Original Paper

LVIS Jr Device for Y-Stent-Assisted Coil Embolization of Wide-Neck Intracranial Aneurysms: A Multicenter Experience

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Keywords

Aneurysm · Stenting · Stent-assisted coiling · Y-stent

Abstract

Background and Purpose: Complex wide-neck intracranial aneurysms are challenging to treat. We report a multicenter experience using the LVIS Jr stent for "Y-stent"-assisted coiling embolization of wide-neck bifurcation aneurysms. **Methods:** Seven centers provided retrospective data on patients who underwent Y-stenting. Technical complications, immediate posttreatment angiographic results, clinical outcomes, and imaging follow-up were assessed. **Results:** Thirty patients/aneurysms were treated: 15 basilar tip, 8 middle cerebral artery, 4 anterior communicating artery, 1 pericallosal, and 2 posterior inferior cerebellar artery aneurysms. The mean aneurysm size was 11 mm and the mean dome-to-neck ratio was 1.3 mm. Twenty-four aneurysms were unruptured and treated electively, and 6 were acutely ruptured. Fifty-eight LVIS Jr stents were successfully deployed without any technical issue. One procedural and transient in-stent thrombosis resolved with the intravenous infusion of a glyco-

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protein IIb/IIIa inhibitor. Five periprocedural complications (within 30 days) occurred: 2 periprocedural neurological complications (1 small temporal stroke that presented with transient aphasia and 1 posterior cerebral artery infarct) and 3 nonneurological periprocedural complications (2 retroperitoneal hematomas, and 1 patient developed a disseminated intravascular coagulopathy). One permanent complication (3.3%) directly related to Y-stenting was reported in the patient who suffered the posterior cerebral artery infarct. Immediate complete obliteration (Raymond-Roy Occlusion Classification [RROC] I–II) was achieved in 26 cases (89.6%). Twenty-four patients had clinical and imaging follow-up (mean 5.2 months). Complete angiographic occlusion (RROC I–II) was observed in 23 patients (96%). A good functional outcome with a modified Rankin Scale score ≤ 2 was achieved in 26 cases. **Conclusions:** In this multicenter case series, Y-stent-assisted coiling of wide-neck aneurysms with the LVIS Jr device was feasible and relatively safe. Follow-up imaging demonstrated very low recanalization rates.

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Introduction

Several stent configurations have been used for the treatment of wide-neck bifurcation aneurysms. Y-stenting was first described by Chow et al. [1], and since then has been used extensively. The technical success of Y-stenting ranges between 88.9 and 100%, with a procedural complication rate between 0 and 21% [2]. In vitro studies comparing different stent constructs with the closed-cell Enterprise stent (Codman) demonstrated that the configuration with crossing-Y-stents had the strongest reduction in flow velocity in the sac of the aneurysm due to lower stent porosity and major flow diversion [3]. However, these in vitro models also demonstrated stent narrowing at the point of intersection of the two stents. Clinical data have also shown that Y-stenting has lower rates of recanalization (8.3%) and retreatment when compared with single-stenting in the treatment of basilar tip aneurysms [4]. However, Y-stenting is not exempt from complications such as stent thrombosis, defective wall apposition of the stent, and incomplete stent opening.

Y-stenting has been described with the closed-cell Enterprise stent and the open-cell Neuroform stent (Stryker). The LVIS Jr (Low-Profile Visualized Intraluminal Support Junior) stent (MicroVention) is a self-expandable stent that consists of a single nitinol wire braid with radiopaque helical strands. It can be deployed through a microcatheter with a 0.0165-inch inner diameter, facilitating easier access to small and tortuous vessels when compared to other stents delivered through 0.021- and 0.027-inch microcatheters. The LVIS Jr stent has braided and compliant 1.5-mm cells which are moveable and allow recatheterization through the stent cells [5].

We describe a multicenter experience in treating wide-neck bifurcation aneurysms with LVIS Jr stents in a Y-stent configuration.

Methods

Nonconsecutive patients from seven tertiary centers (University of Iowa, Iowa City, IA, USA; Baptist Neuroscience Center, Miami, FL, USA; Valley Baptist Medical Center, Harlingen, TX, USA; Boston University, Boston, MA, USA; Sestre Milosrdnice Hospital, Zagreb, Croatia; Sanford Brain & Spine Center, Fargo, ND, USA; and Texas Tech University Health Sciences Center, El Paso, TX, USA) who underwent Y-stenting of wide-neck bifurcation aneurysms using the LVIS Jr device were included in the study. An institutional review board at each institution approved the retrospective analysis of prospectively acquired data. Technical aspects of the procedure, complications, and radiological and clinical outcomes were recorded and analyzed.

