of previous treatment, and clinical complications, or serious adverse events associated with FDSs, as well as the results of neurological and angiographic follow-up assessments, were recorded.

Results: Eighty-six patients (37 males) with 87 aneurysms were included in this study. Eighty (91.9%) aneurysms were in the anterior and seven (8.1%) in the posterior circulation. The initial treatment methods were the primary coiling or balloon remodeling technique in 69 (79.3%) and stent-assisted coiling in 18 (20.7%) aneurysms. The endovascular procedure was successful in all patients. Complications occurred in four patients, for a total complication rate of 4.6%. A technical complication developed in one patient (1.2%). An in-stent thrombosis treated with tirofiban was seen in two cases. Late in-stent stenosis exceeding 50% was treated with balloon angioplasty in one patient. The mean length of follow-up was 21.0 months. The first angiographic follow-up (3–6 months) revealed the complete occlusion of 74 aneurysms (85.1%). While 76 aneurysms (87.4%) were occluded at the last angiographic follow-up (mean: 26.0 months), 11 aneurysms (12.6%) were still filling. Morbimortality was zero.

Conclusion: The drawback of endovascular treatment is aneurysmal remnants or recurrences, which is safely and durably amenable to flow diversion.

Keywords
Recanalization, cerebral aneurysm, residual aneurysm, endovascular treatment, flow diverter

Received 1 October 2020; revised 8 December 2020; accepted 2 January 2021

Introduction

Flow diversion is a recently described endovascular method for the treatment of intracranial aneurysms. The safety and efficacy of flow diversion treatment have been proven for the treatment of large and wide-necked carotid siphon aneurysms.[1–7] Following the promising results of the studies that reported the clinical and angiographic outcomes of flow diversion treatment, flow diversion treatment was recently found to help treat very small aneurysms; ruptured aneurysms such as blister-like examples; and even bifurcation aneurysms located distal to the Circle of Willis.[8–12]

The recurrence of the aneurysms treated with only coiling or stent-assisted coiling, or the remnant of ruptured aneurysms that have been coiled is not infrequent, and the results of retreatment with

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conventional techniques are not satisfactory. The safety and efficacy of flow diversion in the treatment of almost any kind of aneurysm make it a salvageable treatment method for aneurysms.[13] However, data in the literature about the endovascular treatment of recanalized and residual aneurysms with flow diversion are limited.[13–16] In this retrospective, single-arm, and multicenter study, we assessed the safety and efficacy of the flow diverter stents (FDSs) for the treatment of recanalized or residual intracranial aneurysms that had been treated by endovascular techniques other than flow diverters.

Materials and methods

Patient selection

After obtaining institutional ethics committee approval, we retrospectively reviewed the databases of five centers to identify all patients with a recanalized or residual intracranial aneurysm who were treated between 2008 and 2019 with implantation of FDSs. The centers provided unidentified data only for patients who underwent a flow diversion treatment for the recanalized or residual aneurysms that had been previously treated with other endovascular techniques. In general flow diversion was preferred to treat recanalized sidewall aneurysms. However, some recanalized aneurysms treated by other techniques, including previously stented aneurysms in which the wall apposition of the stent was questionable, as well as the majority of the bifurcation aneurysms treated by crossing stents and finally those bifurcation aneurysms which were deemed to be amenable to durable occlusion with further coiling (with or without stent assistance) were not treated by flow diversion and hence were not included in the analysis. Patients with recanalized aneurysms after previous endosaccular treatments who are unlikely to be compliant with dual antiplatelet therapy were also not offered treatment with FDSs. The decision to perform any endovascular treatment including flow diversion was made in cases of a continuous increase of recanalized or residual part of the aneurysms treated with coiling or stent-assisted coiling. The patients' demographics, aneurysm characteristics, treatment histories, clinical complications, or serious adverse events associated with flow diversion, and the results of neurological and angiographic follow-up assessment were recorded. Aneurysm occlusion was evaluated as "complete" or "not".

