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Case Report

Two Patients with Large Aneurysms in Whom Coil Embolization with Overlapping LVIS Stents Was Performed

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Objective: We report two patients with unruptured large aneurysms treated by overlapping stent-assisted coil embolization using low-profile visualized intraluminal support (LVIS) stents.

Case Presentation: Case 1: An 80-year-old woman presented with abducens nerve palsy due to an internal carotid artery aneurysm. Case 2: A 75-year-old man presented with a partially thrombosed fusiform aneurysm in the vertebral artery (VA). Both patients were treated by overlapping LVIS stent-assisted coil embolization (overlapping LSACE). Digital subtraction angiography (DSA) a few months after embolization demonstrated complete occlusion of the aneurysm, although immediate angiography revealed dome filling.

Conclusion: Overlapping LSACE may be an effective treatment method for aneurysms that are difficult to treat by standard SACE and result in better flow-diverting effects.

Keywords ▶ overlapping stent, LVIS, flow-diverting effect, large aneurysm of the internal carotid artery, fusiform aneurysm of the vertebral artery

Introduction

Since stents for cerebral aneurysms became covered by health insurance, many studies have reported that coil embolization of cerebral aneurysms improved the complete obliteration rate and treatment results.[1–5] However, in patients with large or fusiform aneurysms, the additional treatment rate remains high despite stent-assisted coil embolization (SACE).[4–6] Recently, the favorable results of treatment using a flow diverter for such refractory aneurysms were reported in Japan,[7] but the indicated sites and physicians/medical institutions responsible for this treatment are limited, thus it is not always available. In this study, we report two patients, one with an unruptured large symptomatic aneurysm in the internal carotid artery and one with a partially thrombosed fusiform aneurysm of the vertebral artery (VA), in whom coil embolization using two low-profile visualized intraluminal support (LVIS) (Microvention Terumo, Tustin, CA, USA) stents (overlapping LVIS stent-assisted coil embolization, overlapping LSACE) was performed to obtain flow-diverting effects, leading to favorable results. We also provide a literature review.

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Case Presentation

Case 1

An 80-year-old woman. She had a history of hypertension and osteoarthritis of the hip. She consulted a local hospital for diplopia, which persisted for 1 month. Magnetic resonance imaging (MRI) revealed an aneurysm in the right internal carotid artery and she was referred to our department. On the initial consultation, abducens nerve paralysis of the right eye was noted. Magnetic resonance angiography (MRA) and three-dimensional computed tomography angiography (3D-CTA) demonstrated an aneurysm medially and downwardly protruding into the cavernous sinus