Fig. 1. Schematic representation of Y-stent-assisted coil embolization of a basilar tip aneurysm. The coiling microcatheter (yellow) is “jailed” in the aneurysm. The first coil is usually partially deployed before stenting. In this way we decrease the risk of aneurysmal perforation, since the coiling microcatheter may move back and forth during stenting. After the first stent has been deployed in the posterior cerebral artery with the most difficult access, we deploy the second stent through the first stent. We then access the aneurysm with a Headway 17 microcatheter (green) through the interstices of the second stent to perform a two-microcatheter coiling. In this way we achieve better packing, since the aneurysm is coiled from two different compartments.

Anticoagulation and Antiplatelet Protocols

All elective cases received dual antiplatelet therapy at least 7 days before the procedure: acetylsalicylic acid (ASA) (81/325 mg/day), clopidogrel (75 mg/day), or ticagrelor (90 mg b.i.d.). Patients with an acute subarachnoid hemorrhage received a loading dose of 325 mg ASA, 300 mg clopidogrel, or 90 mg ticagrelor the day before the procedure. One patient received cilostazol (100 mg b.i.d.) due to ASA allergy. Four of the seven participating centers monitored and modified the antiplatelet therapy based on individual responses. If responses to ASA and clopidogrel were below the therapeutic range, patients were given an extra dose of ASA or clopidogrel before the procedure. During the procedure, heparin was administered to achieve an activated clotting time ≥ 250 s.

Endovascular Technique

All interventions were performed under general anesthesia after informed consent had been obtained. In general, an intermediate access catheter was positioned in either the intracranial internal carotid artery or the V3 segment of the vertebral artery. The aneurysmal sac was accessed with a 0.017-inch microcatheter, and a loop of the first coil was partially deployed in the aneurysm to prevent perforation of the aneurysm while stenting. Subsequently, the side branch with the most challenging access was catheterized with a Headway 17 microcatheter (MicroVention). Then the first stent was slowly deployed while the first microcatheter was jailed. A second LVIS Jr stent was then deployed to achieve a “Y configuration.” In this way, the second stent was placed through the first stent. The aneurysm was then coiled through the jailed microcatheter (Fig. 1). In some cases the Headway microcatheter used to deploy the second LVIS Jr stent was used to access the aneurysm and perform dual coiling with two microcatheters of two different aneurysmal compartments. This was intended to achieve a better packing density (Fig. 1).

Clinical and Radiological Follow-Up

Patients were closely monitored in the intensive care unit after treatment. In general, dual antiplatelets were administered for at least 3 months. Postoperative follow-up with a catheter angiogram or magnetic resonance angiography was typically performed within 6 months after the intervention. Angiographic occlusion of the aneurysm was graded utilizing the Raymond-Roy Occlusion Classification (RROC). Functional outcome was defined utilizing the modified Rankin Scale (mRS).

Results

A total of 30 patients were treated, 20 of whom were women (66.6%). The mean age was 63 years (range 42–78). The following aneurysms were included: basilar tip ($n = 15$); middle cerebral artery (MCA) ($n = 8$); anterior communicating artery ($n = 4$); pericallosal artery ($n = 1$); and posterior inferior cerebellar artery (PICA) aneurysms ($n = 2$). A PICA aneurysm and the pericallosal artery aneurysm had a fusiform shape, the rest were saccular aneurysms. Twenty-four aneurysms were unruptured and treated electively, and 6 were acutely ruptured. The mean aneurysm size was 11 mm (range 3–30), with a mean dome-to-neck ratio of 1.3 mm (range 0.7–2.3). Fifty-eight LVIS Jr stents were successfully deployed. No technical difficulties with stent deployment were reported (Table 1). One procedural and transient in-stent thrombosis (IST) occurred after placement of the first stent in re-treating an anterior communicating artery aneurysm (patient 19). The IST was probably related to tortuosity of the A1/A2 segment and poor stent expansion at this level. The IST resolved after angioplasty of the stent with a Scepter balloon (MicroVention) to achieve better wall apposition and after intravenous administration of a glycoprotein IIb/IIIa inhibitor (GPI).

