Article

Urgent Off-Label Use of Flow–Diverter Stents In the Endovascular Management of Tonsillar Loop-Associated Internal Carotid Artery Dissections Presenting with Carotid Occlusion or Near-Occlusion and Major Ischemic Stroke

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Abstract: We present our experience with the implantation of flow diverter stents (FDSs) for the management of intern carotid artery (ICA) dissections in tortuous tonsillar loop segments. 16 patients (10 women, 62.5%; mean age 39±8 years; median baseline NIHSS 13; median ASPECTS 8.5) with acute ischemic stroke due to ICA dissection in a tortuous tonsillar loop segment, with/without large intracranial vessel thrombotic occlusion, from 6/2015–2/2022 were included in this retrospective study under a waiver of informed consent. An FDS device was deployed from the petrous ICA toward the upper cervical ICA, completely covering the tonsillar loop. Stentriever-assisted thrombectomy was performed when indicated. A dual antiplatelet regimen was used during and after the procedure. Thrombocyte inhibition levels were evaluated before, during, and after the intervention. The ICA occlusion/near occlusion was successfully recanalized in all 16 patients with postangioplasty residual stenosis of 34±14% (range 0–50%). Stent-assisted embolectomy was performed in 15/16 patients (93.7%), achieving revascularization (TICI 2b–3) in all. There were no procedural complications and no intraprocedural embolic events; one asymptomatic petechial hemorrhage was detected. At 3-month follow-up, mRS 0–2 was seen in all patients. This report provides pilot data for a subsequent study on the use of flow diverter stents for ischemic cerebrovascular conditions. Our encouraging preliminary results await confirmation from further experience and prospective randomized studies.

Keywords: antiplatelet therapy; cervical carotid artery; dissection; flow-diverter stent; ischemic stroke; Pipeline embolization device; stent reconstruction; tonsillar loop; tortuosity

1. Introduction

Flow diverter stents (FDSs) constitute a new generation of very flexible, self-expanding devices with high metal surface area coverage designed specifically for the endovascular management of intracranial aneurysms [1, 2]. FDSs present lower porosity and

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higher pore density as well as different longitudinal flexibility and radial force than regular neurostents, allowing for variable conformity to vessel curves [3-8]. Their low porosity provides efficacious containment of friable thrombotic material between the stent and the vessel wall, preventing thrombi from embolizing out of the stent lumen and facilitating renavigation with other endovascular systems such as angioplasty balloons or intermediate aspiration catheters.

The combination of these technical features, their availability in a wide range of lengths and diameters, and their ease of deployment through flexible microsystems prompted us to evaluate the use of FDSs in the management of tonsillar loop-associated carotid dissections. An optimal endovascular solution is lacking for these dissections since the vast majority of neurostents are unable to adapt to the extreme tortuosity frequently observed in the tonsillar loop. We present our experience with the use of FDSs in the management of anterior circulation acute ischemic stroke caused by tonsillar loop-associated carotid dissections.

2. Materials and Methods

2.1 Patient selection criteria

Consecutive patients presenting from June 2015–February 2022 with acute ischemic stroke after internal carotid artery (ICA) occlusion secondary to tonsillar loop-associated internal carotid dissection, who met our eligibility criteria for FDS implant, were included in the study. In all cases, the decision to use flow diversion for vessel reconstruction was taken during the urgent revascularization procedure, and was presented and discussed with the patient and/or family afterwards. Patients were considered eligible for FDS implant only if: (1) they presented with acute ischemic stroke secondary to tonsillar loop-associated ICA dissection causing complete/near complete arterial occlusion, with or without intracranial large vessel occlusion; and (2) the tonsillar loop was considered too tortuous to be repaired by means of carotid stents or regular neurostents, and required at least one FDS implant as part of the endovascular revascularization procedure. Patients with traumatic carotid dissections, those with dissections that caused arterial narrowing but not complete or near-complete occlusion, those with carotid dissections on straight arteries that could be treated with regular carotid stents, and those with atherosclerotic occlusions, were excluded from the series.

