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CASE REPORT

Modified Y-configured stents with the waffle-cone technique by use of Solitaire® stent for patients with wide-necked bifurcation aneurysms

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Abstract Endovascular treatment of wide-necked bifurcation aneurysms can be challenging, despite improvements in endovascular techniques. Y stent-assisted coiling is one such technique, but this may not be technically feasible, especially in cases of acute angulation between the proximal and distal parent arteries, and may require use of "modified Y-configured stents with the waffle-cone technique". We report three cases of wide-necked bifurcation aneurysms that were successfully treated by use of the Solitaire® stent.

Keywords Waffle-cone technique · Solitaire® stent · Modified Y-configured stent

Introduction

Endovascular techniques developed to overcome the challenges posed by wide-necked bifurcation aneurysms include balloon remodeling, stent-assisted coiling, and Y-stenting [1–3]. To prevent coil herniation and to provide strong support for the neck of the aneurysm, stent-assisted coiling is frequently preferred for treatment of wide-necked bifurcation aneurysms. Y-configuration double-stent-assisted coiling is another technique used to completely close the neck of an aneurysm [3]. However, reaching the distal edge of the parent artery may be difficult in cases of acute angulation between the proximal and distal parent arteries, and may require the use of "modified Y-configured stents with the waffle-cone technique". In this technique, the correct approach is to insert the distal end of the stent directly into the aneurysm, keeping the proximal end within the parent artery by use of the waffle-cone technique [1, 2, 4].

We report three cases of unruptured, wide-necked bifurcation aneurysms with acute angulation between the proximal and distal parent arteries that were successfully treated by use of the Solitaire® stent (Ev3, Irvine, CA, USA) placed in the manner of "modified Y-configured stents with the waffle-cone technique" instead of Y-stent-assisted coiling, which was the original plan.

Case reports

Case 1

Selective cerebral digital subtraction angiography (DSA) of a 62-year-old hypertensive male patient admitted with a headache that had persisted for the last 6 months revealed an unruptured aneurysm with a 7.4 mm wide-neck on the anterior communicating artery (AcomA), 13 × 14 × 16 mm in size and incorporating the upper and lower divisions (Fig. 1). Endovascular intervention was planned for this aneurysm.