Endovascular procedure

Although there were some differences in the endovascular procedures and follow-up protocols, the basic approach used by the participating centers was similar. All procedures were treated as elective, and patients were premedicated before the interventions. Depending on the preference of each center, daily 100–300 mg of aspirin, and either 75 mg of clopidogrel or 10 mg of prasugrel, was started at least 5 days before the endovascular procedure. The response to the clopidogrel/prasugrel was verified before the procedure with a point-of-care assay. Patients with an inadequate response to clopidogrel were switched to prasugrel with a starting daily dose of 10 mg. All endovascular procedures were performed under general anesthesia using a femoral approach. Systemic anticoagulation was initiated immediately after the insertion of a femoral introducer sheath with a bolus dose of 5000 IU of IV heparin or 70–100 IU/kg heparin based on operator preference. The bolus dose was followed by a slow heparin infusion or a 1000 IU IV bolus dose per hour to maintain an activated clotting time that was approximately 2-fold greater than the baseline value. Access to the target artery (internal carotid or vertebral artery) was achieved with a neurovascular distal access catheter after a long sheath insertion. The distal tip of a 0.021–0.027-inch microcatheter was positioned at the parent artery distal to the aneurysm neck. Then, an FDS [Silk, Balt, Montmorency, France; Derivo, Acandis, Pforzheim, Germany; Surpass, Stryker Neuroendovascular, Kalamazoo, MI, USA; FRED, Microvention Terumo, Tustin, CA, USA, Pipeline Embolization Device (PED), Medtronic Covidien AG, Paris, France] was deployed to cover the neck of the aneurysm. Expansion and wall apposition of the deployed stent was assessed under fluoroscopy and cone-beam CT if needed. In cases of incomplete stent expansion, we performed in-stent balloon angioplasty to achieve a full wall apposition; in one center, stenting with a non-FDS was used to treat malapposition. Post-procedural dual antiplatelet therapy was continued for 6 months and was switched to daily aspirin thereafter.

Follow-up

At the end of the procedure, a cone-beam CT was performed to identify any procedural hemorrhagic complications before waking up the patient. The first follow-up digital subtraction angiography (DSA) was performed at 3–6 months. The second follow-up angiogram, either invasive or noninvasive, was performed at 9–12 months. Patients' neurological status was evaluated during discharge and at the angiographic follow-up using the mRS scale.

Statistical analysis

All data are presented as means and ranges for continuous variables and as frequencies for categorical variables. A Chi-square test was performed to test the significance of the differences between subgroups. The statistical analysis was performed using SPSS statistics (IBM, Armonk, New York).

Results

Eighty-six patients (37 males) with 87 aneurysms were included in this study. The mean age of the patients was 50.0 years (range, 11–78 years). Eighty (91.9%) aneurysms were in the anterior and 7 (8.1%) were in the posterior circulation. Detailed locations of the aneurysms and how they were previously treated are shown in Table 1, in addition to demographic features. The mean time between the initial treatment and FDS insertion was 21 months. The initial treatment methods were the primary coiling or balloon remodeling technique in 69 (79.3%) aneurysms and stent-assisted coiling in 18 (20.7%) aneurysms.

The endovascular procedure was successful in all patients. In four patients (4.6%), peri- and postprocedural complications were encountered. A technical complication developed in one patient (1.2%). In this patient, who had a posterior communicating artery ruptured aneurysm previously treated with only coiling, a Leo stent (Balt) was deployed telescopically inside the Silk stent to correct malapposition. The technical complications remained asymptomatic, and the mRS scores of these patients remained zero at discharge. No hemorrhagic complications were detected on CT performed immediately following the procedure. We observed a periprocedural thrombotic complication in two patients (2.3%). Intraprocedural control DSA images revealed the development of an in-stent thrombus. Intra-arterial infusion of tirofiban through the microcatheter achieved complete resolution of the thrombus in both cases. These patients did not develop any neurological symptoms, and their mRS scores were zero at discharge. We observed a delayed complication in one patient (1.2%), who had a recanalized ICA ophthalmic segment aneurysm treated with a Silk stent, 1 year later. The follow-up DSA examination of this patient revealed in-stent stenosis (>50%), which responded well to balloon angioplasty. The morbimortality was zero. Table 2 shows the procedural and follow-up data, as well as complications. At least one angiographic follow-up was performed in all patients. The mean length of follow-up was 26.0 months (range, 3–92 months). The first angiographic follow-up (3–6 months) revealed the complete occlusion of 74 aneurysms (85.1%). While 76 aneurysms

Table 1. Patient data and aneurysm characteristics.

