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Treatment of Extracranial Dissecting Pseudoaneurysms with Flow Diverters: A Single Center Experience

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Abstract

Purpose: Flow Diverters (FD) have immensely extended the treatment of cerebral aneurysms in the past decade. Despite the growing experience, treatment of extracranial dissection Pseudoaneurysms (PA) remains an off-label use and is limited to small case series in literature.

Methods: Fourteen patients with 15 dissecting PA of the extracranial Internal Carotid Artery (ICA) and vertebral artery who were treated with FDs between 2011 and 2018 were examined retrospectively. Aneurysm occlusion, procedural complications, and clinical outcome were evaluated.

Results: Angiographic follow-up was available for all patients with a mean long-term follow-up time of 17.4 ± 14.5 months. Aneurysms were located in the anterior (86.7%, n=13) and posterior (13.3%, n=2) circulation. Of the ICA, the C1 segment was predominant (53.3%, n=8). Aneurysm morphology was saccular (86.7%, n=13) and fusiform (13.3%, n=2). Adequate aneurysm occlusion (Kamran grade 3 and 4) at long-term follow-up was achieved in 93.3% (n=14). Symptoms of patients were: Headache (42.9%, n=6); Stroke (21.4%, n=3); Horner's-Syndrome (7.1%, n=1); Vertigo (7.1%, n=1). Reported etiologies were spontaneous (71.4%, n=10), traumatic (21.4%, n=3) and iatrogenic (7.1%, n=1). Underlying dissecting stenosis was observed in 21.4% (n=3) with a mean of 69.1 ± 16.8% and decreased significantly at long-term follow-up (12.1 ± 21.0%; p=0.022). Asymptomatic thromboembolic event occurred in 7.1% (n=1). Retreatment was performed in 7.1% (n=1). There was no procedural morbidity or mortality.

Conclusion: Treatment of extracranial dissection pseudoaneurysms using FDs is effective and safe. Further studies with larger case numbers are necessary to establish this treatment method in selected patients.

Keywords: Flow Diverter; Pseudoaneurysms; PED; DED; FRED; p64; SILK

Abbreviations

PA: Pseudoaneurysms; CeAD: Cervical Artery Dissection; FD: Flow Diverters; DSA: Digital Subtraction Angiography; DED: Derivo Embolization Device; PED: Pipeline Embolization Device; FRED: Flow Redirection Endoluminal Device; p64 FMD: p64 Flow Modulation Device; ISS: In-Stent-Stenosis; DAPT: Dual Antiplatelet Therapy; ICA: Internal Carotid Artery; VA: Vertebral Artery

Introduction

Cervical Artery Dissection (CeAD) of the internal carotid arteries and vertebral arteries is a common cause of stroke in young and middle-aged people and results in ischemic events between 8 and 25% in patients <45 years of age [1]. CeAD is caused by a rupture of vascular layers with or without an identifiable environmental trigger or underlying vascular disease leading to an arterial wall hemorrhage. Based on the imaging, dissections are classified as follows: Occlusive, pseudoaneurysmal and stenotic [2]. The etiology of CeAD is usually spontaneous, followed by a traumatic or iatrogenic etiology [3]. The low incidence of CeAD between 3.5 to 2.5 per 100.00 has made it difficult to establish a clear management strategy [4-6]. First line treatment nowadays includes early anticoagulation or antiplatelet therapy which leads to a recanalization rate of 50% to 70% and resolution of symptoms [2,7,8]. However, endovascular treatment may be required in patients at high risk of bleeding or persistent, progressive, and recurring neurological symptoms during conservative therapy. Until today the literature is limited to case reports and systematic

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reviews, which have shown endovascular treatment of dissecting PA of the anterior and posterior circulation using a variety of extracranial stent systems with or without additional coiling [2,9-11], intracranial stent systems [12,13] and Flow Diverters [10,11,14,15]. For the treatment of CeAD with FDs, even fewer and smaller cases, have been reported in the literature, mainly with first generation devices (Pipeline Embolization Device; PED, Medtronic Inc., Minneapolis, Minnesota, USA and the SILK Flow Diverter, SFD, Balt Extrusion, Montmorency, France) showing good angiographic and clinical results [10,11]. Due to the fact that FDs have become a standard treatment option for intracranial aneurysms with promising results [16] and those more complex aneurysms are much easier to treat compared to early methods such as surgical reconstruction or ligation of the patent vessel, further research should be sought in this off-label use of FDs.

