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Clinical Study

Y-Stent embolization technique for intracranial bifurcation aneurysms

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ABSTRACT

Wide-necked bifurcation aneurysms often require the use of the technically complex Y-stent technique, which has recently been shown to narrow bifurcation angle in a hemodynamically favorable manner. We sought to evaluate the single center efficacy and safety of Y-stent supported aneurysm coil embolization. All patients undergoing Y-stent supported coiling between September 2006 and December 2012 were identified; records were analyzed for procedural results and complications, with follow-up evaluated for occlusion rate and neurological adverse events. Twenty consecutive patients underwent technically successful Y-stent supported coiling, with complete aneurysm occlusion achieved in 19/20 cases (95%). There were no peri-procedural clinically evident neurological complications following Y-stenting. Clinical follow-up was available for a mean of 20.0 months and radiographic follow-up was available for a mean of 18.5 months. During the follow-up period, three patients (15%) required re-treatment with through-stent coiling for recanalization. At latest follow-up, Raymond grade I occlusion was achieved in 16 patients (80%), Raymond grade II occlusion achieved in four patients (20%) and Raymond grade III occlusion in zero patients. Y-stenting for complex intracranial aneurysms appears effective in achieving durable aneurysm occlusion with an acceptable safety profile. Though the procedure is technically more complex than single-stent procedures, the Y-stent configuration should be considered when single-stent supported coiling is not feasible or sufficient.

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1. Introduction

Stent assistance for coil embolization of wide-necked intracranial aneurysms has significantly expanded the spectrum of aneurysms amenable to endovascular therapy [1–4]. Indeed, stent-assisted coil embolization may result in greater occlusion rates than coil embolization alone with comparable peri-procedural complications [5]. Despite this potential benefit, complex aneurysms can pose a significant challenge for achieving immediate and durable embolization.

Specifically, for wide-necked aneurysms located at shallow-angle arterial bifurcations, single stent-mediated coiling may provide insufficient support of the coil mass to prevent coil herniation through the aneurysm neck. Introduction of the Y-stent technique [6,7], whereby dual stents are deployed sequentially proximal to the arterial bifurcation and then into each arterial branch, has enabled stent-mediated endovascular therapy for bifurcation lesions too complex for coiling alone. Several small series have reported on the use of this technique with minimal peri-procedural complications and good short and mid-term efficacy [8–10]. These reports have been limited in terms of size and follow-up. Recently, Y-stent mediated coiling has been shown to decrease the arterial bifurcation angle, a finding associated with beneficial hemodynamic alterations [11]. Given the significant potential benefit of this technique suggested by these studies, a larger case series, as well as a review of the literature, is warranted.

In the current series, we report on 20 patients who underwent dual stent deployment in the Y-fashion for treatment of an intracranial aneurysm at a single center. Our experience with this technique may aid in better defining the success rate of Y-stenting procedures and elucidate the complications associated with this technique.

2. Methods

From September 2006 through December 2012, 20 patients underwent Y-stent-mediated coil embolization of bifurcation aneurysms by the senior author (A.M.M.) at Tufts Medical Center, USA. Both the open-cell design Neuroform (Stryker Neurovascular, Fremont, CA, USA) and the closed-cell design Enterprise (Codman Neurovascular, Raynham, MA, USA) stents were used. Patient demographics, clinical information and radiographic data were maintained in a prospectively collected database.

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Three men and 17 women with a mean age of 57.6 ± 10.8 years were treated. Aneurysms were located at the basilar artery (BA) bifurcation in 14 patients, internal carotid artery bifurcation in four patients, and the middle cerebral artery (MCA) bifurcation in two patients (Table 1). Presenting signs and symptoms, reports, and images were reviewed for aneurysm obliteration rates and the occurrence of complications. Follow-up clinical and radiographic records were analyzed for evolution of clinical symptoms, identification of new radiographic abnormalities such as ischemic stroke, and the development of aneurysm recurrence and retreatment. Final aneurysm occlusion rates were measured using the Raymond grade occlusion scale, with grade I indicating complete occlusion, grade II indicating residual neck filling, and grade III indicating residual sac filling.

All patients underwent dual anti-platelet therapy using aspirin 325 mg and clopidogrel 75 mg once a day for at least 3 days prior to the procedure. Platelet aggregation studies were first introduced at our institution in October 2011, and thus these results were not available for the entire population.

