# Intracranial Complex Ruptured Aneurysms Coiled with Overlapping Low-Profile Visualized Intraluminal Support Stents: Another Available Option for Complex Ruptured Intracranial Aneurysms

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■ BACKGROUND: **Overlapping stents represent a new paradigm in endovascular interventions, especially for complex and wide-necked aneurysms. The low-profile visualized intraluminal support (LVIS) device is a new generation of self-expanding braided stents recently introduced in China for stent-assisted coiling of intracranial aneurysms. We report several cases of intracranial aneurysms coiled using overlapping LVIS stents to evaluate its efficacy and safety.**

■ METHODS: **Patients with ruptured intracranial aneurysms treated with double LVIS stents at our center between November 2014 and May 2016 were reviewed. The clinical data and technical results are presented.**

■ RESULTS: **Ten patients with 15 aneurysms were treated with double LVIS stents, with a 100% technical success rate. No mortality was observed. Immediate angiographic outcome evaluation showed complete occlusion in 13 aneurysms (86.7%) and neck remnants in 2 aneurysms (13.3%).**

■ CONCLUSIONS: **Double LVIS stents are safe and effective in the treatment of intracranial aneurysms, especially complex aneurysms.**


## INTRODUCTION

Endovascular treatment of wide-neck, complex, or large aneurysms remains an ongoing challenge.[1] Compared to primary coiling, stent-assisted coiling may reduce recurrence rates and offer benefits with respect to the mechanical barrier, flow diversion (FD), and biological effects.[2] Owing to the excellent blood FD, flow diverters are used more frequently, especially in patients with large or complex aneurysms. However, this excellent blood FD leads to a high potential of branch occlusion, which may cause serious complications.[3-5] Furthermore, FD was not performed in patients with ruptured aneurysms. In such cases, coiling with double stents may be recommended.

The low-profile visualized intraluminal support (LVIS) stent (MicroVention Terumo, Aliso Viejo, California, USA) is a new generation of self-expanding braided stents recently introduced in China that offer an option between conventional coil-assisted stents and flow diverters. It is a self-expanding nickel-titanium, single-wire braid, compliant, closed-cell, retrievable, intracranial microstent designed for stent-assisted coil embolization of wide-necked intracranial aneurysms. The device has 2 forms, the LVIS, which is compatible with a 0.02100 internal diameter Headway microcatheter (MicroVention Terumo) and is recommended for vessels sized 3.0–4.5 mm, and the LVIS Junior, which is compatible with a standard 0.01700 internal diameter microcatheter or dual lumen balloon microcatheter (Scepter C or XC, MicroVention Terumo) and is recommended for vessels sized 2.5–3.0 mm. Because of the size of the parent artery, only the LVIS was used in this study. The LVIS has an unconstrained outer diameter ranging between 3.5 mm and 5.5 mm and comes in unconstrained lengths ranging between 15 mm and 25 mm. Owing to the braided design, the in situ working length is a function of the degree of foreshortening that occurs within the parent artery, which is dependent on the selected device size relative to the vessel diameter. LVIS stents are constrained within an introducer sheath and mounted on a delivery wire. The device is loaded into the microcatheter and delivered to the desired site of deployment.


**Key words**
- Complex
- Intracranial aneurysms
- LVIS stents
- Overlapping
- Ruptured


**Abbreviations and Acronyms**
**BA**: Basilar artery
**DSA**: Digital subtraction angiography
**FD**: Flow diversion
**LVIS**: Low-profile visualized intraluminal support
**MCR**: Metal coverage rate
**VA**: Vertebral artery


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Device deployment occurs as the expanded device is released from the delivery wire. The stent is fully re-constrainable after deployment of up to 80% of its length.

The LVIS device was designed to improve the long-term efficacy of endovascular treatment, while avoiding impact on side branches. Its high metal coverage (23% on average) facilitates improved diversion over other currently available stent-assisted coils.[6] Double LVIS stents may results in a higher metal coverage, which was beneficial to aneurysm neck repair. To the best of our knowledge, studies on aneurysms treated by double LVIS stents are not common. We present the results and prognosis of 10 patients with 15 aneurysms treated with double LVIS stents.

