Flow Diverter Treatment of Tandem Intracranial Aneurysms

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■ OBJECTIVE: **To assess technical success and clinical and imaging outcomes of flow diversion (FD) treatment of multiple, tandem intracranial aneurysms.**

■ METHODS: **Retrospective analysis was performed of patients treated with FD for tandem intracranial aneurysms.**

■ RESULTS: **Twenty female patients with a mean (±SD) age of 60 (±12) years were included. One patient was treated after subarachnoid hemorrhage. In 22 separate procedures, 47 aneurysms, all located in the intracranial internal carotid artery, were treated. In 3 cases, treatment was performed for aneurysm recurrence after previous endovascular treatment. All aneurysms were successfully treated in 1 session. A single stent was used in most (82%) cases, with no adjunctive coiling. There were no intraprocedural complications. Three patients experienced mild, transient neurologic symptoms after the procedure with no long-term neurologic deficits. Follow-up imaging with digital subtraction angiography and/or contrast-enhanced magnetic resonance angiography was available in 18/20 (90%) patients at an average (±SD) of 18.8 (±11.2) months. Of 40 aneurysms with follow-up imaging, 34 (85%) were completely occluded. Clinical follow-up, available in 20/20 (100%) patients, showed that 19/20 (95%) achieved a modified Rankin Scale score of 0–2. There were no cases of aneurysm rupture after treatment, and no patients required retreatment at last available follow-up.**

■ CONCLUSIONS: **FD appears technically feasible, safe, and effective for treatment of tandem intracranial aneurysms, with potential advantages over traditional endovascular or surgical treatment modalities. Larger studies are needed to confirm these findings.**

INTRODUCTION

The technology of flow diversion (FD) has rapidly changed the endovascular options used to treat intracranial aneurysms. The Pipeline Embolization Device (PED) (Medtronic, Minneapolis, Minnesota, USA) was approved by the U.S. Food and Drug Administration in 2011 for endovascular treatment of large or giant wide-necked intracranial aneurysms in the internal carotid artery from the petrous to the superior hypophyseal segment. However, initial encouraging experience led to adoption of FD treatment for solitary aneurysms in other vascular segments, including smaller aneurysms with promising long-term occlusion rates. The application of flow diverters in the treatment of multiple, tandem intracranial aneurysms has not been well studied.

Tandem aneurysms are rare vascular lesions that denote the presence of ≥2 aneurysms in close proximity to each other on the parent vessel. No particular systemic disease, such as Marfan syndrome, Ehlers-Danlos syndrome, or polycystic kidney disease,[1-3] has been associated with the development of tandem aneurysms despite their propensity for increased risk of multiple intracranial aneurysms. Tandem aneurysms present unique challenges for treatment via surgical or endovascular strategies. Endovascular management of tandem aneurysms has traditionally used stent-assisted coiling for wide-necked aneurysms. The need for multiple catheterizations or several interventions for the treatment of separate aneurysms and the potential need for more

Key words
- Aneurysm
- DSA
- Flow diversion
- Pipeline
- Tandem

Abbreviations and Acronyms
DSA: Digital subtraction angiography
FD: Flow diversion
mRS: modified Rankin Scale
PED: Pipeline Embolization Device

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than a single stent based on the interaneurysm distance add complexity to these procedures. We sought to assess our experience using PED for treatment of tandem intracranial aneurysms.

MATERIALS AND METHODS

Research was conducted in accordance with the local institutional review board. All patients at our institution who underwent FD with PED for treatment of tandem intracranial aneurysms were retrospectively identified. FD was intended to treat all tandem aneurysms; this included first-time treatment of aneurysms as well as treatment of recurrences. Informed consent was obtained before all procedures, and off-label use of the Pipeline device was disclosed to patients when clinically indicated.

Clinical information was collected from the electronic medical record, including demographic details and clinical presentation. Aneurysms were divided into ruptured and unruptured lesions. Number, location (segments), and size of aneurysms as well as treatment specifics, including type, size, and number of Pipeline stents, were collected from the baseline treatment records. Details about antiplatelet regimen and technical aspects of the procedure have been reported in detail in previous publications from our institution.[4-6] Aneurysm occlusion was assessed on follow-up catheter angiography that was performed routinely at 6, 12, and 24 months after treatment. Follow-up imaging also included magnetic resonance angiography, and additional angiography was performed when clinically indicated.