Patient 11 developed basilar artery thrombosis after placement of a Woven EndoBridge (WEB) device (Sequent Medical) for treatment of a basilar tip aneurysm. In this patient, LVIS Jr Y-stenting through a Scepter balloon was performed as a bailout maneuver to recanalize the basilar artery. Despite the intra-arterial (IA) administration of tissue plasminogen activator and intravenous administration of a GPI, the patient died due to a basilar artery occlusion. Since the initial thrombotic event was not a direct consequence of Y-stenting with an LVIS Jr stent, this event was not accounted a complication in this series. Patient 30 also underwent placement of a WEB device. However, part of the device was protruding into the basilar artery bifurcation. Y-stenting was performed as a bailout maneuver, achieving great intrasaccular positioning of the WEB device.

Five patients (5/29) experienced periprocedural complications: 2 were neurological complications (1 transient aphasia due to a temporal lobe stroke and 1 posterior cerebral artery infarct) and 3 were nonneurological complications (2 retroperitoneal hematomas and 1 disseminated intravascular coagulation). The patient with the transient aphasia completely recovered before discharge (patient 7). Brain magnetic resonance imaging demonstrated a small stroke in the temporal lobe. Patient 12 developed a posterior cerebral artery occlusion 1 h after extubation. Despite IA infusion of GPIs, the posterior cerebral artery did not recanalize. An attempt to place a balloon into the stent for angioplasty was unsuccessful, and the patient suffered a right midbrain and posterior cerebral artery territory stroke. This patient had an mRS score of 4 on follow-up.

The 2 patients with retroperitoneal hematomas (patients 10 and 17) had symptomatic hypotension. One of these patients was a hyperresponder to clopidogrel with a platelet reactivity of 7 units (reference 194–418). Both patients were discharged home with a normal neurological examination. A patient with a ruptured PICA aneurysm developed disseminated intravascular coagulation during the procedure and required multiple blood and platelet transfusions (patient 22). Despite maximal medical therapy, the patient developed systemic complications with lung hemorrhage and the family decided to withdraw care. Patient 23 presented with a ruptured basilar tip aneurysm and a Hunt and Hess grade of 4. The patient had an eventful hospitalization with vasospasm and multiple medical complications. Although the endovascular treatment was successful, the patient did not show neurological improvement and the family withdrew care. Asymptomatic intimal hyperplasia in an LVIS Jr stent placed in an A2 segment was visualized on the 6-month follow-up diagnostic angiogram of patient 4.

Patient 15 underwent treatment of an MCA bifurcation aneurysm with a Barrel device (Reverse Medical). Due to incomplete neck coverage, it was decided to perform Y-stenting