All patients presenting with acute ischemic stroke were evaluated with the National Institutes of Health Stroke Scale (NIHSS) and the Alberta Stroke Program Early CT Score (ASPECTS) during clinical assessment. At admission, they underwent head CT and CT angiogram (CTA) as well as MRI in selected cases. The extent of revascularization was assessed using the Thrombolysis in Cerebral Infarction (TICI) score [9]. At discharge and late follow-up, they were evaluated with the modified Rankin Scale (mRS), and underwent CTA, DSA, and/or Doppler ultrasound examinations at 1– 24-month follow-up.

This analysis was conducted with institutional review board approval (HMO-03-20). Informed consent for the study was waived.

2.2 Endovascular technique and antithrombosis strategy

All procedures were performed under general endotracheal anesthesia with special care to avoid hypotension. After achieving femoral access with an 8F introducer sheath, a single dose of 3000 U of intravenous heparin was given. Activated clotting time (ACT) was evaluated and then reevaluated every 30 minutes, with a target of 250–300 seconds. Heparin was added if necessary to achieve this ACT range. Diagnostic angiography of the common carotid artery (CCA) allowed placement of an 8F guiding catheter at the distal CCA or the bulb of ICA. At this stage, patients who were not under antiplatelet

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agents received a loading dose of 270 mg of ticagrelor and 300 mg of aspirin administered per nasogastric tube.

A 17 microcatheter (usually XT-17, Stryker) was then navigated through the true lumen of the dissected carotid artery using usual microcatheter techniques. With the aid of different microguidewires and micro-angiographic injections the device was navigated through the tortuous course of the tonsillar loop, with the aim of reaching the petrous ICA beyond the dissected cervical segment. The microcatheter was then exchanged for a 0.027″ microcatheter (usually XT-27, Stryker; Phenom, Medtronic) or, less frequently, for a 0.021″ microcatheter (usually Headway 21, MicroVention) with the aid of a 300 cm long-microguideguire (usually Transend, Stryker).

At this stage, thrombocyte inhibition levels were evaluated using the VerifyNow P12Y12 assay (Accumetrics, San Diego, CA, USA), a standard thrombocyte aggregation test, with a target platelet reactivity unit (PRU) level of <100. If this level was not achieved, an intravenous bolus dose of eptifibatide, 90/180 mcg/kg (Integrilin, Schering), was administered. Half doses were given to patients with large brain infarcts to reduce the risk of hemorrhagic complications.

The first FDS device was then deployed from the petrous ICA toward the upper cervical ICA with the aim of completely covering the tonsillar loop with a single device. The first implant measured 4.0–5.0 mm in diameter and 30–40 mm in length, and was usually a Pipeline embolization device (PED, ev3/Covidien, Irvine, CA, USA), Pipeline Flex (Medtronic, Minneapolis, MN, USA), or Surpass (Stryker, Kalamazoo, MI, USA). The tonsillar loop is not only tortuous and redundant, but is usually the site of more complex dissection anatomy with a large false lumen and severe narrowing. Good distal expansion of the device is usually followed by underexpansion and elongation. An important step of the implantation phase is to ensure a minimal expansion of the proximal end of the device to facilitate recrossing the entire device back with the microcatheter. The microcatheter “massages” the stent and frequently allows some expansion of the FDS. The microcatheter was then exchanged for a double lumen balloon (usually the Eclipse double lumen balloon catheter, Balt Extrusion, Montmorency, France), which was used to expand the FDS with repeated low-pressure inflations. Areas of limited device expansion due to dissection-associated stenosis and compact thrombus were gently angioplastied. A second FDS was then implanted proximally if required.

In cases where the proximal carotid segment had a dissection in a straight course of the vessel, we then implanted a regular carotid Wallstent (Boston Scientific, Marlborough, MA, USA). If the distal end of the FDS remained underexpanded despite angioplasty maneuvers, we implanted a balloon expandable stent, which was navigated with the aid of an intermediate catheter.