## MATERIALS AND METHODS

### Patient Population

Between November 2014 and May 2016, 15 aneurysms, in 10 patients, were coiled with double LVIS stents in the First Affiliated Hospital of Wenzhou Medical University. These included, 4 dissecting aneurysms, 5 blood blister-like aneurysms, and 6 saccular aneurysms. Eight were anterior circulation aneurysms, and the others were posterior circulation aneurysms. The inclusion criteria were as follows: 1) the patient had at least 1 intracranial complex aneurysm, 2) the patient was treated with double LVIS stent-assisted coiling, 3) the patient was treated at our hospital only between November 2014 and May 2016, 4) the patient was followed up for at least 3 months, and 5) the patient had complete angiography data. Exclusion criteria were as follows: 1) the patient was lost to follow-up, 2) angiography data were not complete, 3) the patient died because of some other disease or because of an unknown reason.

The complex aneurysms fulfilling the following criteria were considered: 1) aneurysms with anatomic characteristics and relationships that were difficult to treat by conventional coiling, stent-assist coiling, or clipping, and 2) aneurysms with high recanalization rates, mainly large and wide-necked aneurysms.

The study's primary endpoints included procedural safety, target aneurysm recurrence, and a short-term (3–8 months) follow-up of clinical and angiographic outcomes. Target aneurysm recurrence was defined as any of the following conditions after the initial aneurysm coiling procedure: 1) angiographic recurrence of target aneurysm, 2) hemorrhage of target aneurysm, or 3) retreatment of target aneurysm.

### Endovascular Procedure

The procedures were performed under general anesthesia as early as possible after the diagnosis. The first LVIS was deployed with or without coils as a general procedure. Then the second LVIS stent was transported through the same microcatheter to overlap the neck for reconstruction of the parent artery. The immediate angiographic result was evaluated using the Roy-Raymond scale: 1) grade I for complete occlusion, 2) grade II for neck remnant, and 3) grade III for body filling.

### Perioperative Medication

Almost all of the earlier described patients were admitted in the hospital for subarachnoid hemorrhage, and no anticoagulation or antiplatelet drugs were used. Next, 525 mg clopidogrel was preloaded rectally 0.5 hour before stenting. All patients continued dual antiplatelet therapy consisting of clopidogrel (75 mg/day) and aspirin (100 mg/day) for at least 3 months, followed by aspirin (100 mg/day) only for 1 year.

### Clinical and Angiographic Follow-Up

All patients were followed-up by telephone to assess their general conditions. The patients were admitted to the hospital, and a detailed examination was performed during follow-up 3–6 months after discharge. Digital subtraction angiography (DSA) was performed as the angiographic follow-up. Angiographic follow-up results are divided into 4 categories: 1) cured, 2) further thrombosis, 3) stable, and 4) recurrence. The clinical evaluation and follow-up assessment were performed by 2 experienced neurologists, and angiographic evaluations were conducted by Z.Q.L. and M.Z.

## RESULTS

Ten patients with 15 aneurysms were included in this study. All 10 patients were successfully followed-up for 3–8 months, and the mean follow-up time was 5.4 months. Only 1 patient with a VA dissection and basilar artery (BA) aneurysm was diagnosed with cerebella infarction, whereas the others were diagnosed with subarachnoid hemorrhage. The clinical and demographic data of the patients are summarized in Table 1. Three patients suffered multiple aneurysms. Among the 15 aneurysms, there were 4 dissecting aneurysms, 5 blood blister-like aneurysms, and 6 saccular aneurysms. Among the 4 dissecting aneurysms, 1 was in the posterior communicating artery, 2 were located on the VA, and the rest were located on the BA.

All stents were successfully deployed in the desired location, resulting in 100% technical success. No significant difficulty was encountered during stent delivery and deployment. All stents were fully opened under fluoroscopy.

Immediate postprocedural angiograms showed complete occlusion in 13 aneurysms, and neck remnants in 2 aneurysms. No patient experienced gastrointestinal bleeding or myocardial infarction, and there was no mortality during the periprocedural period.

