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ORIGINAL ARTICLE

Application of the Willis covered stent in the treatment of internal carotid artery blood blister-like aneurysms

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Abstract

The optimal treatment for blood blister-like aneurysm (BBA) has not yet been determined, and BBA has a high recurrence rate after stent-assisted embolization. The purpose of the present study was to evaluate the safety and feasibility of patients with BBA rupture in the acute phase or patients with BBA who have recurrence after stent-assisted coil embolization. Eight patients (8 women, mean age 50.3 ± 3.7 years) who presented with ruptured BBA or recurrence BBA that had been treated by stent-assisted embolization (5 patients after primary treatment of stent-assisted embolization) were retrospectively reviewed. Clinical follow-up was performed at 1 year after endovascular treatment. All patients were successfully treated with the WCS, and immediate postoperative angiography showed that the aneurysms were completely isolated. The ophthalmic artery was covered by WCS in one patient; however, this patient did not show any clinical visual field or vision symptoms. Procedure-related complications such as aneurysm rupture, vasospasm, acute thrombosis, or thromboembolism did not occur in any case. All patients were followed up for 1 year after endovascular treatment, and they were in good condition without recurrence. One patient developed delayed bleeding at the right temporal lobe. All patients had good clinical prognosis (modified Rankin Scale score ≤ 2). WCS implantation may be a safe and feasible strategy for patients with BBA rupture in the acute phase and patients with BBA who have recurrence after stent-assisted coil embolization and is a promising option worth exploring.

Keywords Blood blister-like aneurysm · Recurrence · Willis covered stent · Endovascular treatment

Introduction

The concept of blood blister-like aneurysm (BBA) was first proposed by Takahashi et al. in 1988. He used the Japanese term "chimame," meaning "blister," to describe the shape of this type of aneurysm [24]. Among operatively treated intracranial aneurysms, BBA accounts for 0.3–1.7%; of ruptured intracranial aneurysms, BBA accounts for 0.9–6.6% [1, 16–18]. The typical BBA is located on the dorsal or anterior wall of the nonbranch site of the internal carotid artery (ICA) and is often accompanied by subarachnoid hemorrhage (SAH) [16, 18, 20, 23]. Pathologically, the lesion is covered with thinner fibrous tissue and adventitia and lacks the collagen layer commonly found in typical aneurysms; thus, it is actually a "pseudoaneurysm" [10]. Due to the diverse shape, small size, irregular neck, and weak wall, BBA has a high risk of early recurrence and rebleeding after surgery, which poses great challenges for surgical and endovascular treatment [3].

BBA surgical treatment includes direct clipping, wrapping, clipping + wrapping, surgical trapping, trapping with or without bypass, and suturing [12, 13, 19]. Currently, in the background of continuous breakthrough innovations in endovascular treatment techniques and materials, the method of treating BBA is shifting from open surgical treatment to endovascular treatment. Endovascular treatment includes conventional stents, stent-within-stent, stent-assisted coiling, stent-assisted Onyx embolization, and endovascular trapping [5–7, 9, 15, 26]. In recent years, methods such as flow diverter devices and covered stent treatment have

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emerged [3, 4, 21]. Covered stents have shown clear safety and effectiveness in the treatment of distal internal carotid artery aneurysms and giant aneurysms [14, 25]. However, their therapeutic effect and prognosis for BBA have not been clarified; furthermore, there are few reports on the therapeutic effect of BBA recurrence after treatment with stent-assisted embolization. Here, we report our experiences in the treatment of BBAs by Willis covered stent (WCS) (MicroPort, Shanghai, China) implantation in 8 patients, 3 of whom were primarily treated with WCS and 5 with recurrent BBA after treatment with stent-assisted embolization treated later with WCS.