Table 1. Patient characteristics

Patient	Age, years/ gender	Lo- cation	AS, mm	NS, mm	D/N, mm	P	Stent #1: size, mm	Stent #2: size, mm	Im- mediate RROC	Procedural compl- ications	30-day compl- ications	F/u, months/ modality	F/u RROC	Out-come, mRS score
1	57/F	MCA	6 × 3	3	1	R	LVIS Jr 2.5 × 17	LVIS Jr 3.5 × 23	I	N	N	6/DSA	I	0
2	72/M	MCA	5 × 5	4	1.2	R	LVIS Jr 2.5 × 17	LVIS Jr 2.5 × 23	I	N	N	6/DSA	I	2
3	42/M	BT	10 × 13	11	1.2	UR	LVIS Jr 2.5 × 23	LVIS Jr 2.5 × 17	I	N	N	6/DSA	I	0
4	76/M	ACOM	5 × 4	4	1	UR	LVIS Jr 2.5 × 23	LVIS Jr 2.5 × 23	I	N	N	5/MRA	I	1
5	59/F	BT	8 × 8	7	1.1	UR	LVIS Jr 3.5 × 28	LVIS Jr 2.5 × 23	IIIa	N	N	6/DSA	II	1
6	69/F	BT	6 × 7	5	1.4	UR	LVIS Jr 3.5 × 23	LVIS Jr 2.5 × 23	IIIa	N	N	6/DSA	IIIa	0
7	69/F	MCA	3 × 3	4	0.7	UR	LVIS Jr 2.5 × 23	Neuroform 2.5 × 15	I	N	S	6/DSA	I	0
8	61/F	BT	8 × 9	4	2.2	UR	LVIS Jr 2.5 × 23	LVIS Jr 2.5 × 17	I	N	N	5/DSA	I	0
9	78/F	MCA	7 × 7	5	1.4	UR	LVIS Jr 2.5 × 23	LVIS Jr 2.5 × 17	IIIa	N	N	4/DSA	I	0
10	54/F	BT	16 × 11	9	1.2	UR	LVIS Jr 3.5 × 28	LVIS Jr 3.5 × 28	II	N	RH	7/DSA	I	0
11	62/F	BT	7 × 5	5	1	UR	LVIS Jr 3.5 × 23	LVIS Jr 3.5 × 18	–	N	Death	–	–	6
12	47/F	BT	15 × 15	11	1.3	UR	LVIS Jr 3.5 × 28	LVIS Jr 3.5 × 23	II	N	S	11/DSA	II	4
13	78/F	ACOM	4 × 6	4	1.5	UR	LVIS Jr 2.5 × 23	LVIS Jr 2.5 × 17	II	N	N	6/DSA	I	0
14	71/F	BT	9 × 7	8	0.8	UR	LVIS Jr 3.5 × 23	LVIS Jr 3.5 × 18	I	N	N	6/DSA	I	0
15	62/F	MCA	4 × 4	4	1	R	LVIS Jr 2.5 × 23	Barrel 3.5 × 5 × 20	I	N	N	6/DSA	I	0
16	69/M	BT	5 × 3	3	1	UR	LVIS Jr 2.5 × 23	LVIS Jr 2.5 × 17	II	N	N	3/MRA	II	0
17	63/M	MCA	5 × 4	3	1.3	UR	LVIS Jr 3.5 × 23	LVIS Jr 2.5 × 17	II	N	RH	3/MRA	I	0
18	65/F	BT	8 × 7	4	1.7	UR	LVIS Jr 2.5 × 23	LVIS Jr 2.5 × 17	II	N	N	3/MRA	II	0
19	55/M	ACOM	5 × 4	4	1	R	LVIS Jr 2.5 × 23	LVIS Jr 3.5 × 18	I	IST	N	3/MRA	I	0
20	68/F	BT	30 × 30	13	2.3	UR	LVIS Jr 3.5 × 23	LVIS Jr 3.5 × 23	I	N	N	3/DSA	II	2
21	69/M	ACOM	22 × 22	14	1.6	UR	LVIS Jr 3.5 × 23	LVIS Jr 3.5 × 23	I	N	N	12/DSA	I	0
22	76/F	PICA	3 × 3	3.5	0.9	R	LVIS Jr 3.5 × 23	LVIS Jr 4.5 × 23	I	N	DIC	–	–	6
23	58/F	BT	14 × 14	12	1.2	R	LVIS Jr 3.5 × 23	LVIS Jr 3.5 × 23	I	N	N	0.25/DSA	I	6
24	66/F	BT	9 × 9	8	1.1	R	LVIS Jr 3.5 × 23	LVIS Jr 3.5 × 23	I	N	N	12/DSA	I	0
25	61/M	PICA	4 × 4	4	1	UR	LVIS Jr 3.5 × 23	LVIS Jr 4.5 × 23	I	N	N	6/DSA	I	0
26	66/F	BT	11 × 11	7	1.6	UR	LVIS Jr 3.5 × 23	LVIS Jr 3.5 × 23	I	N	N	6/DSA	I	0
27	67/M	MCA	9 × 9	4	2.2	UR	LVIS Jr 2.5 × 17	LVIS Jr 2.5 × 17	I	N	N	6/MRA	I	0
28	58/M	MCA	5 × 4	3	1.6	UR	LVIS Jr 3.5 × 18	LVIS Jr 2.5 × 13	I	N	N	Pending	Pending	0
29	61/F	Peri- callosal	6 × 4	4	1.5	UR	LVIS Jr 2.5 × 23	LVIS Jr 2.5 × 23	I	N	N	Pending	Pending	0
30	60/F	BT	9 × 8	6	1.5	UR	LVIS Jr 2.5 × 23	LVIS Jr 3.5 × 23	I	N	N	Pending	Pending	0

MCA, middle cerebral artery; BT, basilar tip; ACOM, anterior communicating artery; PICA, posterior inferior cerebellar artery; AS, aneurysm size; NS, neck size; D/N, dome-to-neck ratio; P, presentation; R, ruptured; UR, unruptured; RROC, Raymond-Roy Occlusion Classification; N, none; IST, in-stent thrombosis; S, stroke; RH, retroperitoneal hematoma; DIC, disseminated intravascular coagulation; F/u, follow-up; DSA, digital subtraction angiography; mRS, modified Rankin Scale.