There were 2 large aneurysms in the 6 saccular aneurysms treated with double LVIS stents in this series. Both the immediate and follow-up angiography showed a Roy-Raymond grade I coiled. A patient with a large right-middle artery aneurysm coiled with double LVIS stents is shown in Figure 1. There were 4 dissecting aneurysms treated with double LVIS stents in this series. All of them achieved Roy-Raymond grade I embolization and were stable on short-term follow-up (3–8 months). A patient with a left VA dissecting aneurysm is shown in Figure 2. Five blood blister-like aneurysms were treated with double LVIS stents, and Roy-Raymond grade III embolization was achieved in 2 patients according to the immediate angiography, whereas the others achieved Roy-Raymond grade I embolization. One of the 2 patients developed recurrence and refused retreatment, and the other showed further thrombosis on follow-up angiography (Figure 3).

No mortality was observed. No new permanent neurologic deficits from hemorrhagic or ischemic stroke occurred in any of the treated patients within 30 days after the intervention. Among the patients, 1 was admitted to our neurologic department because

**Table 1.** Intracranial Aneurysms Treated and Location

| Patient Number | Sex | Age (years) | Hunt-Hess Grade | Lesion Position | Dissection | Blood Blister-Like | Perioperation Ischemic Accident | With/Without Coil | Immediate Angiography (Raymond Scale) | mRS Score at Discharge | Follow-Up Time (Months) | mRS Score 90 Days after Discharge | Follow-Up Angiography |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | F | 33 | III | Left PCoA | Yes | No | No | Without | III | 1 | 3 | 0 | Recurrence |
| II | F | 41 | II | Left ICA | No | Yes | No | With | I | 1 | 4 | 0 | Cured |
| III | M | 54 | I | Left VA | Yes | No | No | Without | I | 0 | 6 | 0 | Cured |
| | | | | BA | Yes | No | | | I | | | | Cured |
| IV | F | 64 | III | Left ICA | No | Yes | No | With | I | 1 | 5 | 1 | Cured |
| | | | | Right ICA | No | Yes | | | I | | | | Cured |
| | | | | Right AChoA | No | No | | | I | | | | Cured |
| V | M | 40 | III | Left ICA | No | Yes | No | With | III | 1 | 6 | 0 | Further thrombosis |
| VI | M | 42 | I | Left VA | Yes | No | No | With | I | 1 | 8 | 0 | Cured |
| VII | M | 64 | II | Right MCA | No | No | No | With | I | 1 | 8 | 0 | Cured |
| VIII | M | 49 | II | Left VA | No | No | No | With | I | 1 | 3 | 4 | Cured (infarction) |
| | | | | Right VA | No | No | | | I | | | | Cured (infarction) |
| | | | | BA | No | No | | | I | | | | Cured (infarction) |
| IX | M | 48 | II | Left ICA | No | Yes | No | With | I | 1 | 5 | 0 | Cured |
| X | M | 46 | II | Right VA | No | No | No | With | I | 1 | 6 | 0 | Cured |

mRS, Modified Rankin Scale; F, female; PCoA, posterior communicating artery; ICA, internal carotid artery; M, male; VA, vertebral artery; BA, basilar artery; AChoA, anterior choroidal artery; MCA, middle cerebral artery.

