Overlapping Stent-assisted Coil Embolization for Ruptured Blood Blister-like Aneurysms of Basilar Trunk: Two Case Reports

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Objective: In this report, we discuss the cases of two patients with a ruptured blood blister-like aneurysm (BBA) of the basilar trunk, who we treated with overlapping stent-assisted coil embolization (SACE).

Case Presentation: Case 1: The first patient was a 52-year-old male with a World Federation of Neurosurgical Societies (WFNS) Grade IV subarachnoid hemorrhage (SAH). A 2 mm anterior wall BBA of the basilar artery (BA) was detected on cerebral angiography on day 10 and treated with overlapping SACE. No recanalization was observed at 12 months after surgery. Case 2: The second patient was a 62-year-old female with WFNS Grade I SAH. A 1.7 mm posterior wall BBA of the BA was detected on cerebral angiography on day 5, which was treated with overlapping stents alone, but a residual aneurysm was noted on day 14, and SACE was additionally performed. Infarction of the perforating branch was noted after surgery, but the aneurysm was completely occluded on follow-up after 1 week. No recanalization was observed at 10 months after surgery.

Conclusion: Although overlapping SACE may be effective for ruptured BBAs of the basilar trunk, attention should be paid to the damage of the perforating branch after surgery in cases of aneurysm of the posterior wall of the BA. For appropriate multiple overlapping stents, accumulation of cases and further investigations are necessary.

Keywords: basilar trunk, ruptured blood blister-like aneurysms, overlapping stent-assisted coil embolization, low-profile visualized intraluminal support, barrel technique

Introduction

It is well known that direct surgery for the treatment of ruptured blood blister-like aneurysms (BBAs) of the basilar trunk is highly invasive and technically difficult compared with other dissecting aneurysms, and there have recently been increasing reports on the efficacy of endovascular treatment of anterior wall BBAs of the internal carotid artery (ICA) and basilar artery (BA).1-5) BBAs are fragile not only in the aneurysm itself but also in the parent vessel, and strengthening and repairing the parent vessel are necessary, unlike coil embolization of normal aneurysms. Moreover, there are problems such as a high intraoperative rupture rate, perioperative complications, and postoperative antiplatelet therapy, and no consensus concerning the treatment method has yet been established.1-5)

We encountered two patients in whom a ruptured BBA of the basilar trunk was treated with overlapping stent-assisted coil embolization (SACE) using low-profile visualized intraluminal support (LVIS) (Terumo Corp., Tokyo, Japan). Here, we report their cases centering on the surgical strategy, including the diagnosis, treatment, and perioperative management, with a literature review.

Case Presentation

Case 1: The first patient was a 52-year-old male.

History of present illness: The patient was admitted to our hospital for a World Federation of Neurosurgical Societies
(WFNS) Grade IV subarachnoid hemorrhage (SAH) with a disturbance of consciousness.

Past and familial medical histories: None in particular.

Course after admission: On head CT on admission (Fig. 1A), SAH was noted mainly in the posterior cranial fossa, but no feature of aneurysm or vascular dissection was clearly detected on MRA or cerebral angiography (Fig. 1B and 1C), and antihypertensive therapy targeting systolic blood pressure <140 mmHg was performed. On cerebral angiography (3D-DSA) performed on day 10 after the onset (Fig. 2A and 2B), an approximately 2 mm BBA of the wall of the basilar trunk at the superior cerebellar artery (SCA) bifurcation level was detected and treated with overlapping SACE using LVIS Blue.

Endovascular treatment: Under general anesthesia, the right femoral artery was punctured, and a 6 Fr Roadmaster (Goodman Co., Ltd., Aichi, Japan) was placed in the distal right vertebral artery (VA). Headway 21 (Terumo Corp.) was guided to the P2 of the left posterior cerebral artery using a CHIKAI 14 microguidewire (Asahi Intecc, Aichi, Japan), and a \(3.5 \times 22 \text{ mm}\) LVIS Blue was set at standby. Then, an Echelon 10 (Medtronic, Minneapolis, MN, USA) was placed at the SCA level with the aneurysm using a GT 12 guidewire (Terumo Corp.), and the \(3.5 \times 22 \text{ mm}\) LVIS Blue was expanded in the left P1 over the BA in which the delivery wire (barrel technique) was pushed deeper than that in the normal push/pull technique to increase the metal coverage of LVIS Blue, which increased the flow diverter effect. Then, a \(2.5 \times 4.0 \text{ cm}\) nano-Target 360 (Stryker Corp., Kalamazoo, MI, USA) for the anterior wall at the SCA level was selected through the Echelon 10 described above, and embolization was performed with four coils. A \(4.5 \times 23 \text{ mm}\) LVIS Blue was placed in the BA tip over the right VA through a Headway 21 (overlapping stenting), aiming at holding down the region concerned as the entry flap of dissection. The barrel technique was also applied as...
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Fig. 2  DSA during perioperative period for Case 1. (A and B) Preoperative 3D-DSA on day 10 shows a blood blister-like anterior wall aneurysm of basilar trunk (A: anterior view, B: lateral view). Arrows: the aneurysm. (C) Angiogram (lateral view) just before overlapping SACE shows the blood blister-like anterior wall aneurysm of basilar trunk (arrow). (D) Angiogram (lateral view) after overlapping stent by two LVIS stents with coil embolization shows complete occlusion of the aneurysm (arrow). White arrowhead: the proximal marker of LVIS 3.5 × 22 stent. Black arrowhead: the proximal marker of LVIS 4.5 × 23 stent. (E) Cone-beam CT and final angiogram (anterior view) show overlapping stent by two LVIS stents with coil embolization. LVIS: low-profile visualized intraluminal support; SACE: stent-assisted coil embolization