After femoral arterial access was obtained, a heparin bolus was administered intravenously to achieve anticoagulation with confirmed activated clotting time >220 seconds. A 5- or 6-French Envoy guide catheter (14 patients, 70%, and six patients, 30%, respectively) was introduced into the target arterial system. Dual guide catheters were employed in one patient (5%) while the remaining 19 procedures (95%) were performed using a single guide catheter.

Guide catheters were navigated to the cerebral circulation, and the target vessel was selected and cannulated. Prior to advancement of guide catheters into parent vessels, verapamil 5 mg was infused to mitigate iatrogenic vasospasm and ease catheter manipulation. The Neuroform stent was advanced through a Neuro Renegade 0.027" microcatheter over a Synchro or Synchro-2 soft microwire (all Stryker Neurovascular) in the artery and deployed using the transfer technique, with the second daughter vessel microcatheterized using a tri-axial technique using the stent insert pusher over the microwire. The Enterprise stent was deployed using a Prowler Plus microcatheter (Codman Neurovascular, Raynham, MA, USA). In cases where stent deployment was followed by coil embolization of the target aneurysm, a microcatheter was navigated through the deployed stent cells and into the aneurysm dome. After placement of a framing coil, further coiling was carried out until there was undue risk of coil herniation into the parent vessels with further coiling. Aneurysm obliteration and cessation of filling was confirmed at the end of the procedure by contrast injection.

The current study was approved by the Institutional Review Board of Tufts Medical Center (IRB# 7525).

Table 1
Demographics and procedural information for aneurysm patients treated with the Y-stent technique

	n	%
Total patients	20	–
Sex		
Male	3	15
Female	17	85
Average age (years)	57.6	–
Aneurysm location		
Basilar artery bifurcation	14	70
Internal carotid artery bifurcation	4	20
Middle cerebral artery bifurcation	2	10
Treatment method		
Stent coiling	18	90
Stenting only	2	10
Stent type		
Neuroform-Neuroform[a]	18	95
Neuroform-Enterprise	1	5
Enterprise-Enterprise[b]	1	5

[a] Stryker Neurovascular, Fremont, CA, USA.
[b] Codman Neurovascular, Raynham, MA, USA.

3. Results

Y-stent mediated embolization of an intracranial aneurysm was attempted in 22 patients and was successful in 20 (91%). Stent deployment without coiling was employed in two patients (10%). Dual Neuroform stents were used in 18 patients (Fig. 1), dual Enterprise stents were used in one patient with an MCA bifurcation aneurysm (Fig. 2), and hybrid stents (Enterprise and Neuroform) were used in one patient with a BA bifurcation aneurysm.

There were two cases where Y-stenting was attempted but could not be completed; both of these patients presented with coil compaction after initial single stent-mediated coiling. In the first patient, who had previously undergone Neuroform stent-mediated coiling of a BA bifurcation aneurysm, a second stent could not be deployed because micro-wires could not be successfully navigated to the P1 segment of the contralateral posterior cerebral artery (PCA) due to the obtuse angle between the BA and PCA. In the second patient, who had previously undergone Enterprise stent-mediated coiling of a BA bifurcation aneurysm, after the micro-wire was traversed through the closed-cell design cell, the microcatheter was unable to follow because of consistent wedging and trapping within the narrow angle of the trapeze-shaped cell of the deployed Enterprise stent.

Indications for embolization included seven incidentally found aneurysms (35%), four patients with aneurysm discovered during workup for transient ischemic attack (20%) (Fig. 3), three retreatments of recanalized aneurysms that had been acutely coiled after initial rupture (15%), three found during workup for headache (15%), and two retreatments of a recanalized aneurysm that had been acutely stent-coiled after initial rupture (10%), and a previous unsuccessful clipping of a BA aneurysm from undue risk of perforator artery occlusion discovered at the time of microsurgery (5%).

Complete aneurysm occlusion was achieved after the initial embolization procedure in 18 patients (90%). In two patients with increasing residual aneurysm filling after initial coiling of ruptured BA bifurcation aneurysm (42 months post-coiling) and a ruptured internal carotid artery bifurcation aneurysm (4 months post-coiling), dual Neuroform stents were deployed in a Y-fashion without further coiling to induce flow diversion and vascular remodeling. The procedures were technically successful, and residual aneurysm filling diminished and stabilized on follow-up in both patients. All patients were neurologically stable after the Y-stent procedure, upon discharge.