	N (%)
Number of patients	86
Age, years	
Mean	50 (11–78)
Sex	
Male	37 (43.0))
Female	49 (57.0)
Recanalized aneurysms, total	87 (100.0)
Ruptured	65 (74.7)
Unruptured	22 (25.3)
Aneurysm initial size (mean)	3–40 mm (10.3)
Treated with coils	69 (79.3)
Treated with stent and coils	18 (20.7)
With braided	9 (50.0)
With laser-cut	9 (50.0)
Aneurysm location	
Anterior circulation	80 (91.9)
ICA cavernous	2 (2.3)
ICA ophthalmic	41 (47.1)
PComA	17 (19.5)
AChorA	4 (4.6)
ICA terminal	3 (3.4)
MCA	8 (9.2)
ACA	2 (2.3)
ACA, distal	2 (2.3)
AComA	1 (1.1)
Posterior circulation	7 (8.1)
PICA	2 (2.3)
Vertebrobasilar	1 (1.1)
Basilar trunk	2 (2.3)
Basilar tip	2 (2.3)

N: number; ICA: internal carotid artery; PComA: posterior communicating artery; AChorA: anterior choroidal artery; MCA: middle cerebral artery; ACA: anterior cerebral artery; AComA: anterior communicating artery; PICA: posterior inferior cerebellar artery.

Table 2. Procedural and follow-up data, and complications.

	N (mean or %)
FDSs, total used	87 (100.0)
Silk	60 (69.0)
Derivo	9 (10.3)
Surpass	7 (8.1)
FRED	6 (6.9)
Pipeline	5 (5.7)
Number of FD per aneurysm	1.0
Time between initial treatment and FDS (month)	2–96 (21.0)
Follow-up duration, angiographic (month)	3–92 (26.0)
Closure rate, at 3–6th month	
Complete	74 (85.1)
Incomplete	13 (14.9)
Closure rate, overall	
Complete	76 (87.4)
Aneurysm initial size	3–40 (10.0)
Incomplete	11 (12.6)
Aneurysm initial size	4–35 mm (14.7)
Closure rate in coiled aneurysms	
Complete	62 (89.9)
Incomplete	7 (10.1)
Closure rate in stented aneurysms	
Complete	14 (77.8)
Incomplete	4 (22.2)
With braided stent	1 (25.0)
With laser-cut stent	3 (75.0)
Complications, total (per patient)	4 (4.6)
Technical	1 (1.2)
Stent thrombosis	2 (2.3)
Stent stenosis	1 (1.2)
Morbidity	0
Mortality	0

N: number; FDS: flow diverter stent.

(87.4%) were occluded at the last angiographic follow-up (3–92 months, mean: 26.0), 11 aneurysms (12.6%) were still filling. The mean follow-up time of five of 11 aneurysms with the persistent filling was 16 months (range, 3–33 months). The locations of the aneurysms that still had not occluded completely were the internal carotid artery ophthalmic segment in four, the posterior communicating artery in two, the middle cerebral artery in two, the anterior cerebral artery in one, and the basilary tip in two patients. Table 2 also shows the closure rates for each subgroup of patients when the patients were grouped with regard to the initial treatment type.

Chi-square tests performed for closure rates of subgroups showed no significant differences among them (p: 0.231).

Figures 1 and 2 show representative cases.

Discussion

Unlike endosaccular treatments, parent artery endoluminal reconstruction with FDSs for the treatment