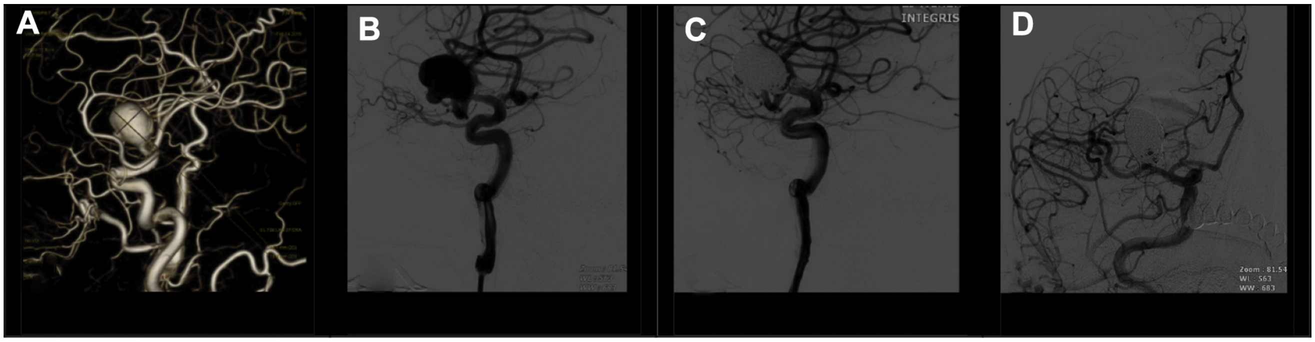


**Figure 1.** A large right middle artery aneurysm coiled with double low-profile visualized intraluminal support stents. (**A**) Three-dimensional reconstruction of the aneurysm. (**B**) The aneurysm in the working projection before treatment. (**C**) The immediate angiography after operation. (**D**) The angiography follow-up 8 months later.

of brain stem stroke 2 months later because he had stopped taking his medications without the doctor's approval.

DSA follow-up was performed for all patients at intervals ranging from 3–8 months. According to the DSA follow-up images of these patients, 1 patient showed aggravation of the coiled aneurysm and required retreatment. The parent vessels of all cases were patent, with no evidence of intimal hyperplasia or in-stent stenosis. In addition, branch arteries covered by the stents also maintained patency, as observed on follow-up angiography.

## DISCUSSION

In recent decades, the general endovascular treatment strategy for aneurysms has focused on the reconstruction of parent vessels rather than on the embolization of the aneurysm sac. Therefore, endovascular stent-assisted embolization has become an important treatment modality for intracranial aneurysms.[7-10] Stent-assisted coiling may reduce recurrence rates and offers benefits with respect to the mechanical barrier, FD, and biological effects.[2] Many types of stents, such as Enterprise (Cordis Neurovascular, Miami Lakes, FL, USA), Neuroform (Boston Scientific/Target, Fremont, CA, USA), and Solitaire (Ev3, Irvine, CA, USA), were applied for endovascular aneurysm embolization, but the long-term efficacy of endovascular treatment and impact on side branches were still worrisome, especially for complex, wide-neck, dissecting, or large aneurysms.

Flow diverters have been introduced as an alternative option for treating complex cerebral aneurysms. Flow diverters can promote aneurysm occlusion through a process of endo-luminal reconstruction of the parent artery and by rectifying blood flow away from the aneurysm sac. However, the potential for branch vessel occlusion is relatively high, which may lead to some serious complications.[3-5]

In recent years, the LVIS stent was introduced in Chinese hospitals. The small cell size design and high metal coverage rate (MCR) made LVIS stents an option among conventional coil-assisted stents and flow diverters. Many previous studies have