The purpose of this retrospective analysis was to share our experience in treating extracranial dissecting pseudoaneurysms of the ICA and VA with different FDs. To the best of our knowledge, this is the first study to report on the treatment of PAs with other flow diverters (Flow Redirection Endoluminal Device (FRED; MicroVention, Tustin, CA, USA), p64 Flow Modulation Device (p64; Phenox GmbH, Bochum, Germany) and Derivo Embolization Device (DED; Acandis, Pforzheim, Germany) in addition to the PED and SILK.

Material and Methods

Patient selection

Ethics committee approval was obtained for this retrospective data analysis. We analyzed our database and screened for patients with extracranial pseudoaneurysms of the ICA and VA treated with flow diverters between January 2011 and December 2018. DSA or Magnetic Resonance Angiography (MRA) was required at fist follow-up (3 to 6 months) and final follow-up (>6 months). Aneurysms additionally treated with coil embolization were also included.

Antiplatelet management and endovascular procedure

All patients received a Dual Antiplatelet Therapy (DAPT) of 100 mg acetylsalicylic acid and clopidogrel 75 mg daily at least 3 days prior to the intervention. Periprocedural a dose of 3000 IU i.v. heparin was administered. DAPT was continued for at least 3 months after the procedure and aspirin indefinitely thereafter. Platelet function testing was not performed since its level of evidence remains controversial [17].

Procedures were performed through femoral access under general anesthesia using either a biplane angiography machine (Axiom Artis; Siemens Healthcare, Munich, Germany) (from 2011 until 2014) or a biplane flat panel detector angiographic system (Artis Q; Siemens AG, Erlangen, Germany) (form 2014 until 2018). The imaging was performed in posterior-anterior and lateral projection (2D-DSA series) with a frame rate of 2 to 4 frames/s and in the working position. A total of 5 different FDs were used for aneurysm treatment in this study; Pipeline Embolization Device (PED; Medtronic Inc., Minneapolis, Minnesota, USA), SILK Flow Diverter (SFD; Balt Extrusion, Montmorency, France), Flow Redirection Endoluminal Device (FRED; MicroVention, Tustin, CA, USA), p64 Flow Modulation Device (p64; Phenox GmbH, Bochum, Germany) and Derivo Embolization Device (DED; Acandis, Pforzheim, Germany). The type of FDs used to treat the aneurysm was at the discretion of the treating physician. The sizing of the FDs was based on the maximum diameter of the parent vessel into which the FDs were to be implanted. The length of the implanted FD was selected based on the width of the aneurysm neck to be covered and the underlying vascular course. All devices were delivered using a 0.027-inch microcatheter via a bi- or triaxial approach in a standard deployment technique. First, the microcatheter was placed distal to the aneurysm neck and then the FD was inserted into the microcatheter. In cases in which additional coiling was performed a second 0.017-inch microcatheter (Echelon-10, Medronic, Duplin, Ireland) was placed in the aneurysm in jailing-technique. The placement of the FD was achieved by a combination of withdrawing the microcatheter and gently holding/pushing the delivery wire of the FD in place of the desired destination.

Angiographic evaluation

Aneurysm occlusion was assessed using a five-point scale previously described in literature [18] as follows: Grade 0, no endo-aneurysmal flow changes; grade 1, residual filling >50%; grade 2, residual filling <50%; grade 3, near complete occlusion with residual filling at the aneurysm neck; grade 4, complete occlusion. Aneurysms showing grade III and IV were classified as adequately occluded. Dissecting stenosis was assessed using the minimum lumen diameter in relation to the normal diameter of the parent vessel distal to the located stenosis. The stenosis was classified as follows low-grade (<50%), moderate (50% to 75%) and high-grade (>75%). The patency of the parent artery and the covered side branches were also assessed.