Materials and methods

Patients

We retrospectively reviewed the records of 8 patients with BBA arising from the C6 segment of the supraclinoidal ICA who were treated by WCS implantation in our hospital from December 2016 to October 2019. Head CT showed SAH and was used to assess the patients' initial clinical status with the Hunt & Hess grading system. The diagnosis was confirmed by digital subtraction angiography (DSA), and all patients had type I BBA [2]. Eight patients were women, with a mean age of 50.3 ± 3.7 years (range 46–58 years). Among them, 3 were treated with WCS for the first time, with head CT scan showing SAH and initial clinical status assessed with the Hunt and Hess grading system; 5 patients were treated with WCS as secondary treatment after recurrence of stent-assisted embolism, with a recurrence time of 1–3 months and an average of 1.9 ± 0.6 months. This retrospective study was approved by the ethics committee of Beijing Chaoyang Hospital according to the principles expressed in the Declaration of Helsinki.

Inclusion criteria

The inclusion criteria were as follows: (1) diagnosed with BBA; (2) primary disease or recurrence and indications for WCS treatment; and (3) treated by implantation of the WCS in our hospital from December 2016 to October 2019. The diagnostic criteria of BBA were similar to those in previous studies [5]: (1) aneurysms located at nonbranching sites of supraclinoidal ICA; (2) typical aneurysm features such as a wide neck and a typical blister-like shape; (3) initially small (maximum diameter < 10 mm); (4) diagnosed after rupture, presenting with SAH; (5) rapid growth (< 2 weeks) on repeated angiograms; and (6) irregular wall of the aneurysm or the parent artery. An aneurysm was diagnosed as a BBA when criteria 1–4 were fulfilled and either criterion 5 or 6 was met.

Treatment procedure

All patients were treated by intravascular WCS implantation under general anesthesia via a right femoral approach. First, an 8-F guiding catheter (Envoy, Codman Neurovascular, USA) was positioned into the C1 segment of the ICA. Then, the size of the WCS and Navien support catheter (Medtronic, Minneapolis, MN, USA) was chosen according to the actual situation. Both sides of the stent should extend at least 2 mm into the neck of the aneurysm. The diameter of the stent needs to be wider than the diameter of the parent artery by approximately 0.5 mm. The WCS was advanced along the microguidewire and covered the aneurysm orifice. At the same time, multiangle angiography was performed to confirm the position of the stent and avoid covering any important side branches. Finally, the balloon was slowly inflated, and the stent was released; angiography was performed immediately after the operation. Intraoperative complications such as aneurysm rupture, vasospasm, stent displacement or collapse, acute thrombosis, or thromboembolism were evaluated. We also checked whether the aneurysm was completely blocked, whether it was an endoleak or whether important branch arteries were well preserved. Unenhanced head CT and nervous system examinations were routinely performed after the operation to exclude intracranial ischemia or hemorrhage.

Antithrombotic treatment

For emergency cases, tirofiban was given intravenously before the stent was released. The initial dose was 10 μg/kg, the intravenous bolus was completed within 3 min and then the drip was maintained at a rate of 0.15 μg/kg/min. After the operation, tirofiban was instilled at a maintenance dose for 24 h and then subcutaneously injected with low molecular weight heparin at a dose of 5000 U/12 h for 48 h. For nonemergency cases, clopidogrel 75 mg/day and aspirin 100 mg/day were given 5 days before the operation. After the operation, low molecular weight heparin was routinely injected at a dosage of 5000 U/12 h for 72 h subcutaneously. During the procedure, all patients received systemic intravenous heparin to obtain an activated clotting time of 250–300 s. All patients continued to receive dual antiplatelet therapy (clopidogrel 75 mg/day and aspirin 100 mg/day) for at least 6 months after the operation. We detected the metabolic genes of aspirin and clopidogrel in all patients before WCS implantation using digital fluorescence molecular hybridization (DFMH) technique. No mutation was found in aspirin GP IIIA PL and Pear1, and the results of clopidogrel were poor metabolism (in 3 cases) and intermediate metabolism (in the other 5 cases).