Fig. 2. Three patients with acutely ruptured basilar artery (**a**, **b**) and anterior communicating artery (**c**) aneurysms underwent balloon-assisted coiling (BAC). The posttreatment angiograms demonstrated a minimal residual neck (**a1–c1**). The 6-month follow-up diagnostic angiograms demonstrated aneurysm recurrence and coil compaction (**a2–c2**, white arrows). The patients underwent Y-stenting (**a3–c3**) with no evidence of recurrence on follow-up imaging.

Fig. 3. a Unruptured left middle cerebral artery aneurysm treated with two LVIS Jr stents (2.5 × 13 mm in the superior M2 division and 3.5 × 18 mm in the inferior M2 division). **b** Notice the change of angulation and superior division side branch geometry after placement of the LVIS Jr devices.

with an LVIS Jr stent. Patients 3, 16, and 19 presented with ruptured aneurysms and were treated with balloon-assisted coiling, achieving an RROC of II (Fig. 2). Recanalization was documented on the follow-up diagnostic angiography, and Y-stenting was performed as a definite treatment. Patient 7 presented with recanalization of a previously treated left MCA aneurysm with stent-assisted coiling (Neuroform). This patient underwent successful

retreatment with an LVIS Jr stent in a Y-stent configuration with the previously deployed stent.

Immediate complete obliteration (RROC I–II) was achieved in 26 cases (89.6%), and residual aneurysm (RROC IIIa) in 3 cases (11%). Twenty-four patients had clinical and imaging follow-up (a mean of 5.2 months). Angiographic occlusion of the aneurysm (RROC I–II) on follow-up was observed in 23 patients (96%), and partial aneurysm recanalization (RROC IIIa) in 1 patient (4%). A good functional outcome (mRS score ≤ 2) was observed in 26 cases. No patients underwent additional endovascular treatments after Y-stenting. Only 1 patient (3.3%) had permanent neurologic deficits related to Y-stenting on follow-up.

Discussion

Y-stent-assisted coiling has been described as a feasible alternative to microsurgical clipping for a subset of challenging bifurcation aneurysms. This multicenter case series demonstrates that Y-stenting with the braided low-profile stent LVIS Jr is technically feasible. We did not experience any complications accessing bifurcation branches or during stent deployment. Fifty-seven of the 58 deployed stents were well apposed to the parent artery and protected the aneurysm's neck for coiling. In 1 case the stent was not well apposed to a tortuous A1/A2 segment and required angioplasty. In 2 cases the Y-stent construct was formed with an LVIS Jr stent and a different device: a Neuroform stent and a Barrel device.

Y-stenting offers multiple advantages in aneurysm remodeling: support to prevent coil mass herniation, blood flow diversion, a scaffold for neo-endothelialization, modification of the parent vessel-aneurysm geometry, and remodeling of the affected branches (Fig. 3) [6, 7]. Moreover, the flow diversion effect of Y-stenting or even of LVIS Jr alone could result in successful and stable aneurysm occlusion without aneurysm coiling [8–10]. This has been reported for small bifurcation aneurysms in which the angioarchitecture of the parent arteries and the aneurysm is modified, favoring aneurysm occlusion. Computational fluid models have shown that Y-stent configurations redirect the flow away from the center of the aneurysmal neck, resulting in the greatest cross-neck flow reduction of wide-neck basilar aneurysms, more than with single stenting or T-stenting [11]. Y-stenting also decreases the shear stress inside the aneurysm sac by $>40\%$ [12].