Clinical outcome evaluation

Clinical outcome was evaluated preinterventionally, at discharge and at follow-up using the modified Rankin scale. Good clinical outcome was classified as a mRS 0-2. Treatment-related morbidity was classified as a mRS 3-5.

Statistics

Continuous variables are expressed as means ± standard deviations. Categorical variables are presented as frequencies and percentage, unless stated otherwise. Analyses were performed using Fisher's exact and χ^2 tests. Statistical significance was accepted at a two-sided p value of <0.05. All data analyses were performed using SPSS Statistics 25TM (IBM Inc., Chicago, IL, USA).

Results

Patient and aneurysm characteristics

Fourteen patients with 15 extracranial PAs treated with FD implantation in our department were retrospectively analyzed. From our collective all patients were available for follow-up (9 women and 5 men). 86.7% of the aneurysms were located in the anterior and 13.3% in the posterior circulation. According to the Bouthillier classification of the ICA most aneurysms (53.3%) were located in the C1 segment. Both PA treated in the posterior circulation were located in the V2-Segment of the VA. 86.7% of the aneurysms treated in this study were saccular and 13.3% fusiform in morphology. Of the flow diverters available on the market, five were used to treat the aneurysms. Seven patients (50%) were treated with a PED, three patients (21.5%) with a FRED, two patients (14.3%) with a DED, one patient (7.1%) with a SILK and one patient (7.1%) with a p64. Most of the saccular aneurysms treated in this study were narrow-necked. Telescoping with multiple FDs was performed in 4 patients (28.6%). One patient was treated with two DEDs, another patient with 2 PEDs. Three FREDs were implanted in one patient and in the last patient 4 FREDs have been used. Additional coiling was performed in 2 patients (13.3%). On average, the patients in this study received

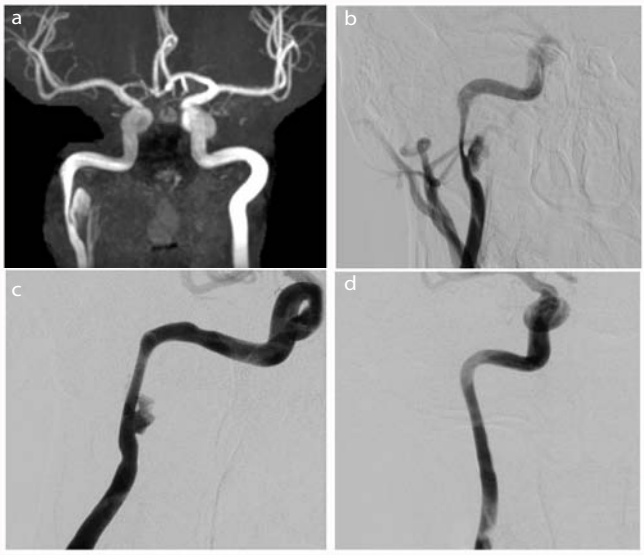

Figure 1: Time-of-flight angiography of a pseudoaneurysm (8.6 mm x 6.2 mm × 13.8 mm) arising from the right ICA (C1 segment) (a). DSA shows partially thrombosed pseudoaneurysm with an underlying dissecting stenosis of 75% (b). DSA immediately after implantation of a PED showing delayed filling of the PA and improved stenosis of 50% (c). DSA after 6 months showed a complete occlusion of the PA (Kamran 4) and a residual stenosis of approximately 30% (d).

a DAPT of 8.0 ± 6.3 months (median 6 months). Demographic data, aneurysm location and morphology are presented in detail in Table 1. Table 2 shows details of the interventional procedures for all patients.