Follow-up

DSA or CT angiography (CTA) was performed for all patients within 6 months after the operation to check residual endoleaks, aneurysm regrowth, and important branches. The follow-up was performed by telephone calls or outpatient visits every 3 months for 1 year. Postoperative neurological recovery was recorded, and the modified Rankin Scale (mRS) score was used to evaluate the clinical status of the patients postoperatively. Scores of 0 to 2 indicated a good prognosis, 3 to 5 a poor prognosis, and 6 death.

Results

We retrospectively reviewed the basic information, intraoperative conditions, and postoperative follow-up results of the 8 BBA patients, as shown in Table 1. Among the patients, 3 underwent implantation of WCS for the first time; 5 who had recurrence after stent-assisted embolization with low-profile visualized intraluminal support (LVIS) (MicroVention-Terumo, Tustin, CA, USA) underwent implantation of WCS as secondary treatment. Only one WCS was implanted in each patient. The eight patients were all females, with a mean age of 50.3 ± 3.7 years (range 46–58 years). Hunt and Hess grades were II in 5 patients and III in 3 patients. During the WCS implantation, 2 patients experienced stent detachment from the dilating balloon at the ophthalmic segment of the ICA, and the detached WCS was retrieved successfully. Then, a new WCS was successfully implanted. The remaining 6 patients had successful operations, and no procedure-related complications, such as aneurysm rupture, vasospasm, stent displacement or collapse, or acute thrombosis or thromboembolism, occurred during the operation. Immediate postoperative angiography showed that the aneurysm was completely blocked, with no endoleak, and revealed an occlusion of the ophthalmic artery in one patient. However, due to good compensation by the external carotid artery, the patient had no visual loss. The important branch arteries, including the ophthalmic artery and anterior choroidal artery, of the remaining 7 patients were well preserved. After discharge, 8 patients were followed up by DSA or CTA. The mean follow-up time was 4.3 ± 1.9 months (range 1–6 months). No residual endoleak, aneurysm regrowth, etc., was found. The BBA was completely blocked, and the parent artery was unobstructed. One patient developed delayed remote region bleeding at the right temporal lobe, which was considered a procedure-related complication, and the mRS score was 2 during follow-up. The remaining 7 patients had mRS scores of 0. The 8 patients were followed up for 1 year after the operation, and they were in good condition without recurrence.

Illustrative cases

Case 1

A 52-year-old female experienced a sudden severe headache and vomiting and was referred to the hospital. Brain CT plain showed an SAH; her Fisher score was III, and her Hunt-Hess score was III. DSA showed a BBA arising from the dorsal wall of the ophthalmic segment of the left ICA. BBA was suspected, and endovascular treatment was proposed. We inserted a Headway 21 microcatheter, an Echelon-10 catheter (Medtronic, Minneapolis, MN, USA) with "S" shaping. The aneurysm was coiled with an LVIS 4.5 × 20 mm stent using the "Semi-Jailing" technique [22]. The BBA was embolized successfully. However, recurrence was confirmed by follow-up DSA 3 months later. We planned to use a Willis covered stent inside the LVIS stent to isolate the blood flow. We first performed a balloon occlusion test using Hyperform 4 × 7 mm (Medtronic, Minneapolis, MN, USA) because the covered stent was suspected to cover the initial part of the ophthalmic artery. Collateral circulation compensation from the external carotid artery branch was confirmed, and we began the second endovascular treatment. Because the CCA proximal part was meandering, we set the tip of the 8-F guide at the initial part of the CCA and inserted the 6-F Navien support catheter (Medtronic, Minneapolis, MN, USA). We planned to cross the LVIS stent first and then insert the Willis covered stent. However, because the tail of the LVIS stent did not open adequately, the Navien catheter could not enter it. Therefore, we inserted the remodeling balloon (Hyperform 4 × 7 mm) and entered the LVIS stent via a microwire, after which the balloon was inflated and the Navien catheter was guided across through to the distal part of the LVIS. We inserted the Willis stent inside the Navien after reaching the lesion, pulled back the Navien, and then released the Willis covered stent. The disappearance of the BBA was confirmed by repeated DSA; ophthalmic artery perfusion was poor, but the patient did not show any clinical symptoms due to good compensation by the external carotid artery (Fig. 1). DSA reexamination after discharge showed no endoleak, aneurysm growth, etc. In addition, the BBA was completely blocked, and the parent artery was unobstructed. Follow-up was planned for 1 year.