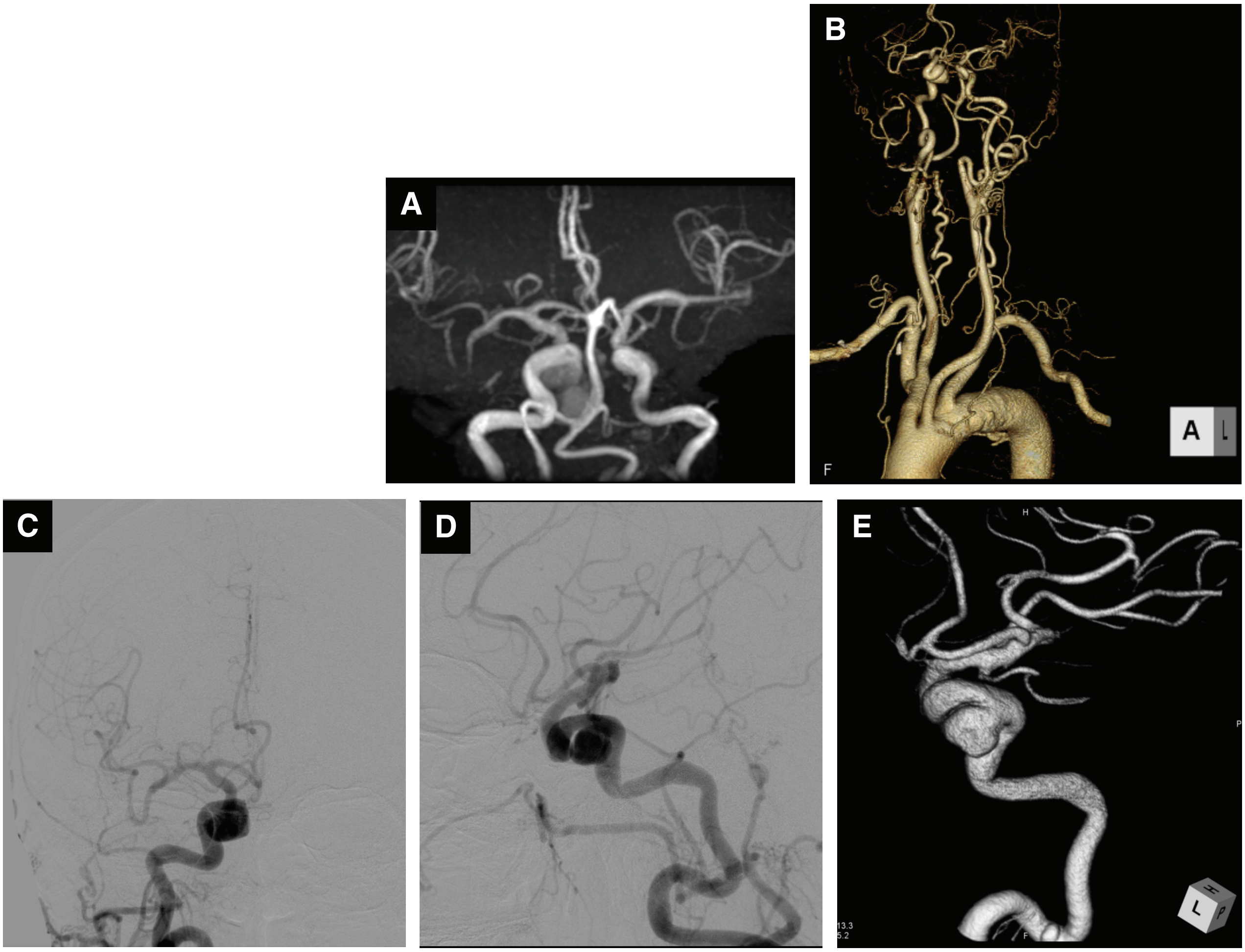

Fig. 1 (**A**) MRA shows a right-sided ICA aneurysm at the cavernous segment. (**B**) 3D-CTA shows a type III aortic arch with a sharply branched brachiocephalic artery and tortuous right-sided ICA. (**C–E**) Right ICA angiography showing a large cavernous carotid aneurysm. (**C**) Anteroposterior view. (**D**) Working lateral view. (**E**): 3D rotational angiogram. ICA: internal carotid artery; MRA: magnetic resonance angiography

of the right internal carotid artery (**Fig. 1A** and **1B**). Digital subtraction angiography (DSA) confirmed a large aneurysm measuring 18.2 mm, 10.2 mm, 11.8 mm, and 7.2 mm in maximum diameter, minimum diameter, height, and neck length, respectively (**Fig. 2C–2E**). Furthermore, on 3D-CTA of the trunk, the brachiocephalic artery sharply branching from the type 3 aortic arch and marked flexion of right cervical internal carotid artery, in addition to aortic torsion, was observed (**Fig. 1B**). We explained that the insertion of a flow diverter was a first-choice procedure when performing endovascular treatment on the assumption that bypass-combined obliteration of a parent blood vessel may be radical treatment. However, it was also explained that a flow diverter was not available at our institution and that SACE was appropriate for obtaining flow-diverting effects. The patient and her family strongly wished to undergo endovascular treatment at our institution. Coil embolization using two LVIS stents was selected. Furthermore, catheter guiding via a transfemoral approach was considered to be difficult based on preoperative systemic vascular assessment and a treatment strategy with direct puncture of the carotid artery was adopted. The oral administration of aspirin at 100 mg and clopidogrel at 75 mg was started 2 weeks before treatment. Under general anesthesia, a 5-cm transverse incision was made in the right cervical region and vascular tape was placed on the right common carotid artery to secure the site of puncture. Under direct vision, the anterior wall of the common carotid artery was punctured with an 18 G puncture needle and a guiding sheath with a short effective length (6 Fr Ansel Flexor 55 cm (Cook Japan, Tokyo, Japan), which had been allowed to penetrate the subcutaneous tissue under a guidewire inserted into the internal carotid artery, was guided and sutured/fixed to the skin. Systemic heparinization was