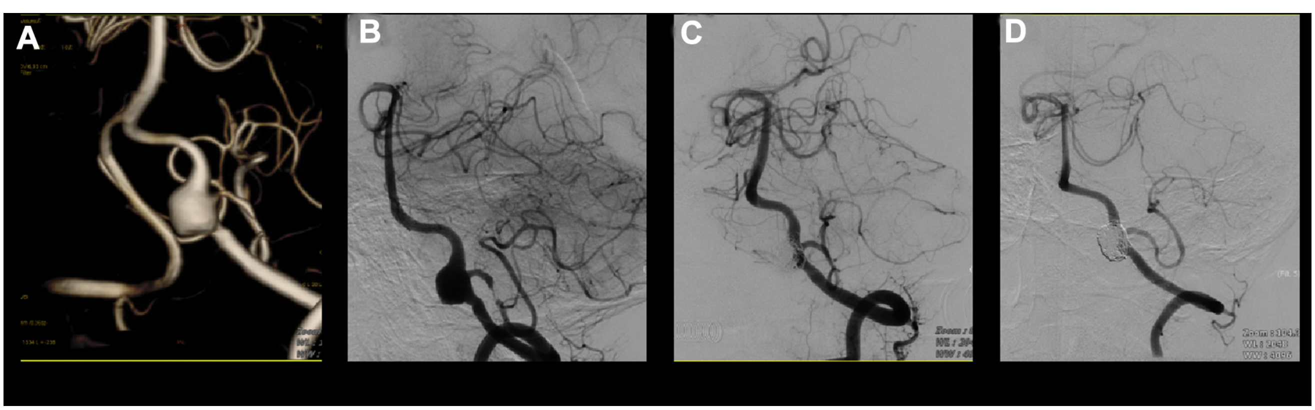


**Figure 2.** A left vertebral artery dissection aneurysm coiled with double low-profile visualized intraluminal support stents. (**A**) Three-dimensional reconstruction of the aneurysm. (**B**) The aneurysm in the working projection before treatment. (**C**) The immediate angiography after operation. (**D**) The angiography follow-up 8 months later.