Discussion

Currently, the best treatment options for BBA have not been identified, which poses challenges for both surgical and endovascular treatment. Studies have shown that surgical treatment may have a good immediate occlusion effect, but with more intraoperative bleeding and postoperative complications [7]. Endovascular approach has emerged as

Table 1 Basic information and intraoperative and postoperative follow-up for 8 patients with BBA

Case no	Sex/age (years)	H&H grade	Aneurysm location	TX course	Intraoperative situation	Immediate results		Follow-up		
						Aneurysm occlusion	Side branch	Time (months)/ method	Complications	mRS
1	F/50	II	ICA-C6	WCS (3.5 × 10 mm)	Successful	Complete	Preserved well	3/CTA	No	0
2	F/52	III	ICA-C6	WCS (3.5 × 10 mm)	Successful (detachment)	Complete	Preserved well	6/DSA	No	0
3	F/46	II	ICA-C6	WCS (3.5 × 10 mm)	Successful (detachment)	Complete	Preserved well	6/DSA	No	0
4	F/51	II	ICA-C6	Primary: Single LVIS + coil This time: WCS (4.0 × 7 mm)	Successful	Complete	Preserved well	6/DSA	No	0
5	F/48	II	ICA-C6	Primary: Double LVIS + coil This time: WCS (3.5 × 10 mm)	Successful	Complete	Preserved well	3/DSA	No	0
6	F/46	III	ICA-C6	Primary: Single LVIS + coil This time: WCS (3.5 × 7 mm)	Successful	Complete	Preserved well	6/DSA	No	0
7	F/52	III	ICA-C6	Primary: Single LVIS + coil This time: WCS (3.5 × 10 mm)	Successful	Complete	Ophthalmic artery occlusion	1/CTA	No	0
8	F/58	II	ICA-C6	Primary: Single LVIS + coil This time: WCS (3.5 × 10 mm)	Successful	Complete	Preserved well	3/DSA	Delayed remote region bleeding	2