Angiographic follow-up

First follow-up was performed after 4.9 ± 2.5 months (median 4) and available as DSA in 12 patients (85.7%) and as MRA in 2 patients (14.3%). Final follow-up was performed after 17.4 ± 14.5 months (median 14.5) and available as DSA in 10 patients (71.4%) and as MRA in 4 patients (28.6%). At first follow-up 11 aneurysms (73.3%) showed complete occlusion (Kamran grade 4), two aneurysms (13.3%) showed residual filling at the aneurysm neck (Kamran grade 3), one aneurysm (6.7%) revealed residual filling <50% (Kamran grade 2) and one aneurysm (6.7%) revealed residual filling >50% (Kamran grade 1). Respectively, leading to an adequate aneurysm occlusion (Kamran grade 3 and 4) of 13 aneurysms (86.7%) (Figure 1). At final follow-up 13 aneurysms (86.7%) showed complete occlusion (Kamran grade 4), one aneurysm (6.7%) had residual filling at the aneurysm neck (Kamran grade 3, Figure 2h) and one aneurysm (6.7%) revealed residual filling <50% (Kamran grade 2). Respectively, leading to an adequate aneurysm occlusion (Kamran grade 3 and 4) of 14 aneurysms (93.3%). Comparison of adequately occluded aneurysms (Kamran grade 3 and 4) at both follow-up periods revealed no significant differences (p=0.469). In one patient, a fusiform PA of the right ICA was treated with 4 telescopic FREDs, whereby only a marginal overlap of the proximal aneurysm was achieved, which led to inadequate aneurysm occlusion (Kamran grade 2) at the final follow-up after 10 months. Retreatment in this case was recommended but never carried out because the patients decided to seek a second opinion in another hospital.

Three patients (21.4%) had an underlying dissecting stenosis with a mean of 69.1 ± 16.8%. Treatment was performed in all cases using a PED. Immediately after implantation of the FDs the stenosis was already decreasing with a mean of 44.9 ± 18.3%. Immediately after implantation of the FDs, the stenosis had already decreased with a mean of 44.9 ± 18.3%. At long-term follow-up 11.0 ± 10.4 months the stenoses decreased significantly with a mean of 12.1 ± 21.0% and a p-value of 0.022.

Clinical characteristics

A traumatic history could be determined in three patients (21.4%). One patient suffered blunt head trauma in a brawl, one patient suffered penetrating neck trauma after a bicycle accident, and the last patient was involved in a car accident. Of these patients two were clinically asymptomatic and one patient presented with a stroke. Overall, three patients (21.4%) presented with minor strokes, most likely caused by the PAs located in the same vascular areas. Two of these PAs were located at the ICA (C1 and C2-segment) and the other at the VA (V2-segment). Symptoms caused by the PAs were hemihypesthesia (C1-segment PA) and vertigo (V2-segment PA). The C2-segment PA was caused iatrogenic ally during treatment of an intracranial aneurysm three months earlier. During the follow-up, the PA was noted and small acute punctiform infarcts were observed on Magnetic Resonance Imaging (MRI). The patient did not show any neurological symptoms. In total 6 Patients (42.9%) presented with headaches, 1 patient (7.1%) vertigo and 1 patient (7.1%) with Horner's-Syndrome. Overall, 7 patients (50%) presented with no neurological symptoms. Details of the treatment and clinical characteristic are presented in Table 2.

12 (85.7%) patients entered this study with mRS 0 and two patients (14.3%) with mRS 1. Pre-interventional mRS 1 was caused by vertigo due to small embolic infarctions from a V2-Segment pseudoaneurysm of the VA in one patient. The other patient presented with Horner's syndrome and hemi hypesthesia due to a growing pseudoaneurysm of the left ICA (C1 segment) after blunt head trauma with small embolic middle cerebral artery infarctions. No changes in the mRS were observed after the intervention or at discharge. At first follow-up 13 (92.9%) patients presented with mRS 0 and one patient (7.1%) with mRS 1 due to a residual Horner's syndrome. At final follow-up all patients presented with mRS 0. Overall, there was no treatment-related morbidity or mortality.