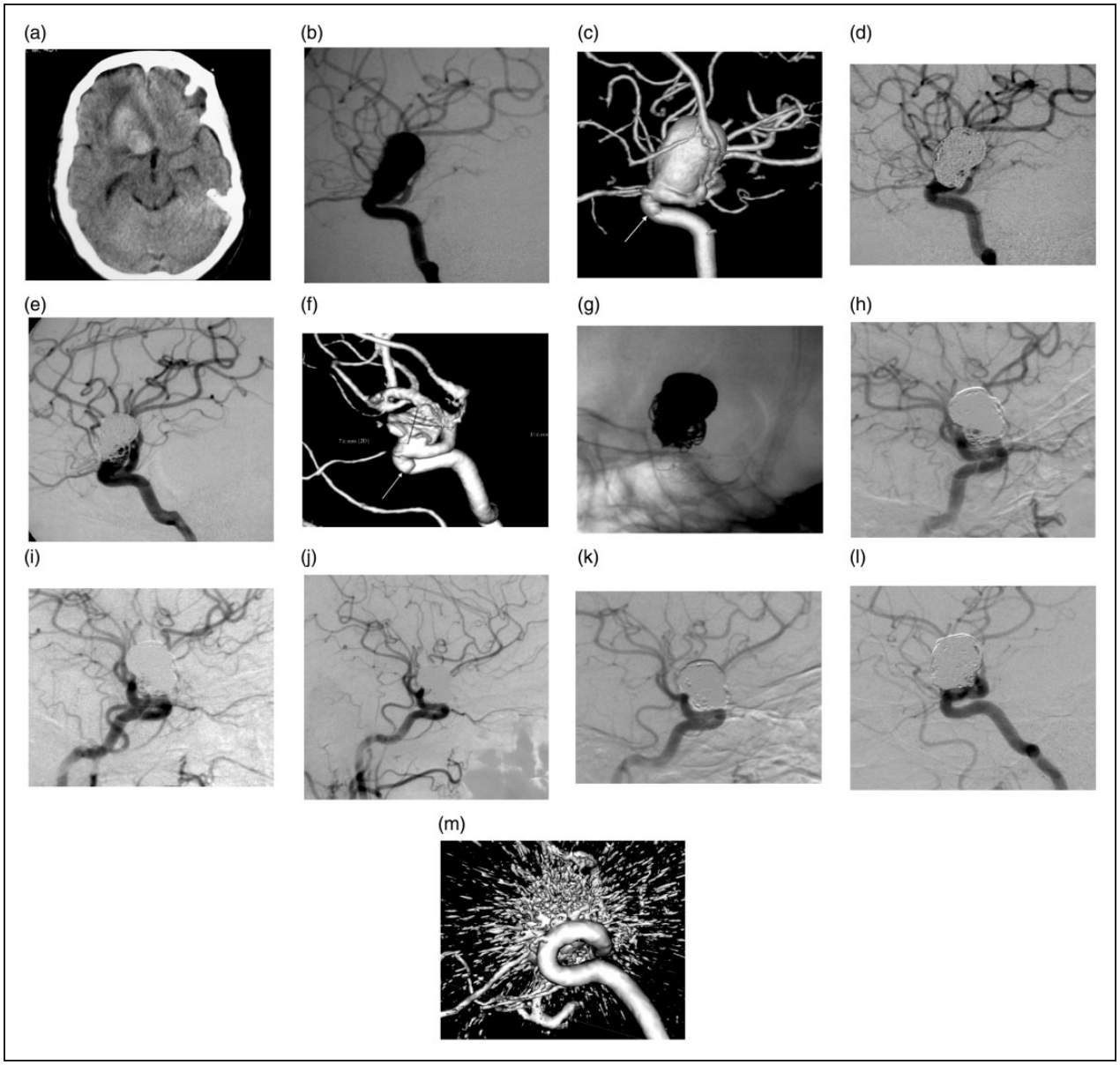

Figure 1. Recanalization after coiling: A patient with a ruptured right internal carotid artery (ICA) ophthalmic segment aneurysm: Axial CT slice (a) showed the aneurysm and frontal hematoma adjacent to the aneurysm. A large ICA ophthalmic segment aneurysm projecting cranially was seen on lateral 2 D (b) and 3 D (c) angiograms. There was also a small aneurysm bleb (c, arrow) just before the ophthalmic artery on the medial wall. The aneurysm was treated with coil embolization, and a small remnant was left in the neck (d). Six-month-follow-up angiograms revealed significant recanalization in the ruptured one (e) and some growth of the small aneurysm (f, arrow). The recanalized part and the small aneurysm were treated with a Silk flow diverter without coiling (g). While angiograms performed 6 (h) and 12 (i) months later showed a small aneurysm filling at the neck, angiograms after 18 (j) and 66 (k, l) months showed complete closure of the large and small aneurysms (m).