H&H Hunt and Hess, *TX* treatment

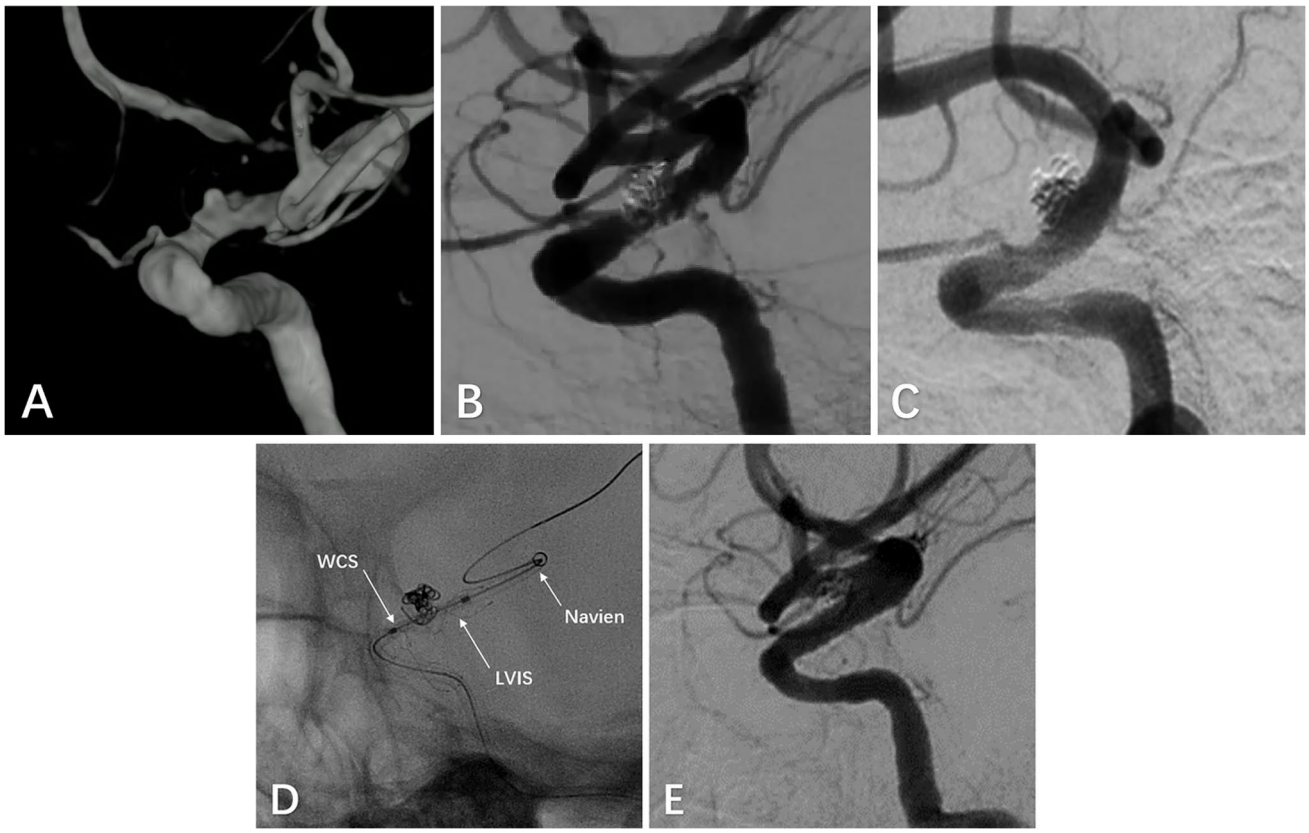

Fig. 1 Illustrative case of a 52-year-old woman. **A** DSA showed a BBA arising from the dorsal wall of the ophthalmic segment of the left ICA. **B** The BBA was embolized successfully by a stent-assisted coil. **C** Three months later, the recurrence was confirmed by follow-up DSA. **D** The Navien catheter (6F) was placed distal to the LVIS stent, and the Willis covered stent (3.5×10 mm) was inserted inside the Navien and reached the lesion. **E** Repeated DSA confirmed that the BBA had disappeared after the WCS was successfully released