Complications

In one patient a small pseudoaneurysm of the C1 segment of the left ICA increased significantly within a period of two months

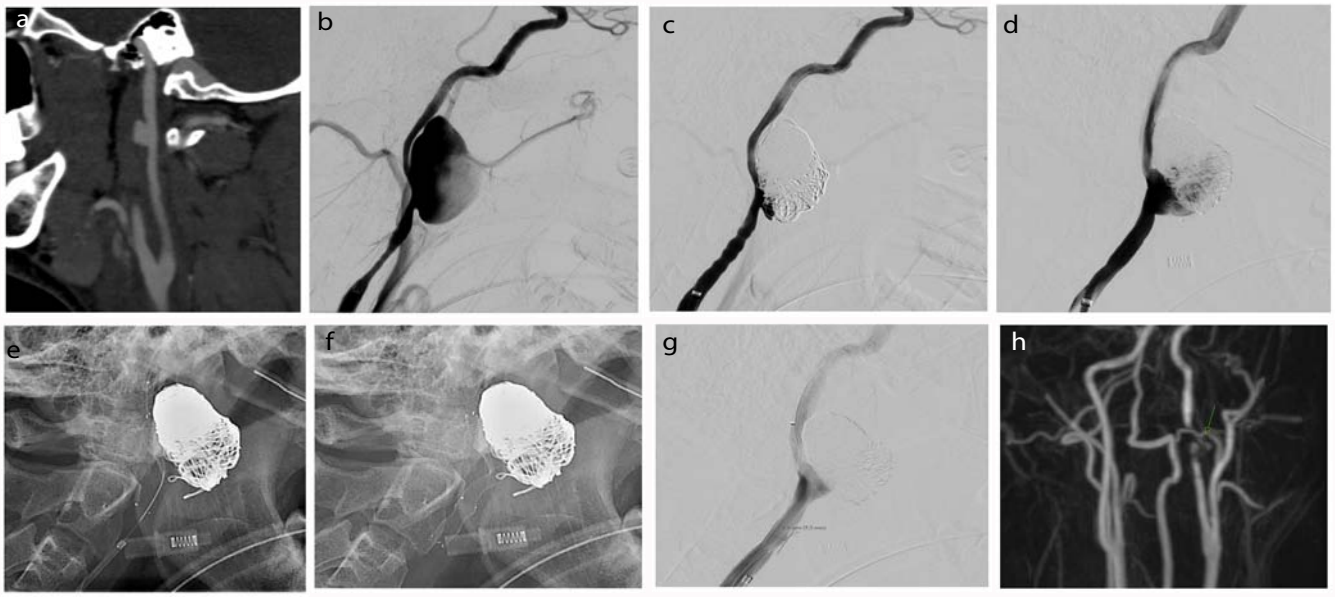

Figure 2: CT-Angiography and DSA of a pseudoaneurysm of the C1 segment of the left ICA with significant growth (33.3 mm × 19.1 mm × 18.2 mm) within two months after blunt neck trauma (a and b). DSA after treatment with a PED and additional coiling (c). DSA after 6 months revealed inadequate aneurysm occlusion (Kamran grade 1) due to a proximal foreshortening of the PED with partial dislocation into the aneurysm (d). Fluoroscopy after retreatment with a low-profile intracranial stent (Acclino Flex, Acandis, Pforzheim, Germany) to ensure vascular access (e). Fluoroscopy and DSA after implantation of another FD (DED) and additional coiling (f and g). MR-Angiography 12 months after retreatment showed a near-complete occlusion of the PA (Kamran grade 3, green arrow) (h).

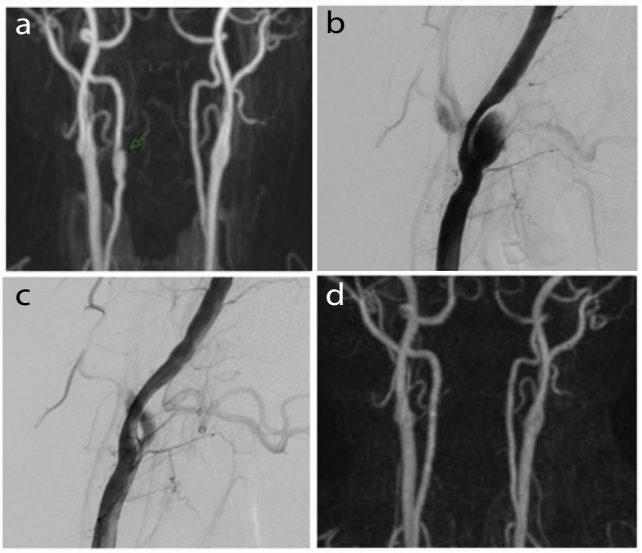

Figure 3: Overall, we observed one ischemic event (7.1%) without clinical sequelae, one retreatment (7.1%) after foreshortening at follow-up.