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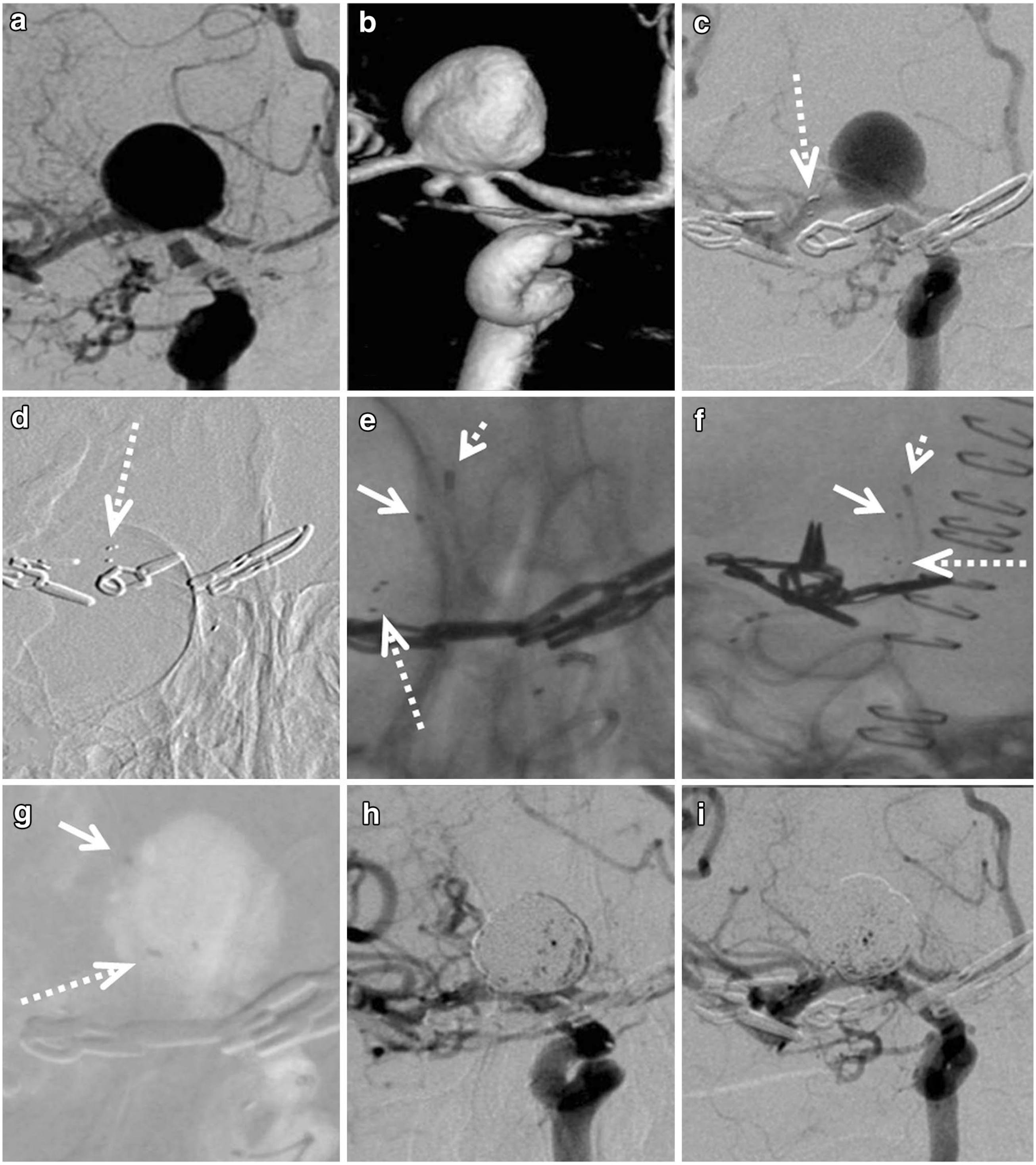
Case 2

DSA of a 57-year-old female patient admitted with sudden onset of severe headache revealed aneurysms of the AcomA, the terminal segment of the right internal cerebral artery (ICA), right middle cerebral artery (MCA) bifurcation, and upper division of the right MCA bifurcation, which were 4.5, 3.5, 6, and 3.5 mm in diameter, respectively. DSA also revealed an unruptured aneurysm with a 7 mm wide-neck on the right ICA bifurcation, which was 15 × 15 × 16 mm in size (Fig. 2). The first four aneurysms were treated by clipping. However, as a result of atherosclerotic alterations in the aneurysm neck, the wide-necked right ICA bifurcation aneurysm could not be treated by clipping because of potential stenosis of the parent artery. Instead of clipping, endovascular intervention was planned for this aneurysm.

Fig. 2 Endovascular treatment of the right bifurcation aneurysm of the ICA of patient 2. Preembolization images: wide-necked, 15 × 15 × 16 mm aneurysm on frontal projection of the right internal carotid DSA (**a**) and volume-rendered right internal carotid DSA (**b**). Intraprocedural images: placement of the Solitaire® stent on the right ICA terminal and right MCA M1 segments covering the aneurysm neck from the right side on frontal projection of the right internal carotid DSA image (**c**) and frontal projection of the right internal cerebral fluoroscopic image (**d**). Placement of the Prowler Select Plus microcatheter and the Excelsior SL-10 microcatheter in wide-necked bifurcation aneurysms of the ICA on frontal projection of the right cerebral (**e**) and lateral projection of the right cerebral fluoroscopic images (**f**). Placement of the Solitaire® stent with the waffle-cone technique in wide-necked bifurcation aneurysms of the ICA on frontal roadmap image (**g**). Post-embolization images: incomplete obliteration of the aneurysm of the ICA (**h**) and residual patency in the 3rd month of follow-up of the aneurysm of the ICA (**i**) after the procedure on the frontal projection of the right internal carotid DSA. (*long dashed white arrow* Solitaire® stent, *short dashed white arrow* Prowler Select Plus microcatheter, *white arrow* Excelsior SL-10 microcatheter)