less invasive and more efficient in the therapy of BBA. In the case of BBAs, aneurysms are usually wick-neck and not large enough to hold coils without compromising the parent vessel. Intraluminal reconstruction is another treatment option with high degree of concern. Ryan A. Grant et al. once used single over-sized, open-celled self-expanding Neuroform 3 stents (Boston Scientific, Natick, MA, USA) in the parent vessel to treat five BBAs. The rational to upsizing Neuroform stent is to increase the surface metal area coverage over the aneurysm to promote blood flow stagnation and promote aneurysmal thrombosis as the author explained. And in one patient, a stent-in-stent technical was attempted; however, the second stent became entangled with the microwire [8]. Also, it is essential to be alert to the possibility of regrowth of the aneurysm or rebleeding which was found in Gaughen et al.'s study. Stent-assisted coiling is another choice to treat BBA with a certain effect, such as Neuroform, Enterprise, and LVIS stents-assisted coiling. But with fragile walls and an indistinct neck compared with saccular aneurysms, operators are more likely to choose a conservative strategy to prevent fatal intraprocedural aneurysm rupture and result in low coil packing density. Studies have shown high level of aneurysm rupture, recurrence, and rebleeding risk with stent-assisted coiling treatment [27]. Flow diverters (FDs), with low porosity which is believed to promote healing of aneurysms by changing the blood flow parameters, avoiding the risk of using telescoping stents technique, are currently being used to treat BBAs in many clinical centers which. Based on flow-diverter alone without the use of additional embolic material, progressive aneurysm thrombosis and reverse remodeling of the aneurysm and the vessel wall are expected. However, the time course of this process is uncertainly which may relate with individuals, such as FD type, parent vessel geometry, aneurysm size and morphology, and blood coagulation. During this time, there may be some fatal adverse events for some BBAs. Zhu DY [29] once made a meta-analysis including 165 patients with BBA; complete occlusion after flow-diverter stent treatment rate was 72%. Recurrence and rebleeding occurred respectively in 3% of patients. Operators changed their direction to place some coils in the aneurysm but have to be caution with the fragile aneurysm wall [28].

WCS is such a kind of intracranial covered stent that can immediately isolate aneurysms from parent arteries.

Previous attempts to treat BBA with WCS have been shown to be feasible [4]. Among the 8 patients treated with WCS, no acute procedure-related complications occurred during the operation, and continuous follow-up for 1 year after the operation showed that the aneurysms were completely isolated without recurrence. Moreover, the patients were in good condition. In this series, all BBA patients were female, which is in line with previous research results [11].

Although BBA has a high recurrence rate after stent-assisted coiling embolization, there are few reports on the treatment strategy of BBA after such recurrences. Of our 8 patients, 5 had BBA recurrence after LVIS stent-assisted embolization. We used WCS for secondary treatment. The success rate was 100%. No stent detachment, removal position, collapse, or thrombosis occurred during the operation. Immediate postoperative angiography showed that the aneurysm was completely isolated, and no recurrence occurred during follow-up. The WCS was used to treat recurring BBA and achieved satisfactory results.

When using WCS to treat BBA, WCS may cover important side branches. Therefore, the possibility of covering important branches should be considered before the operation, and a balloon occlusion test can be performed to evaluate the safety of WCS implantation. In one of the patients in our series, it was considered that the ophthalmic artery may be covered after WCS implantation. Therefore, before stent implantation, an ophthalmic artery compensatory test was performed on this patient using a balloon. Although the ophthalmic artery of this patient was covered by the WCS, no additional clinical symptoms were observed due to good blood supply compensation by the external carotid artery. During the procedure, the WCS needs to be advanced in the original LVIS stent, but there is friction between the original LVIS stent and the biofilm of WCS, and such friction may cause the biofilm to fall off and form serious thrombosis, especially at the corners. There is a large tortuous angle at the siphon carotid artery, which causes resistance and difficulty in advancing the WCS into the original LVIS stent. In this regard, we adopted the following methods during the procedure. First, the Navien support catheter was guided into the original LVIS stent by a Hyperform balloon and successfully reached the distal of the original LVIS stent. Next, the WCS was advanced in the Navien support catheter and reached the aneurysm orifice. Finally, the Navien support catheter was withdrawn slowly, and the balloon was inflated to release the WCS in the original LVIS stent. In this way, WCS can be safely and successfully advanced into the original LVIS stent and cover the aneurysm orifice, effectively reducing friction between the WCS and the original LVIS stent and avoiding intraoperative complications.

In summary, 8 patients, including ruptured BBA cases and BBA cases with recurrence after stent-assisted coil embolization, achieved ideal treatment results with WCS, which has relatively high safety and effectiveness. Therefore, for this type of aneurysm, endovascular treatment with WCS is a strategy worth exploring. The results of short-term and medium-term follow-ups are good, and long-term follow-up is necessary.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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