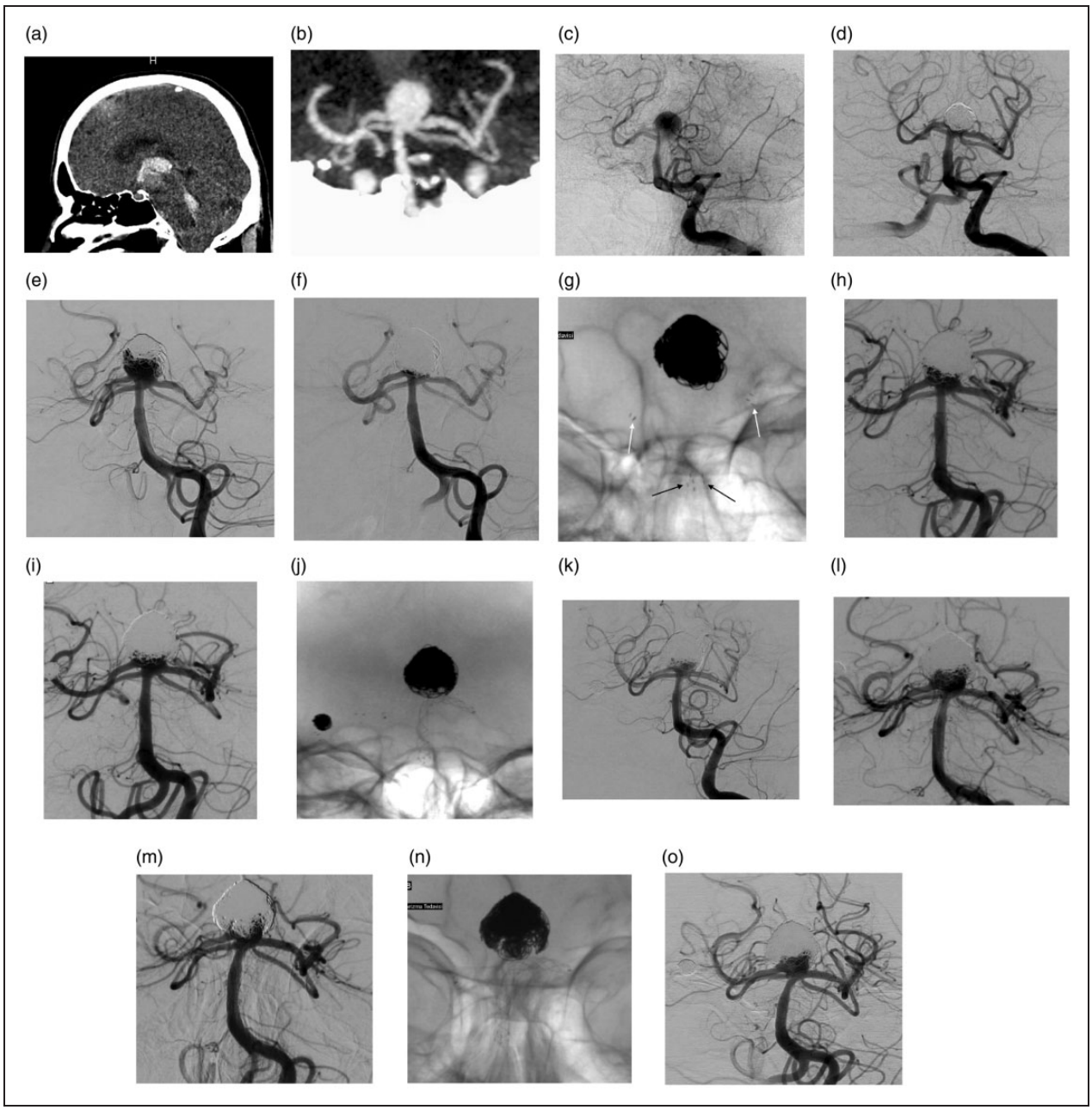

Figure 2. Recanalization after stent-assisted coiling: A patient with a ruptured basilar tip aneurysm: A sagittal CT section (a), CT angiography (b), and DSA (c) showed subarachnoid hemorrhage next to the aneurysm and inside the ventricles (a), and wide-necked saccular aneurysm that bilateral posterior cerebral and superior cerebellar arteries came out from the aneurysm neck (b). The aneurysm was completely coiled with a remodeling balloon (d). A large recurrence at the aneurysm neck six months later was seen (e) and treated with Y-stent-assisted coiling (f) using two Neuroform Atlas stents (Stryker). Arrows in (g) denote the proximal (black) and distal (white) markers of the stents. In the same session, the patient's small, right middle cerebral artery bifurcation aneurysm was also treated with stent-assisted coiling using the same stent, Neuroform Atlas (not shown here). Follow-up DSAs performed 6 and 12 (h) months later showed a recanalization increasing. This recanalization was treated with stent-assisted coiling using two telescoped Leo stents (Balt) extending from the basilar artery to the left posterior cerebral artery (i, j). Recanalization and growth of the aneurysm were seen again on 6- and 18-month angiograms (k, l). This time, the aneurysm was subtotally embolized (m), and a Pipeline Shield flow diverter (Medtronic) was inserted from the basilar artery to the left posterior cerebral artery, inside the telescopically deployed Leo stents (n). Remnant growth of the basilar tip (o) was seen on follow-up angiograms performed 6 months later.