Fig. 1 Endovascular treatment of the AcomA bifurcation aneurysm of patient 1. Preembolization images: wide-necked, 13 × 14 × 16 mm aneurysm on the frontal projection of the right internal carotid DSA (**a**) and volume-rendered right internal carotid DSA (**b**). Intraprocedural oblique roadmap images: placement of the Prowler Select Plus microcatheter and the Excelsior SL-10 microcatheter in wide-necked bifurcation aneurysms of the AcomA (**c**) and placement of the Solitaire® stent with the waffle-cone technique in wide-necked bifurcation aneurysms of the AcomA (**d**). Postembolization right oblique internal carotid DSA images: incomplete obliteration of aneurysms of the AcomA after the procedure (**e**) and absence of recurrence and residuals in the 3rd month of follow-up of the aneurysm of the AcomA (**f**). (*Long dashed white arrow* Solitaire® stent, *short dashed white arrow* Prowler Select Plus microcatheter, *white arrow* Excelsior SL-10 microcatheter, *white arrowhead* the distal markers of Enterprise stent)



Case 3

DSA of a 52-year-old female patient admitted with headache revealed an unruptured aneurysm with a 5.1 mm wide-neck on the left MCA bifurcation, which was $8 \times 9 \times 10$ mm in size (Fig. 3). Endovascular intervention was planned for this aneurysm.

Endovascular treatment

All patients were treated with 100–300 mg/day acetylsalicylic acid (Aspirin; Bayer, Leverkusen, Germany) and 75 mg/day clopidogrel (Plavix; Sanofi Pharma Bristol-Myers Squibb, Paris, France) 5 days before the procedure. Informed consent was obtained from all patients. After