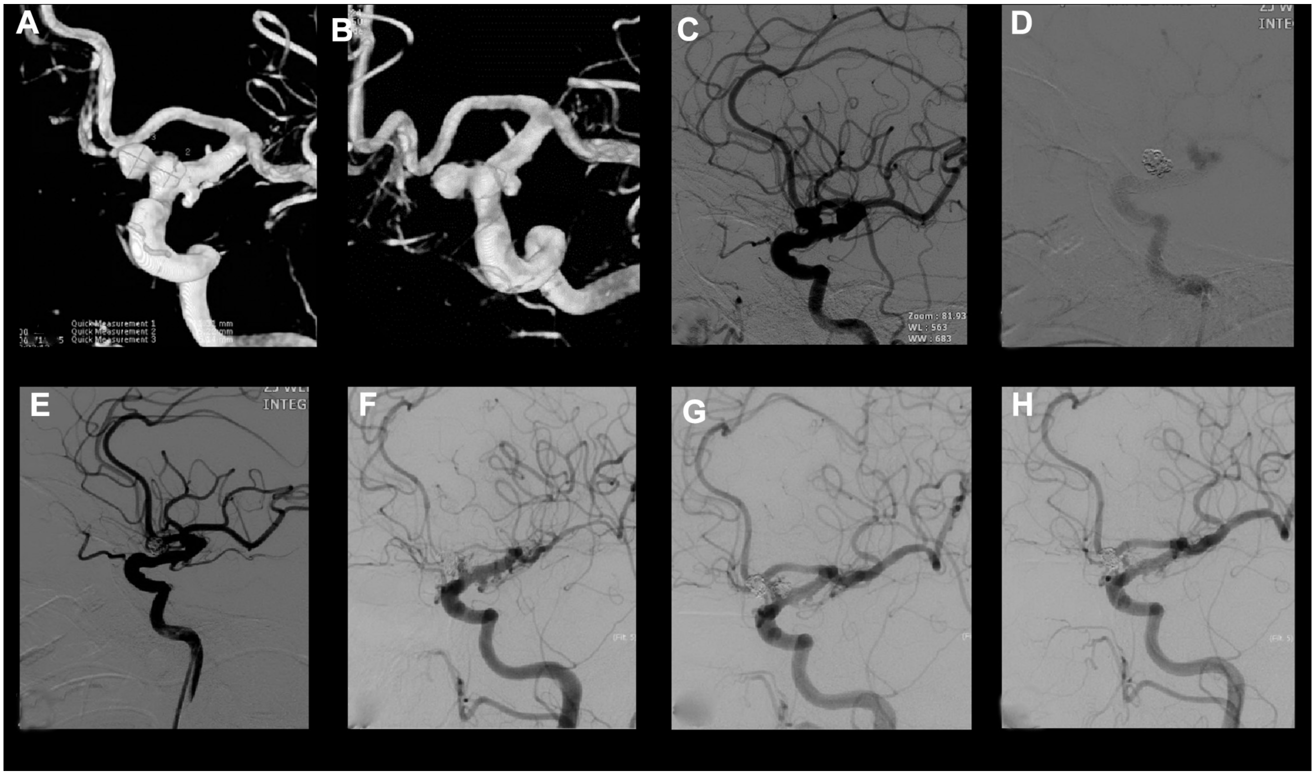


**Figure 3.** Angiograms of a 40-year-old man with a left internal carotid artery blood blister-like aneurysm. (**A** and **B**) Three-dimensional reconstruction of the aneurysm. (**C**) The aneurysm in the working projection before treatment. (**D**) The aneurysm was coiled assisted with double low-profile visualized intraluminal support stents. (**E**) The immediate angiography; the patient took aspirin (100 mg/day) and clopidogrel (75 mg/day) orally for antiplatelets after stents were deployed. (**F**) The angiography follow-up 1 month later, the aneurysm was stable, and the parent artery was patent. (**G**) The angiography follow-up 2.5 months later; the patient took aspirin (100 mg/day) only in the followed time. (**H**) The angiography follow-up 6 months later, the aneurysm showed further thrombosis.

shown that endovascular coiling with the LVIS stent appeared safe and effective for the treatment of intracranial aneurysms.[6,11,12] Many studies have demonstrated that endovascular treatment with LVIS assist was not worse than the other stents. A single-center study was conducted by Feng et al.,[6] who reported a high procedural success rate and low complication rate, and the mid-term angiographic results were better compared with previous studies reporting endovascular coiling with other stents. Furthermore, Feng et al.[13] reported that the rates of complete and near-complete occlusion between the LVIS and Enterprise stents were similar. Furthermore, the LVIS stents were associated with lower rates of recanalization and in-stent stenosis, although the difference was not significant. Wang et al.[12] concluded that LVIS/LVIS Junior stents promote better progressive aneurysm complete occlusion than Neuroform and Enterprise stents.

However, wide-neck, complex, or large aneurysms remain an ongoing challenge, and the optimal treatments remain controversial. It has been confirmed that a higher MCR is useful for the aneurysm neck endothelialization, which helps to reduce recurrence, reconstruct the parent artery, and ultimately heal the lesion.[11] The LVIS stent provides a higher degree of metal coverage (approximately 23%), which is denser than the conventional Enterprise stent (8%), but slightly lower than the Pipeline embolization device (Medtronic/Covidien, Irvine, CA, USA) (approximately 30%—35%). A recent study showed that a single LVIS stent caused more flow reductions than the double Enterprise stent but less than a Pipeline embolization device. The double LVIS stent resulted in a better flow diverting effect than a Pipeline embolization device.[14] This may indicate that double LVIS stents may have a better performance in the treatment of complex aneurysms. Therefore, in this series, we demonstrated effective and safe management of these types of aneurysms with a standard endovascular approach using overlapped LVIS stenting combined with coiling.

The large or wide-neck aneurysms usually have lower rates of successful occlusion and higher rates of recanalization. Especially in cases of acutely ruptured large aneurysms, coiling is associated with less-than-ideal long-term obliteration rate. Many studies had confirmed that traditional stents were insufficient for the treatment of large intracranial aneurysms.[15-17] A single-center study by Mu et al.[15] concluded that reconstructive endovascular treatment with traditional intracranial stents for the treatment of large and giant vertebrobasilar dissecting aneurysms carries a high failure rate and substantial risk of complications. Furthermore, Li et al.[17] reported that stent-assisted coiling may not be superior to parent artery occlusion in selected patients with giant/large internal carotid aneurysms after short-term follow-up. The recanalization and retreatment rates were 33% in a long-term study, which was quite high, and may have increased more as the follow-up time increased.[18] However, flow diverters had a better performance. Miyachi et al.[19] reported that FD was a relatively safe and reliable method for the treatment of large carotid cavernous aneurysms. Because double LVIS stents have a higher MCR and flow diverting capacity, it may have better performance than flow diverters. In our series, large aneurysms in 2 patients were coiled with double LVIS stents. The stents were deployed successfully in both patients, and the immediate and 6-month follow-up angiographies both showed Roy-Raymond grade I coils. No in-stent stenosis and ischemic accidents were observed.