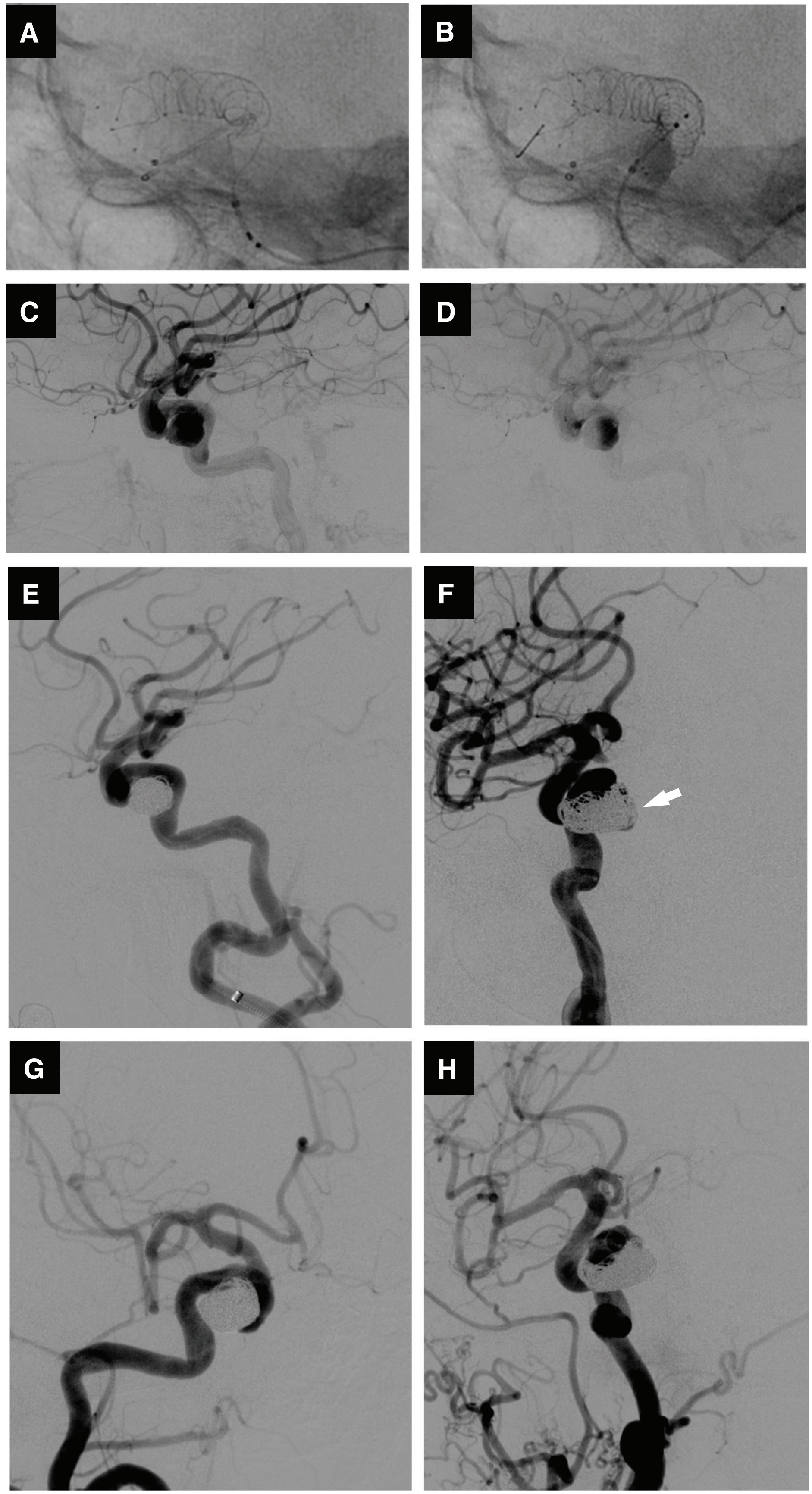

Fig. 2 Right ICA angiography during and after endovascular treatment. (**A**) Immediately after the first LVIS stent deployment (lateral view). (**B**) Immediately after deploying the overlapping LVIS stent, revealing contrast medium stasis into the aneurysmal sac (lateral view). (**C**) Fluoroscopy immediately after deploying the first LVIS stent (lateral view). (**D**) Fluoroscopy immediately after deploying the overlapping LVIS stent (lateral view). (**E** and **F**) Immediately after embolization, showing dome filling of the aneurysm (arrow). (**E**: lateral view, **F**: left anterior oblique view). (**G** and **H**) Three months after endovascular treatment, showing complete occlusion of the aneurysm without in-stent stenosis (**G**: right anterior oblique view, **H**: left anterior oblique view). ICA: internal carotid artery; LVIS: low-profile visualized intraluminal support

conducted and a Headway 21 (Microvention Terumo) was guided to an area distal to the aneurysm using a CHIKAI 14 (Asahi Intecc, Aichi, Japan) to preset the LVIS stent 4.5 mm × 32 mm. Subsequently, an Excelsior SL10 (Stryker, Neurovascular, Fremont, CA, USA) was guided into the aneurysm using the CHIKAI 14 and rotated once. Its tip was placed on the outflow side and the LVIS was deployed at the aneurysmal neck for the jailing technique (**Fig. 2A**). Next, another LVIS stent 4.5 mm × 32 mm was deployed to overlap with the stent that was just placed. The two LVIS stents were deployed while pushing the stent delivery to the Headway 21 together using the stent & system push technique only at the aneurysmal neck, and placed such that the mesh interval was dense (**Fig. 2B**).