after blunt neck trauma into a giant pseudoaneurysm (33.3 mm × 19.1 mm × 18.2 mm) (Figure 2a, 2b) and caused minor stroke. Initial treatment was performed with a PED and additional coiling (Figure 2c). First follow-up revealed a distinct proximal foreshortening with partial dislocation of the PED into the aneurysm and inadequate aneurysm occlusion (Kamran grade 1) (Figure 2d). Retreatment was performed after successful navigation through the dislocated PED by implantation of a low-profile intracranial stent (Acclino Flex, Acandis, Pforzheim, Germany) to ensure vascular access (Figure 2e). After that the residual pseudoaneurysm was treated by implantation of another FD (DED) and additional coiling in jailing-technique (Figure 2f, 2g). Post-interventional MRI of this patient revealed a punctate middle cerebral artery infarction without neurological symptoms. One other patient suffered a peri-interventional occlusion of a peripheral parietal branch of the middle cerebral artery after treatment of a right C2-segment ICA PA. The occlusion was completely recanalized by administration of 15 mg i.v. thrombolysis (Actilyse, Boehringer, Ingelheim, Germany). The patient had no clinical symptoms.

Overall, we observed one ischemic event (7.1%) without clinical sequelae, one retreatment (7.1%) after foreshortening at follow-up.

In-Stent-Stenosis (ISS) was seen in 4 patients (28.6%) at first follow-up (1 PED, 1 DED and 2 FRED) compared to 1 remaining stenosis (7.1%) at last follow-up (1 FRED). ISS was mild overall (15.5 ± 6.7%) and decreased at last follow-up (2.7% ± 5.4%).

We observed no peri-interventional bleeding, delayed aneurysm

Table 1: Demographics, aneurysm location and morphology.

	Total
Number of patients (n)	14
Number of aneurysms (n)	15
Mean age	49.1 ± 14.3
Median age	52
Age range	25-70
Female/male sex	9/5
Aneurysm location n (%)	
Anterior circulation	13 (86.7)
ICA C1	8 (53.3)
ICA C2	2 (13.3)
ICA C3	3 (20.0)
Posterior circulation	2 (13.3)
VA V2-Segment	2 (13.3)
Aneurysm morphology n (%)	
Saccular	13 (86.7)
Fusiform	2 (13.3)
aneurysm width [mm]	7.8 ± 3.6
aneurysm height [mm]	10.0 ± 8.6
aneurysm depth [mm]	7.2 ± 3.4
aneurysm neck [mm]	5.1 ± 3.1
Dome-to-neck ratio	1.6 ± 0.4
aneurysm volume [mm^3]	570.1 ± 1429.2

rupture or occlusion of the implanted FDs. There was no procedural morbidity or mortality (Figure 3).

Discussion

CeAD accounts for 8% to 25% of strokes in young patients and is the leading cause of stroke in patients <45 years of age [1]. The manifestation of CeAD occurs stenotic in 47%, stenotic in combination with a PA in 28%, occlusive in 18% and as a PA alone in 7%. Thus, one third of the patients with CeAD develop a PA [4,19]. The recurrence rate of ischemic stroke after symptomatic dissection of the ICA and VA varies between 2% to 30% in the literature [2,20-22]. Medical management with anticoagulation or platelet inhibition for 3 to 6 months is the therapy of choice today and leads to good clinical outcomes in most patients. However, the superiority of one of the two drugs has not yet been proven [2,7,8,23]. Endovascular treatment should be considered for selected patients with failure of medical therapy such as new ischemic events, worsening of neurological symptoms and enlargement of PA [9].

