Flow diversion of tandem cerebral aneurysms: a multi-institutional retrospective study

Al-Wala Awad, MD,¹ Karam Moon, MD,² Nam Yoon, MD,¹ Marcus D. Mazur, MD,¹
M. Yashar S. Kalani, MD, PhD,¹ Philipp Tausky, MD,¹ Cameron G. McDougall, MD, FRCS,³
Felipe C. Albuquerque, MD,² and Min S. Park, MD¹

¹Department of Neurosurgery, University of Utah Health Care, Salt Lake City, Utah; ²Barrow Neurological Institute, Phoenix, Arizona; and ³Swedish Neuroscience Institute, Seattle, Washington

OBJECTIVE Flow diversion has proven to be an efficacious means of treating cerebral aneurysms that are refractory to other therapeutic means. Patients with tandem aneurysms treated with flow diversion have been included in larger, previously reported series; however, there are no dedicated reports on using this technique during a single session to treat this unique subset of patients. Therefore, the authors analyzed the outcomes of patients who had undergone single-session flow diversion for the treatment of tandem aneurysms.

METHODS The authors conducted a retrospective review of flow diversion with the Pipeline embolization device (PED) for the treatment of tandem aneurysms in a single session at 2 participating medical centers: University of Utah, Salt Lake City, Utah, and Barrow Neurological Institute, Phoenix, Arizona. Patient demographic data, aneurysm characteristics, treatment strategy and results, complications, and follow-up data were collected from the medical record and analyzed.

RESULTS Between January 2011 and December 2015, 17 patients (12 female, 5 male) with a total of 38 aneurysms (mean size 4.7 ± 2.7 mm, mean $\pm$ SD) were treated. Sixteen patients had aneurysms in the anterior circulation, and 1 patient had tandem aneurysms in the posterior circulation. Twelve patients underwent only placement of a PED, whereas 5 underwent adjunctive coil embolization of at least 1 aneurysm. One PED was used in each of 9 patients, and 2 PEDs were required in each of 8 patients. There were 2 intraprocedural complications; however, in both instances, the patients were asymptomatic at the last follow-up. The follow-up imaging studies were available for 15 patients at a mean of 7 months after treatment (216 days, range 0–540 days). The mean initial Raymond score after treatment was 2.7 ± 0.7 , and the mean final score was 1.3 ± 0.7 .

CONCLUSIONS In this series, the use of flow diversion for the treatment of tandem cerebral aneurysms had an acceptable safety profile, indicating that it should be considered as an effective therapy for this complicated subset of patients. Further prospective studies must be performed before more definitive conclusions can be made.

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KEY WORDS Pipeline embolization device; tandem aneurysms; endovascular; flow diversion

ENDOVASCULAR intervention has proven to be a safe and efficacious means of treating intracerebral aneurysms.^{9,15,27} The development of the Pipeline embolization device (PED; Medtronic) has enabled even further expansion of the use of endovascular treatment for aneurysms.^{3,5,23} Such devices have been used to successfully treat cerebral aneurysms by diverting flow across the aneurysm neck to decrease aneurysm wall stress without entering or manipulating the fragile aneurysm sac.¹⁷ Although it is still early in the clinical use of these flow diverters, prospective trials have demonstrated their safety with high rates of aneurysm occlusion.¹⁶

The incidence of intracerebral aneurysms is estimated to be up to 3.2% in the general population, with as many as 34% of patients having multiple aneurysms.^{21,28} Within this cohort, a smaller group will have tandem, multiple aneurysms on the same parent vessel. Although this subset of patients has been successfully treated with endovascular coiling or surgical clipping, this unique arrangement of tandem aneurysms presents the opportunity to simultaneously treat multiple aneurysms during a single procedure.^{25,29} Here, we report outcomes in this unique patient subset through a multicenter effort to treat tandem aneurysms in a single treatment session using PEDs.