After stent-based reconstruction of the ICA, we navigated an intermediate catheter (usually SOPHIA, MicroVention, or less commonly Navien A+ 058, Medtronic) across and beyond the distal end of the construct and proceeded with stentriever-assisted thrombectomy maneuvers under proximal intermediate catheter aspiration. The intermediate catheter tip placed beyond the stent construct protected the stentriever from entangling with the FDS mesh. A final angiogram was performed to assess revascularization.

Immediately after the procedure, patients were transferred to the intensive care unit for hemodynamic and neurological monitoring. The introducer sheath was removed manually after ACT normalization, sedation was discontinued, and the patients were extubated. Thrombocyte inhibition levels were routinely reevaluated 1 hour after the intervention in patients who did not receive eptifibatide and after 48 hours in patients who received the antiplatelet drug. CT was routinely performed after 12 hours in patients

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showing clinical improvement, or earlier in patients with clinical suspicion of a hemorrhagic complication. CTA was usually requested at 1-, 6-, and 12-month follow-up. Patients were usually kept under a dual antiplatelet regimen for 12 months (ticagrelor 60–90 mg bid plus aspirin 100 mg/day), and then ticagrelor was discontinued. For the first 3 months after FDS implant, patients underwent regular platelet function testing every 3 weeks and the antiplatelet regimen was adjusted as indicated. Testing also encouraged compliance with antiplatelet therapy.

Patients at high risk of acute stent thrombosis, such as those with significant clot burden, multiple stent implants, suboptimal stent expansion, or in-stent clot protrusion, were also treated with associated anticoagulation (IV heparin and later subcutaneous enoxaparin) for 1–3 months.

3. Results

From January 2015 through March 2022, we treated 16 patients with acute ischemic stroke secondary to tonsillar loop-associated ICA dissection causing complete or near complete arterial occlusion, with or without intracranial embolic large vessel occlusion, who required FDS implant as part of the endovascular revascularization procedure. Patient presentation, lesion type, indications for treatment, and procedural data are displayed in Table 1. There were 10 women (62.5%) and six men (36.5%), with a mean age of 39±8 years (range 19–64). The median baseline NIHSS and ASPECTS were 13 (range 6–26) and 8.5 (range 6–10), respectively. Three patients were under aspirin therapy before the intervention; one was under aspirin and clopidogrel. Four patients (25%) received intravenous thrombolysis before the endovascular procedure and none showed signs of clinical improvement or deterioration in relation to this therapy.

Loading doses of ticagrelor (270 mg) and aspirin (300–500 mg) were administered per nasogastric tube to 12 patients (75%) before stents were implanted, and these patients presented a mean PRU of 79 (range 4–186). Intravenous eptifibatide was administered to 13 patients, including seven who had a PRU over 100 at presentation and six who were not loaded before stenting. A full dose of eptifibatide was administered to 10 patients; a half dose was given to three (Table 1, patients 2, 11, and 13) who had been admitted with established infarcts and were presumed to have increased risk for hemorrhagic complications if a full dose of eptifibatide was administered.

All procedures were performed under general anesthesia. A single PED was implanted in 14/16 patients (87.5%) and two stents were required in two cases (patients #15 and #16). In all cases, balloon-assisted postangioplasty was performed to improve or optimize stent expansion and allow navigation of intermediate catheters for intracranial stentriever-assisted thrombectomy.

Endovascular stent-assisted revascularization of the cervical-petrous ICA was performed immediately following FDS implant in 15/16 patients (93.7%) for the management of intracranial occlusions, all via an antegrade strategy. Seven occlusions (47%) involved M1, six M2 (40%), and two the ICA “T” (13%). The most commonly used stentriever was pRESET (phenox) in 12 patients, and Solitaire (Medtronic) was used in three cases. A second stentriever was used as rescue stentriever after failed attempts with a pRESET stentriever in six patients; a second pRESET was used in three, Envi (Neurovasc) was used as a rescue stentriever in two patients and Neva (Vesalio) was used in one case.