The purpose of this retrospective study was to share our experience in treating extracranial dissecting pseudoaneurysm using different FDs.

CeAD affects the ICA more often than the VA and is mostly spontaneous, followed by trauma or iatrogenic events [2,3]. In our study etiology of CeAD was spontaneous in 10 patients (71.4%), traumatic in three patients (21.4%) and iatrogenic in one patient (7.1%). Of the traumatic events observed in our study, 2 were blunt and one was penetrating trauma. Iatrogenic etiology of PA was due to prior endovascular treatment of an intracranial aneurysm. In a systematic review by Pham et al. in 2011, it appeared that most CeAD in need of endovascular treatment had a traumatic cause [9]. None of the PAs treated in our study could be associated with connective tissue disease. Main symptoms patients presented with in this study were headache (42.9%, n=6), vertigo (7.1% n=1) and Horner's-Syndrom (7.1%, n=1). Compared to the a currently published systematic review by Texakalidis et al. in 2020, the rate of asymptomatic patients treated in our study was quite high at 50% [11]. As far as this could be retrospectively evaluated, these aneurysms were treated on the basis of a pronounced treatment request by the patients. Treatment of asymptomatic PAs, however, remains controversial. On the one hand, there are reports with no evidence of thromboembolic events or ruptures [24]. On the other hand, authors report combined stroke

Table 2: Treatment and clinical characteristics.

Patient No.	Sex	Aneurysm Location#	Clinical present.	Aneurysm morphology	Stent	Number of FD	Coiling	DS bevor FD (%)	DS after FD (%)	DS at FU (%)
1	F	C3	H	saccular	DED	1	Y	-	-	-
2	F	C3	H	saccular	P64	1	N	-	-	-
3	F	C3	H/V	saccular	DED	2	N	-	-	-
4	F	C1	-	saccular	SILK	1	N	-	-	-
5	F	C1	H	saccular	PED	1	N	-	-	-
6	M	C2	S	fusiform	PED	2	N	-	-	-
7	M	C1	-	saccular	FRED	2	N	-	-	-
	M	C1		saccular	FRED	1	N	-	-	-
8	F	C1	H	fusiform	FRED	4	N	-	-	-
9	M	C1	T	saccular	PED	1	N	75.7	59.1	36.4
10	F	C2	-	saccular	PED	1	N	-	-	-
11	F	C1	H	saccular	PED	1	N	-	-	-
12	M	C1	HS/S/T	saccular	PED	1	Y	50	24.2	0
13	F	V2	T	saccular	PED	1	N	81.6	51.4	0
14	M	V2	V/S	saccular	FRED	1	N	-	-	-

Note: F: Female; M: Male; H: Headache; V: Vertigo; HS: Horner's-Syndrome; T : Trauma; S: Stroke; FD: Flow Diverter; Y: Yes; N: No; DS: Dissecting Stenosis; FU: Follow-Up
#Bouthillier classification

and death rates of 21% of patients with PAs [25]. Furthermore, PAs seem to constitute a long-term risk of distal embolic stroke [26-29]. In our study three patients (21.4%) presented with minor strokes most likely caused by the underlying PA.

In the past, CeADs were often treated endovascularly with carotid stents [2,9,11] or covered-stents [30,31]. Flow diverters have also been used increasingly for extracranial CeAD treatment in the last decade with good angiographic and clinical outcome [11,14,15,32,33]. The first extracranial ICA PA treated with a FD was reported by Amenta et al. in 2012 using a PED with successful reconstruction of the vessel and complete pseudoaneurysm occlusion after 4 weeks [34]. Reported the first case in the literature in 2013 in which two SILK flow diverters were used to treat a dissecting PA [32]. The first largest clinical case series was published by Brzezicki et al. in 2016, when 11 patients with ICA dissecting PAs were treated with PEDs [35]. A technical success rate of 100% has been reported. Nine patients were available after a mean follow-up time of 5.2 months and showed a complete pseudoaneurysm occlusion rate of 75%. No ischemic or hemorrhagic complications occurred [35]. The most recent multicenter evaluation was carried out by Akinduro et al. in 2020 [36]. 28 PAs were treated with the PED in 24 patients with a mean follow-up time of 21 months without any peri-procedural complications. They achieved complete and near complete pseudoaneurysm occlusion rates of 89% and 11%, respectively. Reports on treatment of extracranial VA PAs are limited to a few singular case reports in literature. All reports have shown technical success rate of 100% and complete pseudoaneurysm occlusion after treatment with the PED [37,38]. To date, there have been no reports of extracranial PAs treated with flow diverters such as the FRED, p64, or DED.