Because of the anatomic complexity and lack of a clippable neck or a favorable neck-to-sac ratio, dissecting or fusiform aneurysms in the VA are often difficult to treat with microsurgical and endovascular techniques. A variety of treatment strategies have been applied for the treatment of VA dissecting aneurysms, including trapping, proximal occlusion, stent-assisted coil embolization, stent-assisted angioplasty, and bypass. Overlapping stents can be used for treating dissecting or fusiform intracranial aneurysms that are not amenable to open surgical treatment or endovascular coil embolization.[20-22] Liu et al.[23] reported a fusiform aneurysm in the left VA that was almost healed with a LEO stent (Balt, Montmorency, France) placed in a Neuroform-3 stent. Overlapping stents may induce spontaneous thrombosis of VA aneurysms and facilitate parent artery reconstruction through flow remodelling and stent endothelialization. Walsh et al.[24] reported on VA dissecting aneurysms treated with more than 4 overlapping stents. As shown in our study, 7 (100%) vertebral or BA aneurysms were completely coiled by overlapping LVIS stents, and no recurrence was observed during follow-up. This confirmed that the overlapping LVIS stents were effective for the endovascular treatment of VA dissecting or fusiform aneurysms.

Blood blister-like aneurysms are a special subtype of aneurysm with a high risk of early recurrence and postoperative rebleeding. Because of the tiny sizes and fragile walls, the mortality and morbidity of surgical or endovascular procedures were not satisfactory. Primary treatment of blood-blister like aneurysms (BBAs), including wrapping, clipping, suturing, encircling clip grafts, conventional coil embolization, stent-assisted embolization, and FDs, has been attempted worldwide, but the optimal treatment is still controversial. The most effective method is to occlude the parent artery internally or surgically, which will expose the patients to increased ischemic risks or an elevated hemodynamic burden of the contralateral internal carotid artery. Bypass can effectively reduce the risks caused by parent artery occlusion, but the technique is quite complicated, and the complication rate is relatively high. Stent-assisted coiling is a useful way to reduce the risk of early rebleeding, but premature rupture and early recurrence were not uncommon. This phenomenon may be because of the low MCR of a single stent.

Overlapping stents increased the MCR and may have a better result. Walsh et al.[24] performed a single-institution series study and review of the literature and showed that the use of multiple overlapping stents as monotherapy is a safe and effective strategy for treating the remodelling of BBAs arising from the supraclinoid internal carotid artery.

Overlapping LVIS stents, which can provide an even higher MCR, may be another alternative. Stent coverage can provide scaffolds for endothelialization and can compromise the blood flow at the inflow zone of the aneurysm. Fang et al.[25] reported that overlapping stents can reduce the recurrence rate of BBAs, especially in those treated with triple stents. It was confirmed by animal studies that a higher MCR was positively related to the angiographic and clinical results. In our series, 5 BBAs were treated with double LVIS stents. The Roy-Raymond grade III coil was achieved in 2 patients according to immediate angiography, among whom 1 patient developed aneurysm recurrence and refused retreatment and the other showed further thrombosis on short-term follow-up angiography. The recurrence may have been because of the tiny size of the aneurysm and the double LVIS stent treatment without coiling.

Overlapping LVIS stents can provide a higher MCR, which helps reduce the recurrence rate and provides an environment for aneurysm neck reconstruction. However, the higher MCR may affect branch vessels. The potential for branch vessel occlusion, which may cause serious complications, is relatively high. Delayed in-stent stenosis should also be of concerned. Dual antiplatelet therapy was routinely applied in our series. Only 1 patient in our study was admitted into our hospital again because of brain stem stroke because he stopped taking his medications without the doctor's approval. Previous experiences of dual anti-platelet therapy after LVIS stent-assisted coiling are quite rare, so the actual risk rate of ischemic events cannot be evaluated. In our opinion, overlapping LVIS stents may increase the risk of ischemic events. Therefore, postoperative oral antiplatelet therapy may be necessary. The optimal dose of antiplatelets is still controversial, but we believe that dual antiplatelet therapy is a reasonable treatment option for patients with double LVIS stents.

There are still many limitations to this study, including the retrospective design, limited cases, and the inadequate angiographic follow-up. Further evaluation and long-term studies are still needed.

## CONCLUSIONS

This study showed that overlapping LVIS stents may be safe and effective in the treatment of intracranial aneurysms, especially for complex aneurysms.

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