RESULTS

Patient and Aneurysm Characteristics

Between 2011 and 2016, we identified 20 patients who underwent FD with PED for treatment of tandem intracranial aneurysms. All 20 (100%) patients were female with a mean (±SD) age of 60 (±12) years. Of these, only 1 patient (patient 17) was treated acutely following a subarachnoid hemorrhage from a ruptured left posterior communicating artery aneurysm. For unruptured cases, the decision to treat was made based on aneurysm size, atypical morphology, family history, patient age, other vascular risk factors, and multiplicity of aneurysms. All treated aneurysms were saccular type. No dissecting, dolichoectatic, or fusiform aneurysms were included. There were 47 aneurysms treated, all located in the intracranial internal carotid artery; 15 patients had 2 tandem aneurysms, 3 patients had 3 tandem aneurysms, and 2 patients had 2 tandem aneurysms on each internal carotid artery. This amounted to 22 separate procedures, as 2 patients had tandem aneurysms on both sides. The locations of the aneurysms are listed in **Table 1**.

Average size (±SD) of the largest tandem aneurysm was 6.6 mm (±5.5), and the second aneurysm was 3.0 mm (±1.4). In 3 patients with a third tandem aneurysm, the average size (±SD) was 2.1 mm (±0.5). We also measured the length of the vessel segment involved with the tandem aneurysms to have a better estimate of the stent size needed for treatment: For patients with 2 lesions, the distance from the proximal neck of the proximal aneurysm to the distal neck of the distal aneurysm was recorded. For patients with 3 aneurysms, the distance involving the 2 farthest aneurysms was taken. For 14 aneurysms in our cohort, the lesions were practically across from each other on the same level but on opposite sides of the vessel wall. In these cases, the PED had to cover only the width of the individual aneurysm necks on each side of the vessel wall. The average distance (±SD) between the remaining 33 aneurysms was 9.1 (±2.5) mm (range, 5–13 mm). In all procedures, the target lesion was the primary and largest aneurysm. Of the 22 primary aneurysms, 21 (95.5%) were intradural, and 1 was an expanding symptomatic large cavernous lesion causing cranial neuropathy. Of the 22 secondary aneurysms, 18 (81.8%) were intradural. All 3 tertiary aneurysms were intradural. Among the 22 cases, 3 (in 2 patients) were performed for aneurysm recurrence after previous endovascular treatment. Two of these 3 cases were in the same patient for recurrent bilateral superior hypophyseal and ophthalmic internal carotid artery aneurysms (prior stent coiling on the left and coiling only on the right). The third case was Pipeline embolization for recurrence of a large posterior communicating artery aneurysm that had previously received stent coiling with an adjacent untreated ophthalmic aneurysm.

Treatment and Complications

All aneurysms were successfully treated in 1 session. An average of 1.3 (range, 1–4) Pipeline stents were used for each vessel with tandem aneurysms. A single stent was used in 18 of 22 (82%) cases. There were no patients with adjunctive coil embolization.

There were no intraprocedural technical complications. After the procedure, 3 patients (15%) experienced mild, transient symptoms. The first patient had a transient episode of speech difficulty without imaging correlate of acute stroke. The second patient also developed slurred speech after procedure that rapidly improved. The third patient experienced mild, transient weakness of the arm, and computed tomography scan of the brain revealed possible hypodensity of the contralateral lentiform nucleus. Magnetic resonance imaging could not be performed in this patient owing to the presence of a pacemaker. All 3 patients improved rapidly with no permanent neurologic deficits. There was no mortality, aneurysm rupture, or hemorrhage associated with any of the cases in the available postprocedure period.

Clinical Outcomes

Clinical follow-up at an average (±SD) of 17.6 (±9.3) months was available in 20 (100%) patients, with 18 (90%) of these patients achieving a modified Rankin Scale (mRS) score of 0–1. This included the single patient treated after a subarachnoid hemorrhage, who achieved an mRS score of 1 at the last follow-up of 9 months. The 2 remaining patients, who did not achieve an mRS score of 0–1, had mRS scores of 2 and 3 at last follow-up owing to disability from unrelated major depression and untreated spine issues, respectively. Of 20 patients, 19 (95%) with available clinical follow-up achieved an mRS score of 0–2.

Imaging Follow-Up

Follow-up imaging (≥3 months) with digital subtraction angiography (DSA) and/or contrast-enhanced magnetic resonance angiography was available in 18 of 20 (90%) patients with a mean (±SD) follow-up of 18.8 (±11.2) months. If both DSA and magnetic resonance angiography were available, aneurysm occlusion was determined on the latest available study. Follow-up imaging was available for 40 of 47 aneurysms (85.1%). Of the 40 aneurysms with follow-up imaging, 34 (85%) were occluded (**Figures 1** and **2**), whereas only 6 (15%) showed residual filling. Imaging follow-up