The LVIS Jr stent can be safely deployed in parent vessels <2 mm through a 0.0165-inch microcatheter [10]. This is the smallest available stent delivery system. Selective catheterization of aneurysmal side branches is easier with smaller microcatheters. The LEO Baby (Balt), Acclino (Acandis), and Neuroform Atlas (Stryker) stents can also be delivered through a 0.0165-inch microcatheter. The LEO Baby stent is a braided stent like the LVIS Jr, whereas the Acclino is a laser-cut closed-cell stent and the Neuroform Atlas is a laser-cut hybrid-cell stent (Table 2). Machi et al. [13] reported a 17% complication rate (3 IST) with the LEO Baby stent. Akmanig et al. [14] reported the largest series of Y-stenting with the LEO Baby stent (4 patients). The authors underlined the advantages of these braided stents over other laser-cut open- and closed-cell stents (Enterprise, Neuroform, and Solitaire [Medtronic]), mainly better wall apposition and scaffolding. Tureli et al. [15] described 11 Y-stenting procedures with the Acclino stent with an 18% complication rate. The authors emphasize the closed-cell design of the Acclino stent with an electropolished surface, which theoretically decreases thrombogenicity. However, this design decreases stent conformability and enhances angular remodeling [15]. Similarly, Kabbasch et al. [16] described 3 cases of Y-stenting with the Acclino stent, with a 33% complication rate: 1 IST, which resolved with IA GPIs. Brassel et al. [17] reported their experience of kissing-Y-stenting with the Acclino stent, with a 14% complication rate (1/7). Ciccio et al. [18] reported their experience with the Neuroform Atlas stent

Table 2. Characteristics of the low-profile stents

Stent	Struts	Cell size, mm	Type	Resheathable length	Visibility
Acclino	Fixed	1.8	Laser cut; closed cell	90%	Proximal – distal ends
LVIS Jr	Mobile	1.5	Braided; closed cell	80%	Entire length
LEO Baby	Mobile	0.9	Braided; hybrid cell	95%	Entire length
Neuroform Atlas	Hybrid	–	Laser cut; hybrid cell	0%	Proximal – distal ends

Fig. 4. **a** In vitro configuration of a Y-stent construct with two LVIS Jr stents (3.5 × 23 and 3.5 × 28 mm) in a silicone model (Courtesy of MicroVention). **b** DynaCT (Siemens) image of a basilar tip aneurysm treated with Y-stenting-assisted coiling (LVIS Jr 2.5 × 23 and 2.5 × 17 mm). Note that the stents are completely expanded at the point of intersection of the two stents in the silicone model (**a**, black arrow) and the DynaCT image (**b**, white arrow).

in treating 36 aneurysms, 2 by Y-stenting. The complication rate was 5.5%, with 1 aneurysm perforation and 1 parent vessel perforation while attempting to implant the stent.

The LVIS Jr device has a small cell size of 1.5 mm, which may improve flow diversion and protect against coil protrusion [19]. The cells are also movable since they are braided, allowing catheterization of the aneurysm through the interstices and better configuration of the Y-stent construct (Fig. 4). This advantage has also been described for the other low-profile braided stent, the LEO Baby [14]. Moreover, the entire LVIS Jr stent is visible during fluoroscopy due to three interwoven radiopaque helical strands. Positioning and expansion of the device can be easily verified after deployment.

Previous series have reported low rates of deployment failure and ease of navigability with the LVIS Jr device [20–23]. Conrad et al. [24] described the first 2 cases of Y-stenting with the LVIS Jr stent for the treatment of basilar tip aneurysms. In their case series of 85 wide-neck aneurysms treated with LVIS Jr stents, Grossberg et al. [21] described only 1 deployment failure (1%). Some studies have reported stent migration with braided stents [14, 25]. We did not encounter any technical issues with the deployment or stability of the device in the 58 cases of this series. Later versions of the LVIS Jr stent have an increased radial force, which may explain why we did not experience any stent migration [23]. As opposed to the Neuroform Atlas stent, the LVIS Jr stent can be resheathed (up to 80%) to achieve a better position. Once completely deployed, we usually access the distal end of the stent with the delivery micro-

Table 3. Published series (≥2 cases) describing Y-stent-assisted coil embolization