Patient follow-up was available for all 20 patients, with clinical follow-up available for a mean of 20.0 ± 16.6 months (range 3–51 months) and radiographic follow-up (magnetic resonance angiography or conventional angiography) available for a mean of 18.5 ± 16.9 months (range 3–51 months).

Following Y-stenting, aneurysms recanalized in three patients (15%) at 9 months, 10 months, and 22 months after Y-stent deployment. These patients underwent through-stent coiling, and the procedures were technically successful without complication in two patients. In the third patient, coiling was arrested with a 1 mm residual remaining because of undue risk of coil herniation on the posterior margin, from which was seen to emanate thalamoperforating arteries. On post-operative day 1, the patient noted intermittent blurred vision; diffusion-weighted MRI demonstrated bilateral thalamic, bilateral occipital lobe, and left cerebellar infarcts. Repeat angiography demonstrated no evidence of in-stent

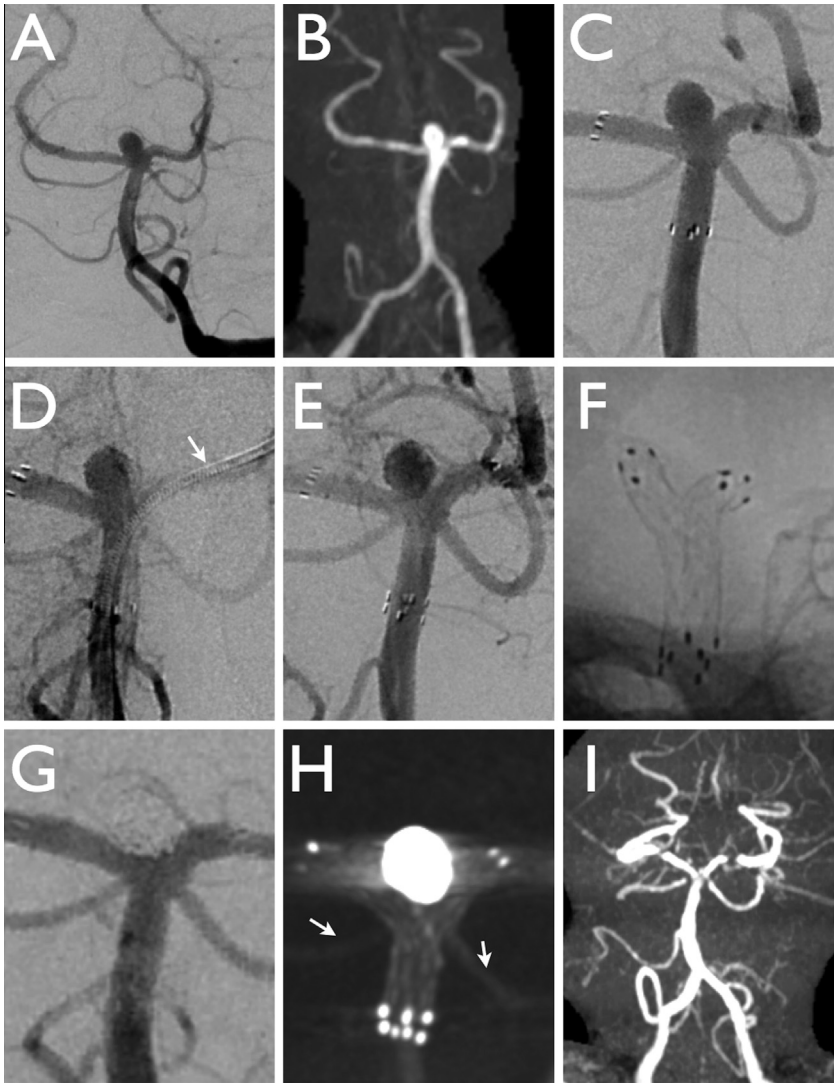


Fig. 1. A pentagenarian presented with an incidentally found 5 mm aneurysm of the basilar artery bifurcation. Anteroposterior (AP) projection digital subtraction angiography (DSA) (A) and three-dimensional magnetic resonance angiography (MRA) reconstructions (B) demonstrate an aneurysm harboring a 3 mm wide neck based off the origin of the right posterior cerebral artery (PCA). After a single Neuroform (Stryker Neurovascular, Fremont, CA, USA) stent-mediated approach to the right PCA (C) was felt to provide insufficient coil support, a micro-catheter (arrow) was navigated into the left PCA (D) and a second Neuroform stent was deployed in Y-fashion (E, AP projection DSA; F, AP projection unsubtracted angiography). With adequate coverage of the aneurysm neck and bilateral PCA protection achieved, the target aneurysm was coiled with no residual at the end of the procedure (G). Dyna-CT imaging (Siemens AG, Munich, Germany) with dilute contrast injection (H) confirmed placement of the stents and patency of the bilateral PCA and superior cerebellar arteries (arrows). MRA (I) acquired 3 months post-operatively showed absence of residual aneurysm filling.

thrombosis. The patient's symptoms stabilized and improved over the course of follow-up, with near complete resolution of symptoms at the time of the latest clinic visit (40 months after Y-stent deployment, 30 months following complication).