Table 1. Demographic, clinical, procedural, and follow-up data in a series of 16 patients presenting with occlusive cerebrovascular disease treated by flow-diverter stent implant

N	NIHSS	ASPECTS	IVT	Approach	Revascularization technique	TICI	Hemorrhagic	3 mo	6 mo

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	Age, Sex				Occlusion site		FDS	Stent retriever		Time to true lumen gain (min)	Transforma-tion	mRS	DSA/CTA
1	41 F	12	8	+	RICA^{O}/M1	Antegrade	PED	Solitaire 4×20	3	17	–	1	Patent
2	19 M	26	6	–	LICA^{O}/M2	Antegrade	PED	Solitaire 4×20	2b	11	–	2	Patent
3	29 F	16	9	+	RICA^{O}/M1	Antegrade	PED	Solitaire 4×20	3	21	–	1	Patent, stenosis
4	32 F	10	9	–	RICA^{O}/M1	Antegrade	PED + Wallstent	pRESET 4×20	3	16	–	0	Patent
5	56 M	18	8	–	LICA^{O}/M2	Antegrade	PED + Wallstent	pRESET 4×20	3	18	–	0	Patent Wallstent, proximal pseudo-aneurysm
6	39 F	8	10	+	LICA^{NO}/"T"	Antegrade	PED Shield	pRESET 4×20/6×30	2b	2	–	0	Patent
7	51 F	6	10	+	LICA^{O}/M2	Antegrade	PED Shield	pRESET 4×20	3	22	–	1	Patent
8	41 F	12	8	–	RICA^{O}/-	Antegrade	PED Shield + Wallstent		3	11	–	1	Patent, stenosis
9	64 M	6	10	–	RICA^{NO}/M2	Retrograde	PED Shield	pRESET 4×20	3	27	PH1	0	Occluded
10	37 M	12	8	–	LICA^{O}/M1	Antegrade	PED Shield + Wallstent	pRESET 4×20/6×30	3	11	–	1	Patent, stenosis
11	39 F	18	6	–	RICA^{NO}/"T"	Antegrade	PED Shield	pRESET 5×40/6×30	3	8	–	2	Patent
12	59 M	12	9	-	RICA^{O}/M1	Antegrade	PED Shield	pRESET 5×40	3	6	–	0	Patent
13	54 F	16	7	-	RICA^{O}/M1	Antegrade	PED Shield	pRESET 5×40	3	14	–	0	Patent
14	37 F	6	10	–	LICA^{O}/M2	Antegrade	PED Shield	pRESET 4×20 + Envi 4×25	3	21	–	1	Patent
15	32 M	14	8	–	LICA^{O}/M2	Antegrade	Surpass Evolve 5×40 + Pipeline Vantage 5.5×40	pRESET 4×20 + Envi 4×25	3	11	–	0	Patent
16	40 F	16	8	–	LICA^{O}/M1	Antegrade	PED Shield 4.5×30/5×35+ Wallstent 7×40	pRESET 5×40 + NEVA 5.5×37	2b	22	–	1	Patent, stenosis

NIHSS – National Institutes of Health Stroke Scale; ASPECTS – Alberta Stroke Program Early Computed Tomography score; IVT – intravenous thrombolysis, LICA – Left internal carotid artery; FDS – flow diverter stent, TICI – Thrombolysis in Cerebral Infarction Score, mRS – modified Rankin score, CTA – computed tomography angiography; DSA – digital subtraction angiography; PH – parenchymal hematoma; LICA – left internal carotid artery; RICA – right internal carotid artery; M1 – first segment of the middle cerebral artery; M2 – second segment of the middle cerebral artery; "T"-internal carotid artery terminus occlusion, ^{NO} – near total occlusion, ^{O} – occlusion; PED – pipeline embolization device

In five patients (31.3%), proximal carotid stents were implanted in a telescoped fashion. Carotid stents were used primarily to anchor the FDS construct, to expand the proximal end of the FDS, to ensure coverage of proximal dissection, and/or to ease macronavigation through the metal construct.

The arterial occlusion/near occlusion was successfully recanalized via FDS implantation in all 16 cases. Postangioplasty residual stenosis was calculated as 34±14% (range 0–50%). Successful revascularization (TICI 2b–3) was achieved in all 15 patients who underwent stent-assisted embolectomy after a mean 3 passes (range 1–9). There were no procedural complications and all procedures were considered technically successful in terms of arterial recanalization. Remarkably, there were no intraprocedural embolic events. An asymptomatic petechial hemorrhage was detected in one case (patient 9) on the first postprocedural head CT.