[8] Angiography immediately after LVIS placement demonstrated the intra-aneurysmal retention of contrast medium (eclipse sign), which was not observed on the insertion of the first LVIS (**Fig. 2C** and **2D**).[9] As a framing coil, a Target XL 360 standard 14 mm × 50 cm (Stryker Neurovascular) was inserted through the intra-aneurysmal SL10, and an ED10 Infini Soft 16 mm × 30 cm (Kaneka Medics, Osaka, Japan), VFC 10-15 mm × 40 cm (Terumo, Tokyo, Japan), two ED coils Complex 10 mm × 30 cm, and two ED coils Complex 8 mm × 30 cm (total: 7 coils, 240 cm) were inserted. As the aneurysm was symptomatic, dense coil embolization was avoided[10] and the procedure was completed with a VER of 18.9% (**Fig. 2E** and **2F**). On sheath removal, purse-string sutures with 6-0 prolene at the site of puncture were ligated. After confirming the absence of arterial hemorrhage, the wound was closed. MRI the day after surgery revealed acutely infarcted minor foci at several points in the right internal carotid artery, but they were asymptomatic. On DSA 3 months after treatment, stenosis of the parent blood vessel at the site of stenting was not observed (**Fig. 2G**), confirming complete occlusion of the aneurysm (**Fig. 2H**). Abducens nerve paralysis persisted for 2.5 months before treatment, but slight improvement was achieved 1 month after treatment and the disappearance of diplopia was confirmed 3 months after treatment. The regimen was switched to monotherapy with aspirin 12 months after treatment. On MRI 20 months after treatment, recurrence was not noted and the course has been favorable.