of aneurysms results in a gradual yet more complete aneurysm obliteration, especially in large and giant aneurysms. As shown in many previous studies,[17–19] it is expected that the branches originating from the area covered by the FDS remain open. An inflammatory reaction occurs due to the flow stasis inside the aneurysm, then thrombosis and healing of the aneurysm are accomplished.[17] The stent aids in neointimal proliferation and remodeling of the parent vessel simultaneously. In studies

investigating the efficacy and safety of FDS, excellent results were obtained, and these studies led to increased utilization of FDSs in a wide range of aneurysm types.[18,19] In addition to the intracranial complex, wide-necked large and giant, fusiform, blister and bifurcation aneurysms,[8,10,12,20,21] another accepted FDS indication of the aneurysm treatment, the efficacy and safety of which were shown by some studies, is the recanalized and residual aneurysms previously treated with other techniques, coiling or stent-assisted coiling.[13,15,16,22–24] When complete aneurysm occlusion is obtained with FDSs, recanalization is rare. This feature is a valid reason for choosing them for recurrent or residual aneurysms[25] because the recanalization of coiled or stent-assisted-coiled aneurysms is not negligible. About 20% of coiled aneurysms[26] and 12% of stent-assisted-coiled ones recur,[27] and half of all recurrences require retreatment. Rebleeding from the aneurysms treated endovascularly with coiling or stent-assisted coiling is low but if it occurs, it may result in catastrophe. A study by Munich et al.[28] including 1292 aneurysms treated with primary coiling or stent-assisted coiling showed residual filling immediately after treatment in almost 50% (n: 626) of the cases. Of these aneurysms, 13 ruptured during the follow-up period (mean 7.3 mo) and 11 of them (84.6%) were ruptured aneurysms. They concluded that while unruptured aneurysms with a remnant after endovascular treatment had a very low risk of rupture (0.6%), ruptured aneurysms had a higher risk of rerupture (3.4%) from a neck remnant. In their systematic review and meta-analysis, given a 5% retreatment rate, Rizvi et al.[29] showed that spontaneous rupture of previously unruptured, small- and medium-sized, well-treated aneurysms was exceedingly rare (0.25%) after coiling. However, it should be taken into consideration that the retreatment of aneurysms after endovascular treatment due to the growing residual or recanalization prevents to be faced more reruptured cases. Therefore, in such conditions, retreatment of those aneurysms should be done, as in our cohort including the growing remnant and recanalized aneurysms that had mostly ruptured at presentation (74.7% of all cases). In a pooled analysis of three large studies by Kallmes et al.,[30] endovascular treatment of intracranial aneurysms with the PED was safe and effective with a combined major morbidity and neurological mortality rate of 7.1%. Because rerupture of the residual aneurysms is quite low when we compare the complication rate of endovascular treatment with FDSs, stable residual and recanalized endovascularly treated aneurysms can be followed under close attention. Beyond the serious life-threatening intracranial bleeding from aneurysms or brain parenchyma, or internal bleeding from other conditions such as epistaxis, melena, hematuria; minor bleeding or "nuisance bleeding" (that is, petechia, ecchymosis, and bleeding from small cuts or bruises) may require reducing the dose or cessation of the antiplatelet therapy.[31] Several studies related to cardiac interventions requiring antiplatelet therapy have been published in recent years,[32,33] and a study by Pressman et al.[31] revealed that nuisance bleeding events occurred in one-third of the patients with intracranial aneurysms treated with PED on dual antiplatelet therapy; moreover, this was more common at older ages. So, nuisance bleeding after treatment with FDSs should be taken into consideration as well, especially in older patients, when endovascular treatment with FDSs will be decided.

How we treat recanalized aneurysms and those ruptured aneurysms that were suboptimally coiled in the acute phase to prevent rebleeding, without targeting an initial complete occlusion, remains a problem.[13] Retreatment of recanalized or residual aneurysms treated endovascularly can be performed either microsurgically or endovascularly. However, there has been a tendency for the endovascular retreatment of these aneurysms due to surgical difficulties created by the previous endovascular procedure (presence of embolic materials, such as coils or stents). The presence of comorbidities in addition to the recurrent aneurysm and the presence of a recanalized posterior circulation aneurysm are additional reasons for preferring endovascular treatment. Microsurgery may be reserved for complex recanalized aneurysms that need an external-internal carotid bypass, in patients with uncorrectable coagulation disorders, or if antiplatelet agents are contraindicated.[34] Waldron et al.[35] treated 43 aneurysms with recanalized or residual aneurysms. Of these, 33 were managed with clipping, 7 were bypassed, and 3 were wrapped. While permanent morbidity was 2%, surgical mortality was 7%. However, with endovascular retreatment, morbimortality is very low in larger series.[11,13,14,20,23] In our study, which encompassed recanalized and residual aneurysms after endovascular treatment with FDSs, the overall aneurysm obliteration rate was 87.4%. Of the 11 incompletely occluded aneurysms, 3 were the bifurcation aneurysms. A side branch coming from the neck of the aneurysm might hinder the complete closure of the aneurysms. This is because the occlusion of the aneurysm depends on whether the territory supplied by this branch receives a collateral supply or not, as has been stated in some studies.[12,36] We noted a technical problem in one (1.2%) patient and stent thrombosis in two (2.2%) patients, but despite in-stent stenosis requiring balloon angioplasty at one year of follow-up, permanent neurological complications and mortality were zero. Table 3 shows a summary of the studies related to flow diversion in recanalized or residual aneurysms.