At 3-month clinical follow-up, a good neurological outcome (90-day mRS 0–2) was seen in all patients; seven patients (43.7%) had reached mRS 0, seven patients (43.7%) had mRS 1, and two patients (12.5%) were assessed as mRS 2. On CTA, implanted FDSs were

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patent in 15/16 patients (93.7%). Patient 9 had developed post-revascularization hemorrhagic changes. As a result, ticagrelor had been discontinued for 36 hours, which may have contributed to device occlusion. The stent occlusion was asymptomatic and discovered only at a routine 3-month CTA follow-up.

Twelve patients (75%) who were evaluated clinically and radiologically 12–18 months after the endovascular intervention were stable with mRS status and stent patency comparable to findings at 3-month follow-up. For the cohort as a whole, the mean clinical follow-up was 21 months (range 6–68 months) and mean CTA and/or DSA follow-up was 16 months (range 3–27 months). During the first year period after stent implant, three patients transiently discontinued ticagrelor in order undergo a total of four surgical interventions with no associated clinical or angiographic deterioration.

4. Discussion

In this preliminary series of patients with acute ischemic stroke secondary to tonsillar loop-associated ICA dissection causing arterial occlusion requiring ICA reconstruction by means of FDS implant, with/without intracranial stentriever-assisted thrombectomy, we found our revascularization strategy was feasible, safe, and effective in achieving arterial recanalization. Cervical recanalization as well as successful reperfusion after thrombectomy (TICI 2b–3) were achieved in all patients, leading to a good outcome at 90 days (mRS 0–2) in all patients. There was clinical stability or improvement in all, with no significant procedural complications directly attributable to the endovascular procedure. The patient cohort has a female predominance and were relatively young compared with other series reporting endovascular treatment of stroke secondary to causes other than carotid dissections.

All procedures were carried out under general anesthesia. We consider this as essential for the success of the intervention, which usually requires delicate microcatheterization maneuvering and long procedure times. Proximal ICA recanalization was obtained in all cases and preceded intracranial revascularization procedures. The antegrade approach was preferred mainly due to the challenges in gaining intracranial catheter access through the true artery lumen prior to dissection repair. Once this access is obtained, it is mandatory to secure the arterial path and avoid endangering it with a thrombectomy-first strategy.

Although FDS devices were originally designed for the endovascular management of cerebral aneurysms, their unique features make them a better alternative than the usual neurostents for the management of selected cases of ischemic cerebrovascular disease [10]. In this series, the technique was used only in patients with major stroke caused by ICA occlusion, with/without intracranial embolic large vessel occlusion that required thrombectomy, and in patients who presented with stroke after symptomatic complete ICA occlusion due to poor collateral supply. In both groups, carotid reconstruction was considered essential. In the first group, complete ICA occlusion impedes angiographic studies, uncomplicated microcatheter navigation, and stentriever efficacy during thrombectomy. In the second group, acute ICA occlusion was the main cause of the symptoms and requires reconstruction.

The approach presented here is, however, technically demanding, costly, and time-consuming. Microcatheterization of the true arterial lumen can be very demanding technically in most patients with tonsillar loop dissection. Microangiograms obtained at “dead end” points and modification of angiographic views usually help to find a path out of the false lumen. Once the true lumen is catheterized, FDS deployment can be completed. Special care should be taken to achieve distal expansion in normal petrosal topography as

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well as sufficient proximal expansion to allow renavigation with the delivery microcatheter. The FDS requires angioplasty in most occlusive ICAs, which is only possible with easily navigable double lumen compliant balloons. Other angioplasty options are usually less efficacious due to limited navigability of balloons through the tortuous stent mesh. Low pressure inflations of double lumen balloon catheters are usually sufficient to expand the FDS to its required diameter. At the proximal straight end of the construct, we frequently add a Wallstent to ensure apposition of the FDS and coverage of residual carotid with unclear dissection, but more importantly, to facilitate ascension of the guiding and intermediate catheters during the thrombectomy phase. Special attention is given to placement of the intermediate catheter tip beyond the distal end of the stent construct to avoid entrapment of the deployed stentriever after thrombectomy attempts. The high cost of FDSs is still a matter of concern, especially if more than one FDS device is required, as was seen in 2/16 patients in this series.