First author [Ref.]	Patients/ aneurysms, <i>n</i>	Location, <i>n</i>	Stents	Technical success rate, %	Immediate RROC, %	Complications, <i>n</i>
Akgul [32]	9	ACOM: 3 MCA: 2 BT: 4	Enterprise and Neuroform	88.9	–	Stent protrusion: 1; IST: 1
Castano [33]	45	ACOM: 17 MCA: 20 BT: 4 ICA: 3 PCOM: 1	Neuroform	100	–	IST: 1
Chalouhi [4]	16	BT	Enterprise and Neuroform	–	I–II: 81	IST: 1
Darkhabani [34]	4	Pericallosal	Neuroform	100	–	None
Fargen [26]	45	ACOM: 3 MCA: 2 BT: 39 Pericallosal: 1	Enterprise and Neuroform	100	I–II: 84	SAH: 2; stent herniation into aneurysm: 1; stent migration: 1; event not specified: 1; cranial nerve palsy: 3; TIA: 1; RH: 1
Ko [35]	20	ACOM: 8 MCA: 1 BT: 9 Pericallosal: 2	Neuroform	100	I–II: 95 III: 5	IST: 6; SAH: 2; VA dissection: 1; coil migration: 1
Limbucci [27]	48	ACOM: 14 MCA: 20 BT: 11 ICA: 2 VB junction: 1	Enterprise	92.3	I–II: 94 III: 6	SAH: 2
Lozen [36]	6	MCA: 1 BT: 5	Neuroform	100	–	SAH: 1; coil failure: 1
Martínez-Galdámez [28]	6	ACOM: 2 MCA: 3 Pericallosal: 1	Solitaire AB	100	I–II: 100	None
Muda [37]	2	MCA: 1 BT: 1	Solitaire AB and LEO	100	–	None
Perez-Arjona [38]	3	BT	Neuroform	100	–	None
Spiotta [2]	19	ACOM: 1 BT: 18	Neuroform	100	I–II: 53 III: 47	SAH: 1; stent migration: 1; VA dissection: 1; stroke: 5
Thorell [39]	7	BT	Neuroform	85.7	I–II: 100	TIA: 2
Yavuz [30]	183	ACOM: 34 MCA: 113 ICA: 15 BT: 21	Enterprise, Neuroform, and Solitaire	–	I–II: 58 III: 42	SAH: 4; IST: 1; stroke: 4
Zhao [31]	9	ACOM: 2 MCA: 3 BT: 3 PCOM: 1	Enterprise and Neuroform	100	I–II: 100	None
Low-profile stents						
Möhlenbruch [25]	8	ACOM: 1 MCA: 3 BT: 4	LVIS Jr	100	I–II: 100	IST: 2
Conrad [24]	2	BT: 2	LVIS Jr	100	I–II: 100	None
Behme [5]	11	AC PC	LVIS Jr, LVIS, Enterprise, and Neuroform	100	I–II: 100	Vasospasm: 1; IST: 4
Kabbasch [16]	3	ACOM: 1 MCA: 1 BT: 1	Acclino	100	I: 100	IST: 1
Akmangit [14]	5	ACOM: 2 MCA: 2 BT: 1	LEO Baby and Enterprise	83	I–II: 100	SAH: 1; stent migration: 1
Tureli [15]	11	–	Acclino	84.6	I: 100	SAH: 1; IST: 1
Current study	30	ACOM: 4 MCA: 8 BT: 15 PICA: 2 Pericallosal: 1	LVIS Jr, Barrel, and Neuroform	100	I–II: 89 III: 11	IST: 1; stroke: 2; RH: 2; DIC: 1

RROC, Raymond-Roy Occlusion Classification; ACOM, anterior communicating artery; MCA, middle cerebral artery; BT, basilar tip; ICA, internal carotid artery; PCOM, posterior communicating artery; VB, vertebrobasilar; AC, anterior circulation; PC, posterior circulation; IST, in-stent thrombosis; SAH, subarachnoid hemorrhage; TIA, transient ischemic attack; RH, retroperitoneal hematoma; DIC, disseminated intravascular coagulation.

catheter to enhance stent expansion and wall apposition. Poncyłjusz et al. [23] described their experience with the LVIS and LVIS Jr stents in treating 78 wide-neck aneurysms. Bioengineering changes achieved with later versions of the LVIS Jr stent have improved the radial force and wall apposition of the device, which may translate into a better success rate during stent delivery. In our series, we only encountered 1 asymptomatic intimal hyperplasia in a stent placed in an A2 segment. We did not encounter any symptomatic stent stenosis, kinking, or stent migration on follow-up.

The reported rates of immediate angiographic occlusion (RROC I or II) with Y-stent-assisted coiling range from 52 to 100% [26–31]. In our series, immediate complete obliteration (RROC I–II) was achieved in 89.6% of the cases, similar to what has been described by Behme et al. [5]. Table 3 summarizes the largest cases series (≥ 2 cases) describing Y-stent-assisted coil embolization [4, 5, 14–16, 24–39].