There have been a few studies focusing on the endovascular treatment of recanalized or residual aneurysms after coiling or stent-assisted coiling. In one such work, Daou et al.[13] treated 33 recanalized

Table 3. Studies showing flow diverter treatment of residual or recanalized aneurysms treated endovascularly.

Study	N of aneu. (P)	Previous treatment			FD	Follow-up period (m)	Complete closure rate (%)	Complications (%)		
		Coil	Stent+coil	Surg.				Tech.	Morb.	Mort.
Benaissa et al.[12]	29 (29)	23	6	–	S, P	5 (3–21)	60.7	12.7	17.2	0
Dau et al.[11]	33 (33)	33	–	–	P	8 (6–16)	76.7	0	3	0
Heiferman et al.[22]	25 (25)	–	25	–	P	12	38	12	4	0
Kühn et al.[14]	24 (24)	18	–	6	P	6	66.7	4.2	0	0
Dau et al.[21]	21 (21)	–	21	–	P	10.4	55.6	0	9.5	4.8
Dornbos et al.[26]	13 (13)	7	2 (FD)	4	P	26.1 (6–53)	100	0	0	0
Zhang et al.[24]	8 (8)	1	7	–	P	16.9 (7–36)	71.4	0	0	0
Bender et al.[20]	20 (18)	–	20 (13 FD)	–	P	13.1 (5–51)	56.0	0	5	5
Park et al.[23]	17 (17)	–	17	–	P	22 (6–48)	94.1	0	0	0
Current study	87 (86)	69	18	–	S, D, SP, F, P	21.0 (2–96)	87.4	1.2	0	0

N: Number; aneu: Aneurysm; P: Patient; Surg: Surgery; m: Month, Tech: Technical; Morb: Morbidity; Mort: Mortality; S: Silk; P: pipeline; D: Derivo; SP: Surpass, F: FRED.

aneurysms after coiling. Their result was excellent, with a 76.7% complete and a 10% near-complete occlusion rate. Of these aneurysms, 53% were ruptured. They did not encounter any technical or neurological complications. In our series, which had a similar rate of coiled patients (79.3%), the angiographic cure rate was 87.4%, which is higher than that reported by Daou et al.[13] In fact, the rate of previously coiled ruptured aneurysms was similar to that found by other studies on the retreatment of a recanalized aneurysm.[14,16,37] This is to be expected, as endovascular treatment of a ruptured aneurysm with only coiling or balloon-assisted coiling may be regarded as rescue therapy. The main purpose of treating ruptured aneurysms in the acute phase is to prevent rebleeding. Therefore, aggressive coiling may not be warranted in an effort to decrease complications, reserving complete treatment for the chronic phase, in which there is a very low or no risk of rebleeding. Another reason for the increased rate of recanalized or residual aneurysms after coiling is the high rate of aneurysm recanalization (up to 50%) associated with coiling only.[13,16,19]