The use of flow diverter stents for the management of ischemic cerebrovascular conditions has been limited but encouraging. Fischer et al [11] reported a cohort of 12 patients treated with PEDs for cervical and skull base carotid dissections. This cohort was included in a larger case series of 65 patients with 69 lesions that were treated with PEDs for extracranial (12 lesions) and intracranial (57 lesions) pseudoaneurysms and fusiform aneurysms of the anterior (31 lesions) and posterior (38 lesions) circulation. There are no characteristics listed specifically for this subgroup in their paper; the authors concentrate on the features and occlusion rates of the pseudoaneurysms.

Cohen et al. [10] presented their preliminary experience with eight patients with stenoocclusive disease of the ICA or vertebral arteries affected by dissections, intraluminal thrombi, or fibromuscular dysplasia who underwent endovascular reconstruction by means of flow-diverter stent implant. Three patients from their cohort presented with spontaneous cervical carotid artery dissections and one patient had a traumatic dissection. Presenting symptoms included cerebrovascular accident (NIHSS 4–13) and transient ischemic attack (TIA). Endovascular intervention was indicated because of flow-limiting stenosis due to dissection in two cases and failed medical management in two patients (heparin drip). In all cases, the procedures were technically successful without procedure-related complications. At 3-month clinical and radiological follow-up, all patients had either improved or remained stable, and stents remained patent in 7/8 cases. One patient had been noncompliant with the antiplatelet regimen.

In our practice, asymptomatic flow-limiting dissection is managed conservatively, and only reconstructed if medical therapy fails and reconstruction is considered feasible. Feasibility of the procedure is greatly influenced by anatomical factors that limit the efficacy of available neurostents but impose fewer constraints on the performance of FDS devices due to their greater flexibility. In the cases reported here, all patients presented with dissections that caused complete or near complete arterial occlusion, and required urgent endovascular revascularization because of acute ischemic stroke. A conservative (medical) approach was not indicated in any of the cases. Intravenous thrombolysis was administered in 4/16 patients (25%) but failed to show any beneficial effect.

Brzezicki et al. [12] retrospectively reviewed all cases of high cervical and skull base dissections treated with a PED, including nine traumatic and four spontaneous dissections. The most common presentation was ischemic events in five patients. Angioplasty was used in 10/14 cases. Complete revascularization (<10% residual stenosis) was achieved in 91% of vessels. The authors concluded that the use of PED in the treatment of dissections is safe and a viable treatment option. However, clinical and imaging findings from late follow-up are needed to fully evaluate the long-term efficacy of such treatment.

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Kurre et al. [13] reported their experience in the management of 73 patients with ICA dissections treated by endovascular means. The majority (60%) had tandem occlusions. Definitive vessel reconstruction was performed by stent implantation in 76 cases (99%). Self-expanding carotid stents were the most frequently used device; carotid stents alone were used in 21 (27%) lesions and in combination with flow diverters in 21 (27%) lesions. Post-dilatation was required in 31 cases (40%), mainly to achieve good FDS wall apposition (21/31). Cervical artery reconstruction was successful in 100% of cases and intracranial thrombectomy in 85%. Thrombus formation in 18% of patients and thromboembolism in 20% were the most frequent adverse events, but were clinically relevant in only 8%. Symptomatic hemorrhage occurred in 5% of the cases.