Case 2

A 75-year-old man. He had a history of hypertension. MRI as a preoperative examination for a thoracic aortic aneurysm (TAA) revealed a right VA aneurysm and he was referred to our department. On the initial consultation, there was no neurological deficit. MRA demonstrated a fusiform aneurysm at an area distal to the bifurcation of the posterior inferior cerebellar artery at the V4 segment of the right VA on the dominant side (**Fig. 3A**). MRI confirmed a partially thrombosed fusiform aneurysm (maximum diameter: 15.8 mm, minimum diameter: 13.0 mm, length: 14.6 mm) compressing the medulla oblongata from the right side (**Fig. 3B** and **3C**). On MRI 4 years previously, the maximum diameter was 13.8 mm, revealing a slight increase. At the department of cardiovascular surgery, total arch replacement for an aortic arch aneurysm measuring 5.5 cm in diameter was scheduled. Brachiocephalic artery bypass with the branch of an artificial blood vessel was considered to make the position of its origin proximal to the ascending aorta, affecting catheter guiding to the right VA via a transfemoral approach. Furthermore, even when selecting the right transbrachial approach, a sharp bifurcation angle between the subclavian artery and right VA was considered to make guiding difficult. As radical treatment, parent blood vessel obliteration of the right VA was considered,

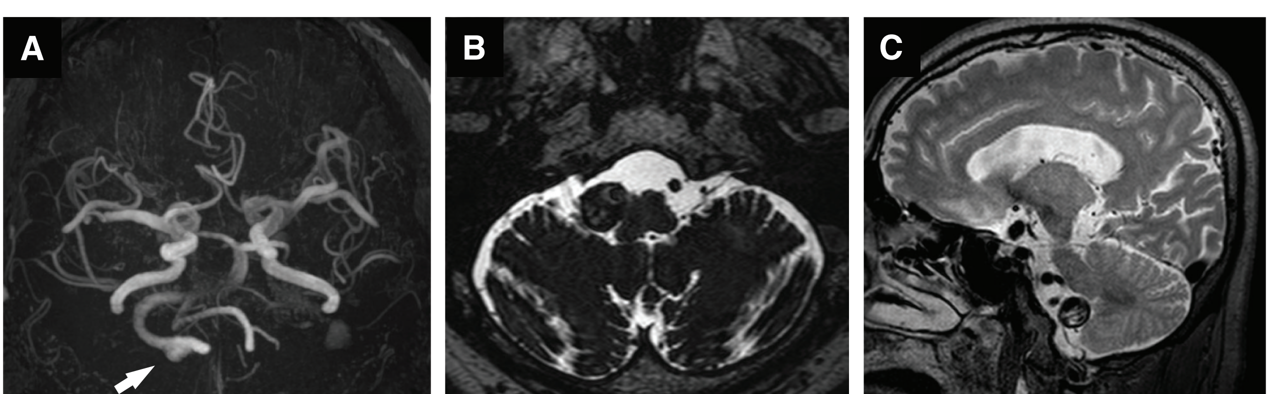

Fig. 3 (**A**) MRA shows a fusiform aneurysm of the right VA (arrow). (**B** and **C**) T2-wighted image shows a partially thrombosed aneurysm at the right side of the medulla. (**B**: axial view, **C**: sagittal view). MRA: magnetic resonance angiography; VA: vertebral artery

but SACE with the preservation of a parent blood vessel prior to TAA surgery was comprehensively selected based on the cardiovascular surgeon's opinion that the bilateral VAs should be patent for reconstruction of three branches (brachiocephalic artery, left common carotid artery, and left subclavian artery) during total arch replacement, in addition to the patient family's wishes. The oral administration of aspirin at 100 mg and clopidogrel at 75 mg was started 2 weeks before treatment. Under local anesthesia and sedation, a transfemoral approach was adopted, but aortic torsion was marked, and a guiding sheath (6Fr SheathLess NV (Asahi Intecc) was inserted into the right subclavian artery and a 6Fr Cerulean catheter DD6 (Medikit, Tokyo, Japan) was inserted into the right VA. On a frontal view of DSA, an angle facilitating the maximum length of the parent blood vessel was established in preparation for stent deployment (**Fig. 4A** and **4B**). On a lateral view, a working angle was established to observe the