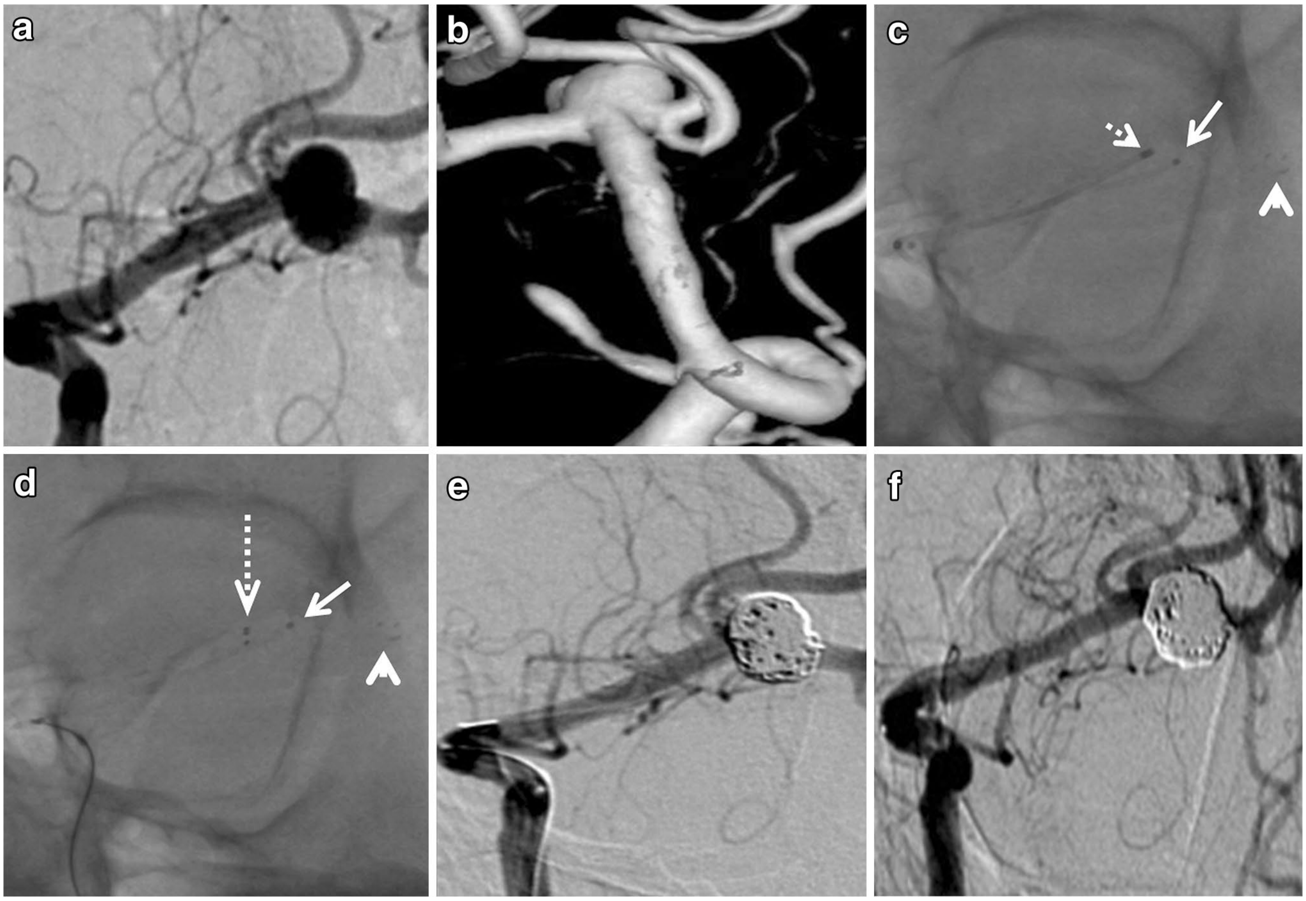


Fig. 3 Endovascular treatment of the bifurcation aneurysm of the left MCA of patient 3. Preembolization images: wide-necked, 8 × 9 × 10 mm aneurysm on frontal projection of the left internal carotid DSA (**a**) and volume-rendered left internal carotid DSA (**b**). Intraprocedural images: placement of the Prowler Select Plus microcatheter and the Excelsior SL-10 microcatheter in wide-necked bifurcation aneurysms of the left MCA (**c**) and placement of the Solitaire® stent with the waffle-cone technique in wide-necked bifurcation aneurysms of the left MCA (**d**) on frontal projection of the left cerebral fluoroscopic images. Postembolization images: incomplete obliteration of the aneurysms of the left MCA (**e**) and residual patency in the 3rd month of follow-up of the aneurysm of the left MCA (**f**) after the procedure on the left oblique internal carotid DSA (*long dashed white arrow*: Solitaire® stent, *short dashed white arrow* Prowler Select Plus microcatheter, *white arrow* Excelsior SL-10 microcatheter, *white arrowhead* Enterprise stent)

induction of general anesthesia, a 6F 80 cm introducer guiding catheter was inserted through the right common femoral artery in all cases. Systemic heparinization was performed, with an activated clotting time of 200–300 s. The petrous portion of the right ICA was reached in cases 1 and 2 and of the left ICA in case 3 with a 6F intracranial access catheter (Fargomax; Balt Extrusion, Montmorency, France) advanced through the 6F introducer guiding catheter. Angiographic images revealed wide-necked aneurysms of the AcomA in case 1, the right ICA bifurcation in case 2, and the left MCA bifurcation in case 3 (Figs. 1, 2, 3).