In our series of patients with carotid dissection and complete or near-complete occlusion, FDS implant preceded thrombectomy in every case. This not only delays thrombectomy and revascularization but also results in technical limitations to effective thrombectomy, which must be performed through a tortuous, already stented artery via an intermediate catheter that is required to bypass the metal construct and avoid potentially problematic stentriever/stent interactions. Despite these challenges, stentriever-assisted thrombectomy was effective in all 16 cases, achieving a Thrombolysis in Cerebral Infarction (TICI) score of 2b-3 in all. In cases when the intermediate catheter cannot be navigated beyond the distal end of the FDS, we assure maximal expansion of the distal end with gentle angioplasty. In these patients, this ensured uneventful stentriever navigation through the FDS.

A major drawback of FDS implant in acute stroke cases is the need for effective dual antiplatelet regimens at the time of stent implant and for a long period afterwards. Platelet inhibition reduces the possibility of in-stent thrombosis; however, in the setting of acute ischemic stroke it also increases the risk of hemorrhagic transformation. This is particularly worrisome in patients who have already been treated with IV thrombolytics. Despite extensive literature on this topic, the optimal antiplatelet regimen in the acute phase following endovascular therapy remains unknown, especially in case of carotid artery stenting. A recent systematic review found a possible increase in the risk of symptomatic intracranial hemorrhage (sICH) with periprocedural use of antiplatelets and a neutral effect on functional outcome [14]. Recently, Kim et al. [15] reported sICH in 8.9% of patients after urgent carotid artery stenting. This is in line with previous reports involving a total of 470 patients, where rates ranged from 4% to 9% [16-19]. Heck et al. [20] reported that stenting of the extracranial carotid artery in patients with acute stroke was associated with an increased incidence of intracerebral hemorrhage only when aggressive antiplatelet therapy was used in elderly patients.

In the present study we did not find an increased risk of hemorrhage with periprocedural antithrombotic use even though intravenous thrombolysis had been administered to 22% of the patients before the procedure and intraprocedure IV heparin was administered in all patients. In the recent TITAN [Thrombectomy in TANdem Occlusions] study [21], patients who were treated with carotid stenting and antithrombotic agents performed better than those who did not receive periprocedural antithrombotic agents.

The clinical course of all patients was uneventful during the follow-up period. An asymptomatic ICA occlusion was detected on follow-up CTA in one patient in whom antiplatelet medications were transiently interrupted in the immediate post-procedure period because a small ICH was observed. Other authors have reported that re-occlusion after the endovascular treatment of ICA dissections does not seem to be infrequent [22, 23]. Inadequate stent expansion, insufficient apposition of stents or flow diverters to the vessel wall, and changing configuration of FDSs resulting in stenosis, as well as noncompliance with antiplatelet regimens have been identified as potential reasons. We routinely proceed with

gentle balloon angioplasty maneuvers after stent implant to enhance proper stent expansion and improve apposition to the vessel wall. In addition, we stress the need for dual antiplatelet compliance and patients undergo regular platelet function testing every 3 weeks for the first 3 months with modification of the antiplatelet regimen as indicated. The testing also encourages compliance with antiplatelet therapy.

We do not routinely perform follow-up catheter-based angiography after FDS implant for dissection unless the patient becomes symptomatic or requires another intervention. Four angiograms were obtained during clinical follow-up of the patients presented here and we did not observe any cases of significant in-stent stenosis in our cohort. CTA is our most common follow-up study; however, despite its accuracy overall, CTA is limited in evaluating in-stent stenosis due to device-related metal artifacts.

The main limitations of our study include small sample size, ongoing long-term follow-up, and the retrospective nature of the study. As with every new application of a device, a larger study will be needed to fully assess the safety and efficacy of treatment based on FDS implant in the management of occlusive dissections in the setting of acute stroke. In our view, FDS devices have multiple comparative advantages to regular neurostents that make them preferable for the management of dissections in tortuous vessel segments. Surface modification of a recently developed new generation FDSs may result in the requirement of only a single antiplatelet agent, which would reduce both the frequency of acute and delayed thromboembolic events and the risk of hemorrhagic complications, and would probably also mitigate the effects of poor antiplatelet compliance.

5. Conclusions

This report provides pilot data for a subsequent study on the use of flow diverter stents for ischemic cerebrovascular conditions. Our encouraging preliminary results await confirmation from further experience and prospective randomized studies.

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