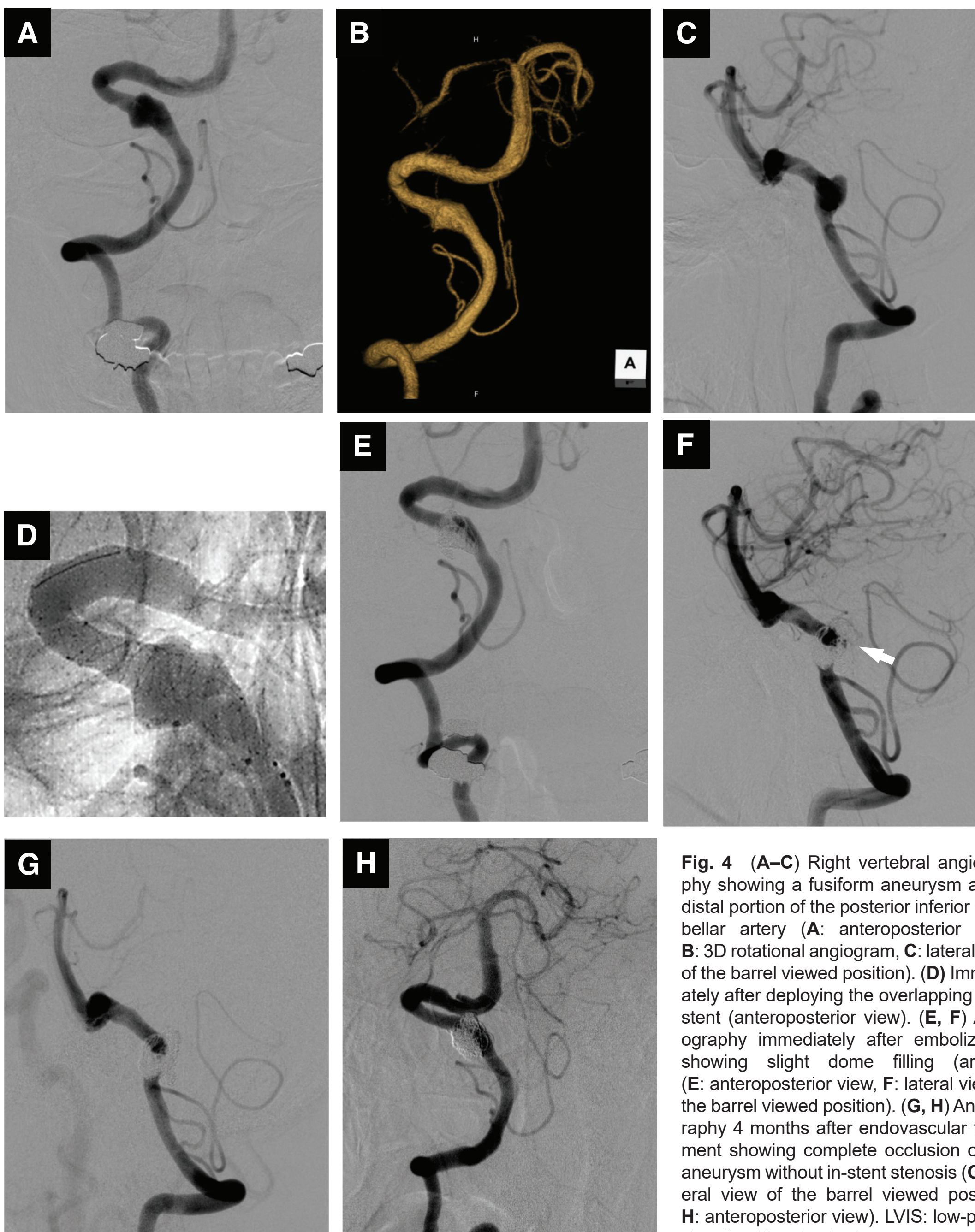

Fig. 4 (**A–C**) Right vertebral angiography showing a fusiform aneurysm at the distal portion of the posterior inferior cerebellar artery (**A**: anteroposterior view, **B**: 3D rotational angiogram, **C**: lateral view of the barrel viewed position). (**D**) Immediately after deploying the overlapping LVIS stent (anteroposterior view). (**E, F**) Angiography immediately after embolization showing slight dome filling (arrow). (**E**: anteroposterior view, **F**: lateral view of the barrel viewed position). (**G, H**) Angiography 4 months after endovascular treatment showing complete occlusion of the aneurysm without in-stent stenosis (**G**: lateral view of the barrel viewed position, **H**: anteroposterior view). LVIS: low-profile visualized intraluminal support