Some studies evaluated flow diversion treatment of recanalized, or remnant aneurysms seen after stent-assisted coiling. According to the results of certain works,[19,22–24] a stent seems to negatively affect the results, with occlusion rates from 38% to 65% and morbidity ranging from 0 to 14.3%. The stent increases technical problems, such as in-stent navigation and FD deployment. Incomplete FD opening caused by a previous stent results in additional complications. Additionally, the flow diversion effect may be reduced by the stent. In studies by Heiferman et al.,[24] Daou et al.,[23] Zhang et al.,[34] Bender et al.,[22] and Park et al.[25] post-stent recanalized or residual aneurysms were treated with FDSs. Although Heiferman et al.,[24] Daou et al.,[23] and Bender et al.[22] suggested a low obliteration rate (38%, 55.6%, and 56%, respectively) of post-stent recanalized aneurysms with flow diversion, in the studies by Zhang et al.[34] and Park et al.,[25] the closure rate was fairly high, at 71.4% and 94.1%, respectively. In the current study, the closure rate of the subgroup of 18 previously stented aneurysms was 77.8%, better than those of previous works, with the exception of Park et al. Our study is unique in two aspects. First of all, none of the previous authors compared the results of FDSs in patients with different initial treatment modalities. Our statistical analysis showed no significant difference between subgroups treated with coiling and stent-assisted coiling. However, the rate of residuals after FDS placement for post-stent cases was numerically higher. Therefore, it is reasonable to state that either the presence of a previous stent does not affect the results of FDSs or the effect of the stent, if actually present, was not shown because the size of our cohort to date is not yet large enough to show a small difference. In either case, the decision to proceed with FDSs in post-stent aneurysms is not altered, given the lack of efficacy of other modalities. On the other hand, it should be noted that both in our series (treated with nine braided and nine laser-cut stents) and that of Park et al., who reported a higher rate of complete occlusion after stenting, not only laser-cut but also braided stents were used (six braided and six laser-cut, stents) in contrast to the other papers mentioned above. Braided stents are well-known for their ability to appose the wall and may well be the underlying reason for the better results after retreatment with FDSs. The use of laser-cut stents in three of the four recanalized aneurysms treated with stent-assisted coiling supports this finding. The second difference is that the earlier reports included only the first generation of stents (Silk and Pipeline) only. Neurointerventional devices have improved rapidly in recent years, including new generation, less thrombogenic, easily deployable FDSs, distal access guiding and intermediate catheters, and highly sophisticated microcatheters.[25] This may also be a reason for the superior results obtained in our study, in which a wide range of devices was used (Table 3). Despite the remarkable size of our

cohort, more research is still needed to be able to prove this assumption due to the limited number of post-stent residual/recurrent aneurysms treated by FDSs reported to date.[22,25]

In the literature, the morbidity and mortality of aneurysm treatment with FDSs vary from 3% to 22.4%, and from 0% to 8%, respectively.[17,30] However, in the PREMIER study, Hanel et al.[7] showed that if the aneurysm size was small- or medium-sized (less or equal to 12 mm), the morbimortality was very low (2.4%). In our series, beyond a technical complication, we encountered two stent thromboses that were treated during the procedure without causing any neurological problems. Additionally, in one patient, in-stent stenosis necessitated balloon angioplasty 1 year after treatment. This did not lead to any neurological deterioration. Overall morbimortality was zero as in similar studies with FDS treatment of recanalized and residual aneurysms performed by Kühn et al.,[16] Dornbos et al.,[37] Zhang et al.,[34] and Park et al.[25] However, in studies by Benaissa et al.,[14] Daou et al.,[23] and Bender et al.,[22] while morbidity was between 3.0% and 17.2%, mortality was approximately 5% due to intracerebral hemorrhage and brain stem infarction that occurred in two patients in two separate studies. Although a direct comparison of complications in retreatments using FDS with aneurysms primarily treated by flow diversion is not appropriate, we can expect a lower rate of permanent neurological complications and mortality occurrence in retreatments. This may be because it is perhaps easier to deploy FDS in a previously placed stent scaffold, and no additional manipulation to fill the aneurysm with coils is required in most cases. Additionally, residual/recurrent aneurysms tend to be small and, generally, the vulnerable part of the dome of the aneurysms has been filled with coils. Therefore, no late aneurysmal hemorrhage is expected secondary to the aneurysm thrombosis. Although our study included large and giant aneurysms, the mean initial size of the aneurysms treated coiling or stent-assisted coiling was 10.3 mm (3–40 mm). We can assume that the residual/recanalized aneurysms were significantly smaller than the initial size. This assumption can explain the low rate of morbimortality in our cases, as found in the PREMIER study that showed lower morbimortality in small- or medium-sized aneurysms treated with FDSs than other FDS studies including large and giant aneurysms.[7,30]

Study limitations

The study was retrospective and there was no control group. Aneurysms locations and FDSs used in the treatment were not standardized.

Conclusion

FDSs are safe, effective, and feasible in the treatment of recanalized or residual intracranial aneurysms treated endovascularly. A low rate of complications makes flow diversion a preferred first-line treatment method in those aneurysms.

Authors' contribution

All authors aided in the collection of data. EA, BH, KA and AA wrote the article.

Ethical approval

Istanbul Medipol University Clinical Research Institutional Ethics Committee approval number: 10840098-604.01.01.E-9268

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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