A microguide wire (hydrophilic 0.016"; Terumo Medical Corporation, Tokyo, Japan) and a Prowler Select Plus microcatheter (Codman Neurovascular, Raynham, MA, USA) were advanced through the 6F Fargomax intracranial access catheter in an attempt to reach the left A2 segment through the right anterior cerebral artery (ACA) in case 1, the right MCA in case 2, and the lower divisions of the left MCA in case 3. A 4.5 × 28 mm Enterprise stent (Cordis Neurovascular, Miami, FL, USA) was placed in the right ACA A1 and left A2 segments in case 1. A 4 mm × 20 mm Solitaire® stent was placed in the right ICA terminal and right MCA M1 segments covering the aneurysm neck from the right side in case 2 (Fig. 2). A 4.5 × 28 mm Enterprise stent was placed in the left MCA M1 segment and the MCA lower division in case 3 through the Prowler Select Plus microcatheter. Different combinations of microcatheters and microguidewires were used to reach the right A2 segment through the right ACA A1 segment in case 1, the right ACA A1 segment through the ICA in case 2, and the MCA upper division through the left MCA M1 in case 3. The aneurysm necks could not be passed in all cases of their acute angulation. After unsuccessful attempts, a Prowler Select Plus microcatheter was advanced into the aneurysm in all cases. An Excelsior SL-10 microcatheter (Stryker Neurovascular, Fremont, CA, USA) was then inserted into the aneurysm (Figs. 1, 2, 3).

A 4 mm × 20 mm Solitaire ® stent was used in these cases, keeping its distal end within the aneurysm, with the help of a Prowler Select Plus microcatheter by use of the waffle-cone technique (Figs. 1, 2, 3). An Excelsior SL-10 microcatheter was fixed between the parent artery and the outer margin of the Solitaire® stent to stabilize the microcatheter within the aneurysm. Embolization was then initiated by use of Target 360° (Stryker Neurovascular, Fremont, CA, USA) coils: 10 mm × 30 cm in case 1, 13 mm × 30 cm in case 2, and 7 mm × 20 cm in case 3, and embolization was completed by use of Target 360° coils and 3D Guglielmi Detachable coils (Stryker Neurovascular, Fremont, CA, USA) of different sizes. Control cerebral DSA performed after the procedure revealed incomplete obliteration of the wide-necked aneurysms but good patency of the parent artery after coil placements in all cases (Figs. 1, 2, 3).

No clinical deficit was observed for the patients after the successful endovascular treatment. Patients with good overall health status were prescribed medical treatment (acetylsalicylic acid 100–300 mg and clopidogrel 75 mg per day) and discharged from the hospital on post-operative day 1. The 3rd month control DSA in case 1 revealed no recurrent or residual aneurysm. However, residual patency of the aneurysms was seen on control DSA of cases 2 and 3 in the 3rd month (Figs. 1, 2, 3).

Discussion

Endovascular treatment of wide-necked bifurcation aneurysms can be technically challenging, because of their anatomical features [5]. One treatment option that can be used for such technically difficult wide-necked aneurysms is the waffle-cone technique [6]. The waffle-cone technique can be useful for wide-necked bifurcation aneurysms with acute angulation between proximal and distal parent arteries. In these cases other endovascular techniques may be unsuccessful in reaching the distal end of the parent artery [1, 2, 4]. This technique has been used in endovascular treatment of bifurcation aneurysms [2]. The waffle-cone technique was first described by Horowitz et al. [7] in 2006 for endovascular treatment of wide-necked bifurcation aneurysms with an open-cell Neuroform stent (Boston Scientific). Recently, Guo et al. [1], Park et al. [2], and Sychra et al. [4] performed the waffle-cone technique with a Solitaire® stent. The most important advantage of the Solitaire® stent is the absence on its distal end of a platinum wire that might perforate the aneurysm. Its closed-cell design and multiple retrieval system are the other important advantages over the Neuroform stent [1, 2]. Considering all these advantages, we preferred to use the Solitaire® stent with the waffle cone technique for endovascular treatment of our cases.

pCONus (Phenox) can be used with the waffle-cone technique to treat wide-necked bifurcation aneurysms. Mpotsaris et al. [8] used double pCONus devices for the first time with the waffle-cone technique in a Y configuration for coil embolization of tandem MCA bifurcation aneurysms. The device was designed to increase intra-aneurysmal stabilization of the coil, and one of its technical advantages is that it is fully retrievable, similar to the Solitaire® stent. However, the disadvantage of the pCONus is its 4 mm pore width which diverts the flow into the aneurysm [8]. WEB is a recently developed technique that can also be used for endovascular treatment of wide-necked bifurcation aneurysms. The device forms an intra-aneurysmal thrombosis and disrupts intra-aneurysmal blood flow. However, thromboembolic complications can occur if the WEB is not properly placed into the neck of the aneurysm. Furthermore, complete occlusion may not be established because of the complex structure of bifurcation aneurysms [9]. Pierot et al. [9] used the WEB for endovascular treatment of bifurcation aneurysms.