In the present series, 1 patient died (patient 11) as a complication of basilar artery thrombosis after deployment of a WEB device and not associated with Y-stenting. Moreover, in a second patient, in whom the WEB device protruded into the basilar artery bifurcation, Y-stenting was used effectively as a bailout maneuver (patient 30). Only 1 patient (3.3%) had permanent neurological damage related to Y-stenting due to thrombosis of the posterior cerebral artery. One patient experienced transient aphasia after the procedure due to a small embolic infarct in the temporal lobe. We experienced 1 IST during deployment of the first stent in a tortuous A1/A2 segment, which resolved with intravenous infusion of a GPI. These complications underline the importance of adequate anticoagulation during the procedure and proper quantification of individual antiplatelet responses. Not all the participating centers in this cases series have an established protocol to quantify the response to ASA and clopidogrel. We strongly encourage platelet function assays to identify poor responders. We experienced 13% (4/30) thromboembolic complications. Other series with Y-stenting have reported complication rates between 11 and 31.6% [25, 26, 29]. Most of these complications are related to thromboembolic events. Ko et al. [35] described a 25% rate of acute IST in a series in which most patients (15/20) were treated with Y-stenting after failure of other neck remodeling techniques (balloon remodeling or single stenting). This underlines the importance of proper antiaggregation before Y-stenting. Ko et al. [35] and other authors [5, 10, 13, 15–17, 25, 40] have reported a complete resolution of procedure-related thromboembolic events after IA infusion of GPIs. The use of low-profile stents in vessels ≤ 2 mm may prompt the use of intravenous GPI infusions as part of the operative protocol to avoid thromboembolic complications.

Spiotta et al. [29] reported 19 cases of Y-stenting with Neuroform stents (first and second generation). The authors chose open-cell stents due to concerns about poor stent expansion with closed-cell stents at the crossing point of the Y configuration. Fargen et al. [26] reported their experience in treating 45 patients with Enterprise and Neuroform stents in a Y configuration. No significant difference was noted in procedural complications or follow-up angiographic occlusions with different stent combinations (Neuroform and Enterprise). Based on our results, braided stents like the LVIS Jr stent appear to have good conformability and expansion in a Y configuration (Fig. 4).

Behme et al. [5] treated 34 aneurysms with the LVIS Jr stent; 2 patients developed IST after stent deployment, which resolved with intravenous GPIs. This series included 11 Y-stentings. Machi et al. [13] argued that the intersection between a low-profile stent like the LEO Baby (braided) and an open-cell stent (Neuroform) theoretically reduces the risk of obstruction of the second stent at the point of intersection with the first stent. Our study includes the largest series of low-profile stents used in Y-stenting. Compared to other open- and closed-cell stent series, we did not encounter an increased risk of thromboembolic events or thrombosis at the intersecting point of the stents.

The main limitations of this study are its retrospective design, the heterogeneity of protocols at the different institutions, the lack of an independent core laboratory for imaging review, and the short duration of follow-up. However, the main aim of the paper was to describe the technical experience with the low-profile braided LVIS Jr stent in Y-stenting. The inclusion of data from multiple centers reflects real-world experience in using LVIS Jr stents for the treatment of complex wide-neck aneurysms.

Conclusions

Y-stent-assisted coiling of wide-neck bifurcation aneurysms with the LVIS Jr device is technically feasible and has a relatively low rate of complications. Moreover, follow-up imaging demonstrated very low recanalization rates.

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Statement of Ethics

This research has been approved by local IRBs.

Disclosure Statement

E.A.S.: consultant for MicroVention; T.N.N.: consultant for Penumbra; G.D.: consultant/speaker for Medtronic, MicroVention, Cerenovus, and Penumbra; shareholder of Surpass, Medina, InNeuroCo, and Three Rivers; I.L.: consultant/proctor for Medtronic, Stryker, and Codman; shareholder of Surpass, InNeuroCo, and Three Rivers; A.E.H.: consultant/speaker for MicroVention, Medtronic, Penumbra, Stryker, and GE Healthcare; A.D.: consultant for Medtronic and MicroVention; A.A.M., V.K., E.K., D.L., A.M., S.D., W.R.G., D.H., and S.O.-G.: nothing to disclose.

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