ABBREVIATIONS ICA = internal carotid artery; PED = Pipeline embolization device.
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Methods

After receiving approval from the institutional review boards at each institution, we performed a retrospective review of flow diversion with the PED to treat tandem aneurysms during a single treatment session. All adults treated in the period from January 2011 through December 2015 at 2 participating centers—University of Utah Hospital in Salt Lake City, Utah, and Barrow Neurological Institute in Phoenix, Arizona—were included in the study. Patient demographic data, aneurysm characteristics, treatment strategy and results, complications, and follow-up data were collected from the medical record and analyzed.

Results

Patient Population

Seventeen patients (12 female, 5 male) with a total of 38 aneurysms (average size 4.7 ± 2.7 mm, mean $\pm$ SD) were included in our cohort (Table 1). Sixteen patients had aneurysms in the anterior circulation, and 1 had tandem aneurysms in the posterior circulation. Fourteen patients had 2 tandem aneurysms, 2 patients had 3, and 1 patient had 4. Twelve patients underwent only placement of a PED, whereas 5 underwent adjunctive coil embolization of at least 1 aneurysm at the time of PED deployment. A single PED was used in each of 9 patients, whereas 2 PEDs were required in each of 8 patients. All patients were premedicated with 325 mg of aspirin and 75 mg of clopidogrel for 5–7 days prior to the procedure and continued on daily dual antiplatelet therapy for 6 months following the procedure.

Outcomes

There were 2 intraprocedural complications: a carotid dissection and a hemorrhage during adjunctive coiling. In both instances, the patients were asymptomatic at their last evaluation. Follow-up imaging studies were available for 15 patients at a mean of 7 months after treatment (216 days, range 0–540 days). The mean initial Raymond score after treatment was 2.7 ± 0.7 , and the mean final score was 1.3 ± 0.7 (Table 2).²²

Illustrative Case

A 30-year-old woman (Case 16) with no significant medical history presented with long-standing headaches. Preoperative angiography demonstrated 2 saccular aneurysms along the right internal carotid artery (ICA) terminus (Fig. 1A). The patient was treated with 2 PEDs that spanned the necks of both lesions (Fig. 1B). There were no intraprocedural complications. Posttreatment angiograms at the 12-month follow-up demonstrated complete obliteration of both aneurysms (Fig. 1C).

Discussion

Flow diversion has quickly joined the growing list of treatment modalities for intracranial aneurysms. Although tandem aneurysms are rare, affected patients present a unique treatment dilemma for which flow diversion represents an attractive option. Impeding aneurysm inflow by

flow diversion not only promotes aneurysm occlusion but also promotes repair of the parent artery to a more physiological state.^{10,30} Importantly, small branching feeders off the parent artery appear to remain intact even when covered by telescoping flow diverters, making these diverters especially useful when treating tandem aneurysms separated by a longer distance.^{4,11,14,26,30}

We successfully deployed 25 PEDs to treat 38 tandem aneurysms in 17 patients. The average Raymond score at the last follow-up was 1.3, and 89% of treated aneurysms had complete occlusion at the last follow-up. Reports on the treatment of tandem aneurysms using the PED mostly consist of small series of patients or case reports.^{12,30} Lin et al. described 6 patients with 12 aneurysms who had a complete occlusion rate of 90% at the last follow-up (20 months).⁶

The ability to treat several aneurysms with a single or multiple telescoping PEDs is a unique advantage of flow diverters, limiting the amount of mechanical manipulation of the aneurysm that is associated with clipping and endovascular coiling. In our study, a single PED was used to treat each of 6 patients with 2 tandem aneurysms, 2 patients with 3 tandem aneurysms, and 1 patient with 4 tandem aneurysms. Eight patients each required 2 telescoping PEDs during the initial treatment.