Endovascular treatment of wide-necked bifurcation aneurysms requires use of double stents in a Y configuration for complete closure of the aneurysm neck. However, placement of the second stent in a Y configuration might be technically difficult in cases of acute angulation between the proximal and distal parent arteries. For endovascular treatment of a wide-necked basilar tip aneurysm, Cho and Kim [3] placed an Enterprise stent between the basilar artery and the left posterior cerebral artery (PCA); however, they could not cross the aneurysm neck because of acute angulation from the basilar artery to the right PCA and they placed a Neuroform stent (Boston Scientific/Target) in the basilar artery by use of the waffle-cone technique. In this way, they described "modified Y-configured stents with the waffle-cone technique". Despite being an effective technique for treatment of wide-necked bifurcation aneurysms with acute angulation between the proximal and distal parent arteries, increased rupture risk because of placement of the stent into the aneurysm and recurrence risk caused by flow diversion into the aneurysm are its disadvantages [3]. Our original plan was to perform Y stent-assisted coiling for endovascular treatment of all cases; however, we switched to "modified Y-configured stents with the waffle-cone technique" because of acute angulation between the proximal and distal parent arteries. We intended to mitigate the potential complication risks by using the multiple retrieval system of the multi-purpose Solitaire® stent in modified Y-configured stents with the waffle-cone technique (Fig. 4). Limbucci et al. [10] similarly combined the

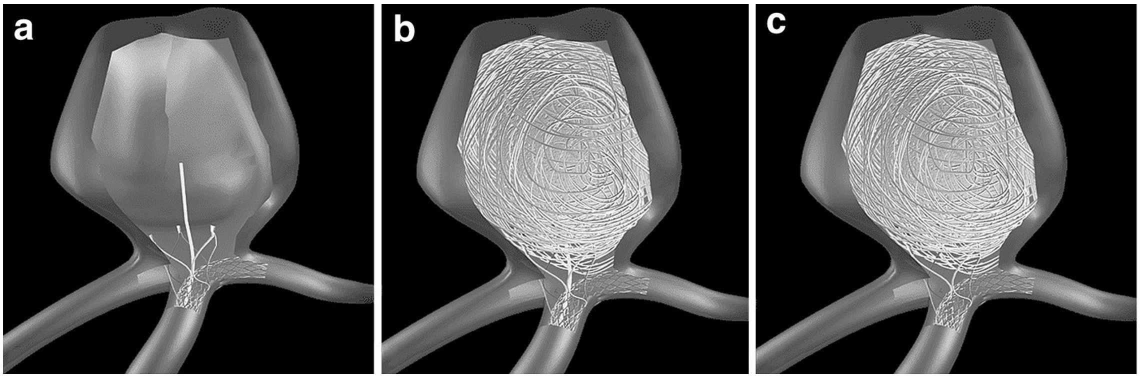


Fig. 4 Schematic images of the Solitaire® stent placed in the manner of modified Y-configured stents with the waffle-cone technique during coil embolization (**a**–**c**)

waffle-cone technique with Y stent-assisted coiling for endovascular treatment of wide-necked bifurcation aneurysm. They used the Solitaire® stent successfully in 3 of 4 cases.

In conclusion, "modified Y-configured stents with the waffle-cone technique" is a safe and effective approach for treatment of wide-necked bifurcation aneurysms with acute angulation between the proximal and distal parent arteries. Furthermore, it can be used with a stent-delivery microcatheter in wide-necked bifurcation aneurysms with an acutely angulated unilateral distal parent artery, for which access is challenging. However, further results and experience are needed before widespread use of this technique.

Conflict of interest The authors each declare that they have no conflict of interest.

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