parent blood vessel from the short-axis direction ("down the barrel view") (**Fig. 4C**).[11] Furthermore, the absence of a penetrating branch in an area adjacent to the aneurysm was confirmed using DSA. The Headway 21 was guided to an area distal to the aneurysm using the CHIKAI 14 to have the LVIS 4.5 mm × 23 mm on standby. Subsequently, the SL10 was inserted into the aneurysm using the CHIKAI 14. As described for Case 1, two LVIS stents 4.5 mm × 23 mm were inserted to the same position using the stent & system push technique (**Fig. 4D**). Using the jailing technique, embolization was started with two Target 360 Soft 6 mm × 20 cm coils. The procedure was finished through dome filling with a total of 20 (210 cm) coils (**Fig. 4E** and **4F**). MRI the day after surgery demonstrated an acutely infarcted focus at one point in the right cerebellar hemisphere, but it was asymptomatic. DSA 4 months after treatment confirmed complete occlusion of the aneurysm (**Fig. 4G**) and the absence of in-stent stenosis (**Fig. 4H**). At this point, the regimen was switched to monotherapy with aspirin. TAA surgery was performed 8 months after treatment. MRI 2 years after treatment did not reveal recurrence. The course has been favorable.

Discussion

Regarding endovascular treatment for cerebral aneurysms, the development of numerous stents for embolizing cerebral aneurysms has facilitated the treatment of large or wide-necked aneurysms, which were previously difficult to treat, and improved the results of treatment.[1–5] The use of a stent made it possible to obtain a high embolization rate while preventing coil deviation into a parent artery. In addition, rectifying effects may have been contributory: stenting may influence the course of a parent artery, reducing blood flow into an aneurysm and promoting intra-aneurysmal thrombosis. Concerning the results of coil embolization of large aneurysms, Oishi et al.[4] reported that the complete occlusion and residual neck rates on initial treatment were 50.6 and 29.2%, respectively (total: 79.8%), whereas the significant recanalization and additional treatment rates were 39.4 and 23.6%, respectively. In their study, the complete occlusion rate in the stent-combined group was the highest and the rate of patients with significant recanalization requiring treatment was low. Gao et al.[5] performed embolization of large or giant aneurysms, and reported that complete occlusion was achieved in 48.1% of the patients and that a neck remnant remained in 28.3%. However, they noted recanalization in 29.6%. Thus, the use of a stent improved the results of treatment, but the recanalization and additional treatment rates were high in patients with large or giant aneurysms.