In more challenging aneurysms, the use of a PED can be supplemented with adjuvant coiling. Five patients (10 aneurysms) in our study were treated with adjuvant coiling. They were treated toward the end of our series after the technique had become more prevalent in the literature.²⁰ The use of a PED with adjuvant coil embolization has resulted in reduced retreatment rates in larger aneurysms and may have the added advantage of a higher obliteration rate in a shorter period of time.^{18,20,26} Although acute and late thrombosis of aneurysms has been described in a limited number of patients with PEDs and adjuvant coiling, the safety and efficacy of this technique has been demonstrated in larger cohorts.^{7,13,16,19,20,24,26}

Flow diverters also have the advantage of treating a wide range of aneurysm types. The treatment of fusiform aneurysms is significantly simplified through the use of a PED, with a high rate of success.^{8,13} However, no tandem fusiform aneurysms were treated in the present series. Pipeline embolization devices can also be safely used to treat small (< 10 mm) aneurysms, as was the case in 92% of aneurysms in our series.² Most recently, PEDs have even been used to treat ruptured aneurysms, further demonstrating their versatility in a wide range of settings, including acute interventions.¹

As noted, there were 2 intraprocedural complications in our series: a carotid artery dissection and a hemorrhage during adjuvant coiling. In the latter case, the aneurysm was particularly small, which made the adjuvant coiling especially challenging. Both of these complications are known to occur with the endovascular treatment of aneurysms and appeared to be unrelated to the use of a PED specifically in tandem aneurysms. Fortunately, both patients were doing well at the last clinical follow-up.

Conclusions

The results of our small series suggest that the use of

TABLE 1. Demographic data and aneurysm characteristics of patients with tandem aneurysms treated with the PED

Case No.	Age (yrs)	Sex	Circulation	Side	Location	Total No. of Aneurysms	Aneurysm Type				Aneurysm Size (mm)				Treatment	No. of PEDs	PED Size (mm)
							1	2	3	4	1	2	3	4			
1	40	M	Pst	Rt	Vertebral artery	2	P	P	—	—	7.7	4	—	—	PED	1	4.25 × 20
2	67	F	Ant	Lt	Cavernous, ophthalmic	2	S	S	—	—	10	6	—	—	PED	2	4.75 × 30, 4 × 30
3	67	M	Ant	Rt	Superior hypophyseal, ophthalmic	2	S	S	—	—	3	2	—	—	PED	1	4.25 × 16
4	41	M	Ant	Rt	Ophthalmic (2×), PCoA (2×)	4	S	S	S	S	7.8	3.6	3	2.5	PED	1	5 × 18
5	60	F	Ant	Rt	PCoA, ant choroidal	2	S	S	—	—	3.4	2.6	—	—	PED	2	4.25 × 14, 5.5 × 16
6	45	F	Ant	Lt	Ophthalmic, superior hypophyseal	2	S	S	—	—	3.5	1.5	—	—	PED	1	4 × 16
7	49	F	Ant	Lt	Ophthalmic, superior hypophyseal	2	S	S	—	—	7	6	—	—	PED	2	4.25 × 18, 3.75 × 20
8	66	F	Ant	Lt	PCoA, ant choroidal	2	S	S	—	—	3	3	—	—	PED	1	4 × 16
9	57	F	Ant	Lt	Cavernous, paracrinoid, PCoA	3	S	S	S	—	3	3	2	—	PED	1	4 × 20
10	72	M	Ant	Lt	Ophthalmic ICA, PCoA	2	S	S	—	—	4	4	—	—	PED	1	4 × 16
11	61	F	Ant	Lt	Ophthalmic, PCoA	2	B	S	—	—	6	2	—	—	Coil/PED	2	3.5 × 20, 3.5 × 14
12	65	M	Ant	Lt	PCoA & ant choroidal	2	S	S	—	—	5	3	—	—	Coil/PED	1	4 × 20
13	74	F	Ant	Rt	Ophthalmic, paracrinoid	2	S	S	—	—	8	2	—	—	Coil/PED	2	4 × 20, 4 × 16
14	74	F	Ant	Lt	Cavernous, PCoA	2	S	S	—	—	13	3	—	—	Coil/PED	2	4.25 × 20, 4.5 × 20
15	61	F	Ant	Lt	Ophthalmic, superior hypophyseal	2	S	S	—	—	10	3.2	—	—	Coil/PED	2	3.5 × 20, 3.75 × 20
16	30	F	Ant	Rt	Ophthalmic, paracrinoid	2	S	S	—	—	9	3	—	—	PED	2	3.5 × 20, 4 × 16
17	40	F	Ant	Rt	Cavernous, ophthalmic, paracrinoid	3	S	S	S	—	5.7	4.8	4.3	—	PED	1	4.5 × 20, 4.75 × 18