At latest radiographic follow-up, Raymond grade I occlusion was achieved in 16 patients (80%), Raymond grade II occlusion in four patients (20%; 1 mm residuals in two patients and 1.5 mm residuals in two patients). One patient was found to harbor clinically silent in-stent stenosis of the BA and bilateral PCA. Follow-up MRI after a mean of 15.4 months demonstrated no evidence of new ischemic events in any patient.

At latest clinical follow-up, neurological examinations remained stable from pre-Y-stenting status with no major subjective complaints in all patients. Latest modified Rankin scale scores for the six patients with a history of subarachnoid hemorrhage were 0 in three patients, 1 in two patients, and 2 in one patient. All neurological deficits for these patients were present prior to Y-stent deployment.

4. Discussion

The current series reports patients undergoing Y-stenting for treatment of intracranial aneurysms at a single institution. A technique first introduced to the neurointerventional literature in 2004 [12], Y-stenting offers a valuable alternative for wide-necked aneurysms located at large intracranial arterial bifurcations.

By providing simultaneous scaffolding of the aneurysm neck and protection of the distal arterial branches, Y-stenting minimizes the risks of coiling alone and single stent-mediated coiling. Chalouhi et al. found that Y-stent patients were no more likely to have a thromboembolic complication than patients receiving a single stent for treatment of a BA bifurcation aneurysm, while the Y-stent cohort featured higher efficacy with regards to recanalization and retreatment rates over both single stent and coiling alone cohorts [13].

Series evaluating the efficacy of single Neuroform stent-mediated aneurysm coiling have overall demonstrated high rates