In our study most patients (50%) were also treated with the PED, since it was the first available FD at times. Later patients have also been treated with the FRED (21.3%), DED (14.3%) and p64 (7.1%). Overall, the adequate pseudoaneurysm occlusion rate observed (93.3%) in our study was higher than that of Brzezicki et al. and comparable to Akinduro et al. as described by both authors, we also did not experience any treatment-related morbidities. There was one ischemic event (7.1%) without clinical sequelae after retreatment of a foreshortened PED, which was partially dislocated into the aneurysm after initial treatment 6 months before. The observed rate of ischemic events is in line with normal expectations when using FDs to treat aneurysms [16]. Overall retreatment was performed in one patient (7.1%) and was also comparable with the current literature [39].

Three patients (21.4%) also presented with underlying dissecting stenoses with a mean of 69.1 ± 16.8%. Flow-limiting stenosis (>80%) alone has been discussed in the literature as a primary treatment indication for extracranial carotid dissections because of a potential risk of cerebrovascular accidents or transient ischemic attacks [35,40]. Two of our cases were in the ICA and one stenosis was found in the VA. Brzezicki et al. treated 10 patients in their small case series presenting with a severe stenoses using a PED. In order to reach full expansion of the PED additional balloon angioplasty was performed in all cases. They reached complete revascularization in 91%; one stenosis with 20% was remaining [35]. In our study no balloon angioplasty was performed. Stenoses treated with the FDs improved immediately post-interventionally from 69.1 ± 16.8% to 44.9 ± 18.3%. At long-term follow-up 11.0 ± 10.4 months the stenoses decreased significantly with only one remaining stenosis of 36%. The regression of a dissecting stenosis as a result of the implantation of a FD was also described by Cohen et al. In their case series, only 3 out of 8 patients had to undergo additional balloon angioplasty, but most stenoses declined without further manipulation. We believe that balloon angioplasty after FD treatment of dissection stenosis might only be necessary in selected cases, as FDs have sufficient radial force to promote revascularization compared to other neurovascular stents-systems. Nonetheless, the role of balloon angioplasty after FD treatment of dissection stenosis needs further investigation.

Asymptomatic In-Stent Stenosis (ISS) was observed in our study in 28.6%, was overall mild with a mean of 15.5 ± 6.7% and resolved with one remaining stenosis of 7.1% at the last follow-up. ISS occurred only in patients with no underlying dissection stenosis. ISS after FD implantation have already been investigated in many studies; the rate observed in our study corresponds to the rate expected in the literature (29% to 57%) after FD treatment [41,42].

Limitations

The main limitations of this study are its retrospective design and the relatively small number of patients. Due to the small number of patients treated with the different FDs, the prerequisites for an adequate statistical comparison were not met. Furthermore, we report the experience of a single center. Availability of large studies assessing the safety and efficiency of FDs for dissecting PAs treatment remains limited. In addition, there are no reports in the literature of treating PAs with the FDs used in our study, making it difficult to compare our results directly.

Conclusion

Our single center experience shows that treatment of extracranial dissecting pseudoaneurysms using different FDs is safe and effective with high occlusion rates and no treatment-related morbidity. In addition, underlying dissection stenosis can also be treated by the implanted FD without the need for balloon angioplasty. However, because of the small, limited population requiring endovascular treatment, larger and multicenter studies are needed to determine the role of FDs in the treatment of dissecting PAs.

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