In Japan, two types of lasercut stents for embolizing cerebral aneurysms have been used: a closed-cell stent, Enterprise VRD/2 (Johnson & Johnson Codman, Miami, FL, USA), and an open-cell stent, Neuroform EZ/Atlas (Boston Scientific/Target Therapeutics, Fremont, CA, USA). In 2015, braded stents, LVIS and LVIS Jr., were approved. They are self-dilating closed-cell stents prepared by braiding a metallic wire and their metallic coverage rate is higher than that of the lasercut stents. In addition, in 2015, a flow diverter, Pipeline, was approved, facilitating its use by medical institutions/physicians meeting the criteria for performing treatment using a flow diverter. Currently, these stents are primarily selected in accordance with conditions in Japan. The metallic coverage rates of an Enterprise, Neuroform, LVIS, and Pipeline are 10, 11, 23 (average), and 30–35%, respectively.[12,13] A study compared the blood-flow-reducing effects of stents for aneurysms using CFD analysis and found that the effects of a single LVIS stent were more potent than those of two overlapping Enterprise stents, and that the effects of two overlapping LVIS stents were significantly more potent than those of a single Pipeline stent.[14] Flow-diverting effects may be obtained at a higher metallic coverage rate and intra-aneurysmal blood flow congestion may induce thrombosis, exhibiting blood flow-reducing effects.[9] Briefly, the use of braded stents may facilitate the progression of occlusion even after coil embolization of large aneurysms, reducing the recanalization rate. Ge et al.[15] and Wang et al.[16] reported that the complete occlusion rate in the LVIS-combined group was higher than that in the Enterprise- and Neuroform-combined groups. An LVIS stent is routinely deployed by crimping it to the vascular wall using the push and pull technique. However, when adopting the stent & system push technique, the stent can be inserted while squeezing the mesh interval. In the present cases, we selected overlapping LSACE in which flow-diverting effects, similar to those of a Pipeline, may be obtained by overlapping two LVIS stents. In Case 1, a symptomatic large internal carotid artery aneurysm with abducens nerve paralysis was observed and we had to avoid tight packing,[10] although it was necessary to achieve complete occlusion. Angiography immediately after the insertion of two LVIS stents demonstrated an eclipse sign, reflecting intra-aneurysmal blood flow stasis, suggesting potent flow-diverting effects. The procedure was completed with a VER of 18.9%. However, DSA after 3 months confirmed complete occlusion. Concerning abducens nerve paralysis, slight improvement was achieved 1 month after treatment and the disappearance of diplopia was confirmed 3 months after treatment. Regarding fusiform aneurysms, the use of a stent facilitated treatment with the preservation of a parent blood vessel, but the recurrence rate ranges from 10% to 15% according to several studies.[17,18] Jeon et al.[17] reported the usefulness of multiple overlapping Enterprise stents. Lv et al.[19] conducted CFD analysis of the insertion of several Enterprise stents for fusiform VA aneurysms and reported that the wall shear stress reduced with an increase in the number of stents to be inserted (1–3 stents), increasing the relative residence time suggestive of intra-aneurysmal congestion. Furthermore, another study suggested that flow diverter stents that promote repair/reinforcement of the vascular endothelium of a parent artery are useful for the treatment of dissection-associated fusiform aneurysms.[20] In Case 2, we selected overlapping LSACE of a partially thrombosed large fusiform VA aneurysm to obtain more potent flow-diverting effects because additional treatment after TAA surgery was considered to be impossible and the use of a Pipeline for the posterior circulation system was not covered by health insurance. Coil embolization was able to be performed while confirming the absence of coil deviation into the lumen of a parent blood vessel by securing a “down the barrel” view.[11] The procedure was finished with dome filling. However, DSA after 4 months confirmed complete occlusion. In both patients, only acutely infarcted minor foci were observed on MRI the day after treatment, but they were asymptomatic and there were no perioperative complications. However, as the limitation of this procedure, close attention must be paid to perioperative in-stent thrombus formation or stenosis of the stent lumen related to a high metallic coverage rate, in addition to ischemic complications related to adjacent or penetrating branch damage. We deployed two LVIS stents at the same position and inserted them such that the mesh interval was dense using the stent & system push technique only at the aneurysmal neck. However, damage of a penetrating branch adjacent to the aneurysm may be avoided by one of the stents deployed in the distal and the other in the proximal to the aneurysm. In the perioperative phase, sufficient antiplatelet therapy is important, but hemorrhagic complications must also be simultaneously considered. If an aneurysm recurs after this treatment, additional coil embolization may be difficult. Therefore, it is also important to prepare a strategy in advance: whether a stent should be further inserted or other treatments should be selected.

Since the LVIS stent was approved, the types of aneurysm to be treated have varied by utilizing all of its features. In the future, treatment using a flow diverter may be primarily indicated for symptomatic large internal carotid artery aneurysms. However, to our knowledge, this is the first report on overlapping LSACE of such aneurysms. In a situation in which a flow diverter is not applicable/available, overlapping LSACE may be useful for achieving complete occlusion through potent flow-diverting effects in patients with refractory large aneurysms, especially symptomatic aneurysms for which dense coil embolization should be avoided or fusiform VA aneurysms for which dense coil embolization may be difficult, as demonstrated in the present cases. The long-term outcome remains to be clarified and careful follow-up must be continued in the future.

Conclusion

Overlapping LSACE of a symptomatic large internal carotid artery aneurysm and partially thrombosed fusiform large VA aneurysm was performed, leading to complete occlusion. There has been no mid-term recurrence in either case. This procedure may be useful for the treatment of aneurysms that are difficult to treat using standard SACE.

Disclosure Statement

The authors declare no conflict of interest.

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