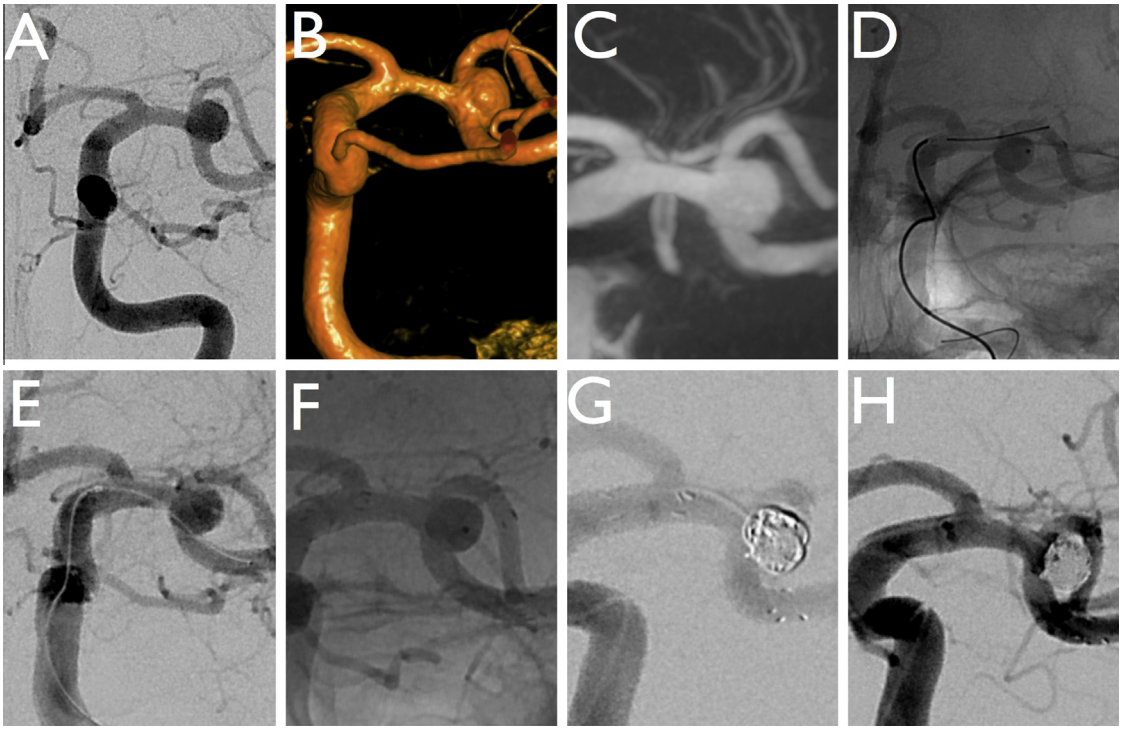


Fig. 2. A pentagenarian presenting with headache was found to harbor a 6.8 mm aneurysm of the left middle cerebral artery. Anteroposterior (AP) projection digital subtraction angiography (DSA) (A), three-dimensional reconstruction (B), and cone-beam CT angiography (C) demonstrate a wide 3.9 mm neck. Treatment was planned with two Enterprise stents (Codman Neurovascular, Raynham, MA, USA), the first of which was deployed in the superior division of the middle cerebral artery (MCA) (D, AP projection unsubstracted angiogram) and the second of which was deployed in the inferior division of the MCA (E, AP projection DSA). After deployment of the two Enterprise stents in a Y-fashion (F, AP projection unsubstracted angiogram), the target aneurysm was coiled (G, AP projection DSA) with no evidence of residual filling at the completion of the procedure. Angiographic follow-up at 3 months (H, AP projection DSA) demonstrated persistent removal of the aneurysm from the cerebral circulation. (This figure is available in colour at http://www.sciencedirect.com/.)