— = not applicable; ant = anterior; B = blister aneurysm; ICA = internal carotid artery; P = pseudoaneurysm; PCoA = posterior communicating artery; pst = posterior; S = saccular aneurysm.

TABLE 2. Outcomes in patients with multiple tandem aneurysms treated with the PED

Case No.	Total No. of Aneurysms	Raymond Score Postdeployment for Aneurysms 1–4, as Applicable				Raymond Score at Last FU for Aneurysms 1–4, as Applicable				Last FU (days)	Complications
		1	2	3	4	1	2	3	4		
1	2	3	3	—	—	1	1	—	—	98	None
2	2	3	3	—	—	NA	NA	—	—	1	Lt ICA dissection
3	2	3	3	—	—	1	1	—	—	405	None
4	4	3	3	3	3	NA	NA	NA	NA	107	None
5	2	3	3	—	—	1	1	—	—	126	None
6	2	3	3	—	—	1	1	—	—	42	None
7	2	3	3	—	—	1	3	—	—	540	None
8	2	3	3	—	—	1	1	—	—	420	None
9	3	3	3	3	—	NA	NA	NA	—	0	None
10	2	3	3	—	—	3	3	—	—	7	None
11	2	3	3	—	—	1	1	—	—	360	None
12	2	3	3	—	—	3	2	—	—	270	Intraop hemorrhage
13	2	1	3	—	—	1	1	—	—	240	None
14	2	2	3	—	—	1	1	—	—	210	None
15	2	2	1	—	—	1	1	—	—	210	None
16	2	1	3	—	—	1	1	—	—	365	None
17	3	2	1	2	—	1	1	2	—	270	None

FU = follow-up; NA = not available.

FIG. 1. A: Right ICA angiogram demonstrating a small, laterally directed, 3-mm aneurysm at the anterior genu and a larger, 9-mm ophthalmic artery aneurysm (arrows). **B:** Same right ICA angiogram in the lateral projection. The anterior genu aneurysm is partially obscured by the course of the ICA (arrows). **C:** One-year follow-up angiogram demonstrating complete occlusion of both aneurysms.

flow diversion for the treatment of tandem cerebral aneurysms has an acceptable safety profile and can be an effective therapy for a complicated subset of patients. We successfully treated a wide range of tandem aneurysm types including saccular, blister, and pseudoaneurysms in both the anterior and posterior circulation. Further prospective studies must be performed before more definitive conclusions can be made, but our preliminary results indicate the technique can be safe and effective.

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Disclosures

Dr. Taussky is a consultant for Covidien/Medtronic. Dr. McDougall is a consultant for ev3, MicroVention, and Aashish Tech.

Author Contributions

Conception and design: Park, McDougall, Albuquerque. Acquisition of data: Awad, Moon, Yoon, Mazur. Analysis and interpretation of data: Park, Awad, Moon, Yoon, Mazur. Drafting the article: Park, Awad. Critically revising the article: Park, Awad, Kalani, Taussky, McDougall, Albuquerque. Reviewed submitted version of manuscript: Park, Awad, Taussky, McDougall, Albuquerque. Approved the final version of the manuscript on behalf of all authors: Park.

Correspondence

Min S. Park, Department of Neurosurgery, Clinical Neuroscience Center, University of Utah, 175 N Medical Dr. East, Salt Lake City, UT 84132. email: neuropub@hsc.utah.edu.