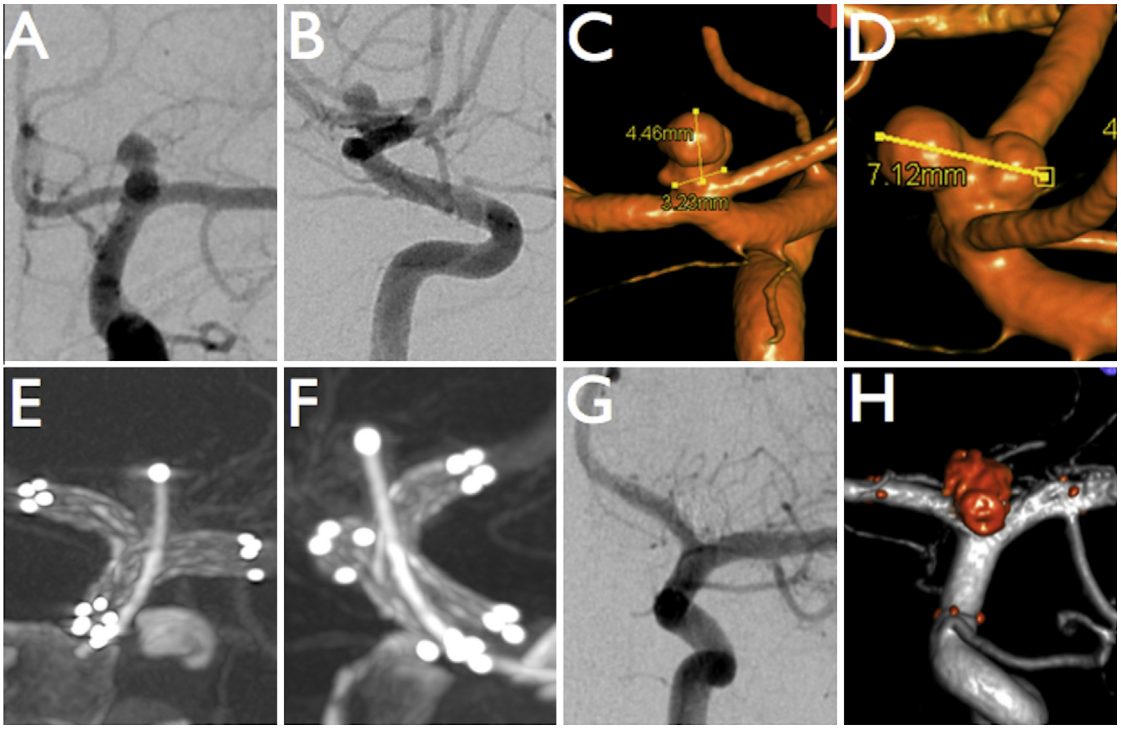


Fig. 3. A quadragenarian presenting with transient ischemic attacks was found to harbor a left internal carotid artery (ICA) bifurcation aneurysm on (A) anteroposterior (AP) and (B) lateral-projection digital subtraction angiography (DSA). With a 4.46 mm dome and a wide 3.23 mm neck on AP projection three-dimensional (3D) reconstruction (C), the aneurysm harbored a large maximum length of 7.12 mm with a posteriorly oriented daughter aneurysm on lateral-projection 3D reconstruction (D). Treatment was planned with dual Neuroform stents (Stryker Neurovascular, Fremont, CA, USA) deployed in a Y-fashion, with the dome of the aneurysm selected using a microcatheter after stent deployment, shown on AP (E) and lateral-projection (F) cone-beam CT angiography. The aneurysm was successfully coiled and 1 year follow-up (G) AP projection unsubstracted angiography and (H) 3D reconstruction angiography demonstrated no residual filling of the aneurysm. (This figure is available in colour at http://www.sciencedirect.com/.)

of aneurysm occlusion with low retreatment and complication rates. Santillan et al., in a report on 79 aneurysms treated with single Neuroform stent-mediated aneurysm coiling, identified a 69.7% rate of complete aneurysm occlusion at 12 months, a finding that progressed to 96.5% at 84 months with a 14% rate of retreatment within 8.6 months [14]. Biondi et al. [2] noted a 7.1% rate of procedure-related morbidity and mortality, while other reports on delayed clinical outcome have indicated unfavorable clinical outcomes in 9.3–16.7% of patients [15,16].

For comparison, in the current series utilizing Y-stent technique, Raymond grade I or II occlusion was achieved in 100% of aneurysms after a mean follow-up of 20.0 months. Aneurysm retreatment was required in 3/20 patients (15%), with neurological complications (symptomatic cerebrovascular accident) in one patient (5%). For comparison, Spiotta et al. studied 19 patients with aneurysms embolized by the Y-stent technique over 21.4 months and identified a 63% occlusion rate, 21% retreatment rate, and neurological complications in six patients [17]. A multicenter study of 45 patients with Y-configuration stents with a mean clinical follow-up of 7.8 months and a mean radiographic follow-up of 9.8 months identified procedural complications in 11% of patients with 92% of patients achieving Raymond grade I or II occlusion [18]. These authors noted no difference in aneurysm occlusion rates or clinical outcomes between patients treated with closed-cell or open-cell design stents.

As previously noted by our group, stent reconstruction of arterial bifurcations can induce cerebrovascular remodeling that redistributes hemodynamic forces at the peri-aneurysm site [19,20]. Following Y-stent deployment, the subsequent straightening and narrowing of the bifurcation angles resulted in shifting and focusing the area of high shear stress gradients at the aneurysm neck. Cekirge et al. noted that Y-stenting performed in the absence of coiling still resulted in a high rate of aneurysm occlusion [21]. The authors of that study attributed their finding to flow diversion by the stent struts away from the aneurysm neck. Given the high porosity of the Neuroform and Enterprise stents, the principles of cerebrovascular remodeling and flow diversion may provide summative effects responsible for the low observed rate of aneurysms requiring retreatment after undergoing Y-stent embolization.

Deployment of dual intracranial stents in a Y-configuration remains technically complex. Once the first stent has been deployed from the BA to the PCA, navigation of a microcatheter to the contralateral PCA can be difficult. In some instances, navigation into a PCA may be technically unfeasible due to an unfavorable bifurcation angle. Further, navigation across the struts of the primary stent may also be complex, especially with the closed-cell design struts of the Enterprise stent. Once both stents have been deployed, one must navigate a microcatheter into the dome of the aneurysm in order to proceed with coiling.

The Y-stenting technique for embolization of bifurcation aneurysms appears both safe and effective. Y-stenting may improve aneurysm occlusion rates through both cerebrovascular remodeling and flow diversion. With concerns regarding the preservation of perforator arteries after deployment of flow diverters in the vertebro-basilar circulation [22], Y-stenting may offer a suitable alternative for those patients amenable to this technique as the large porosity of the Neuroform and Enterprise stents can preserve flow to basilar perforators.

Conflicts of Interest/Disclosures

A.M.M. has received unrestricted research support from Microvention, Stryker Neurovascular, Codman Neurovascular, Siemens, Ansys, and CD-Adapco for unrelated work. The other authors declare that they have no financial or other conflicts of interest in relation to this research and its publication.

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