Fig. 3  Postoperative MRI and angiogram for Case 1. (A) Postoperative DWI shows no acute cerebral infarction. (B) Postoperative angiogram at 12 months shows no recurrence of the aneurysm. DWI: diffusion-weighted imaging

described above in this procedure. Disappearance of the aneurysm, conservation of blood flow in the parent vessel, and the position and press fitting of the stent to the parent vessel were confirmed on DSA and cone-beam CT, and surgery was completed (Fig. 2C–2E).

Postoperative course: During surgery, systemic heparinization, 300 mg of aspirin, and 300 mg of clopidogrel were loaded through a nasogastric tube, and 80 mg of Ozagrel Sodium was intravenously administered after stenting. Dual antiplatelet therapy (DAPT) with 100 mg of aspirin and 75 mg of clopidogrel was continued from the day following surgery to prevent intra- and postoperative in-stent thrombosis although there was a risk of rebleeding. Sufficient fluid replacement and administration
Fig. 4 Image findings at hospitalization and day 5 for Case 2. (A) Head CT (sagittal view) shows significant subarachnoid hemorrhage in the posterior cranial fossa. (B and C) MRA and 3D-DSA show no aneurysm and dissection. (D and E) Preoperative 3D-DSA on day 5 shows a blood blister-like posterior wall aneurysm of basilar trunk (A: posterior view, B: lateral view). Arrows: the aneurysm.
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of Eril and Ozagrel were continued for 2 weeks after surgery to prevent cerebral vasospasm. Complete occlusion of the aneurysm was confirmed on cerebral angiography immediately after surgery (Fig. 2D). On MRI, performed on the day following surgery (Fig. 3A), no acute cerebral infarction was clearly detected. No cerebral vasospasm occurred after surgery, but hydrocephalus developed, for which the drug therapy was reduced to single antiplatelet therapy (SAPT) with 100 mg of aspirin alone 1 week before lumboperitoneal (LP) shunt. The LP shunt was performed to treat the hydrocephalus approximately 1 month after surgery, and the patient was rated mRS 3 and transferred to another hospital for rehabilitation on day 50. As of 12 months after surgery, no recanalization has occurred (Fig. 3B).

Case 2: The second patient was a 62-year-old female.

History of present illness: The patient was admitted to our hospital for WFNS Grade I SAH with a sudden headache. SAH centered on the posterior cranial fossa was observed on head CT on admission (Fig. 4A), but no feature of

Fig. 5 DSA during perioperative period for Case 2. (A) Angiogram (lateral view) just before overlapping stent shows the blood blister-like posterior wall aneurysm of basilar trunk (arrow). (B) Angiogram (lateral view) after overlapping stent by two LVIS stents shows slight residual aneurysm (arrow). White arrowhead: the distal marker of LVIS Jr. 3.5 × 18 stent. Black arrowhead: the proximal marker of LVIS Jr. 3.5 × 23 stent. (C) Arterial late phase of the angiogram (lateral view) after overlapping stent by two LVIS stents shows slight residual aneurysm (arrow). (D and E) Final angiogram (D: anterior view, E: lateral view) after overlapping stent by three LVIS stents with coil embolization during reoperation show slight residual aneurysm (arrow). White arrowhead: the distal marker of LVIS Jr. 3.5 × 18 stent. Black arrowhead: the proximal marker of LVIS Jr. 3.5 × 18 stent. LVIS: low-profile visualized intraluminal support.
Endovascular treatment (Second): Under general anesthesia, the right femoral artery was punctured, and a 6 Fr Roadmaster was placed in the distal right VA, followed by guiding the Headway 17 (Terumo Corp.) to the left P2 using a CHIKAI 14 microguidewire and setting a 3.5×18 mm LVIS Jr. at standby. An Echelon 10 was placed at the SCA level at which the aneurysm was present using a GT 12 guidewire, and a 3.5×18 mm LVIS Jr. was partially expanded in the right P1 over the BA (partial stenting). Then, coil embolization was applied to the posterior wall at the SCA level using a 2.5×4.0 cm nano-Target 360 (Stryker Corp.) through the Echelon 10, and the 3.5×18 mm LVIS Jr. was completely expanded (complete stenting) (Fig. 5D and 5E) in which the barrel technique was applied as much as possible. The aneurysm was slightly visualized on DSA (Fig. 5E), but surgery was completed expecting thrombosing by the flow diverter effect.

Course after surgery: Systemic heparinization and 80 mg of Ozagrel Sodium were intravenously administered after stenting in the second surgery. DAPT with 100 mg of aspirin and 75 mg of clopidogrel was continued from the day following the second surgery. On MRI performed on the day following surgery, a right pontine infarction that was considered to have been caused by occlusion of the perforating branch was present in the region of the basilar paramedian artery (Fig. 6A). A transient right medial longitudinal fasciculus syndrome developed, but fortunately the symptoms were improved within approximately 1 day. The aneurysm was gradually thrombosed and complete occlusion of the aneurysm was confirmed on cerebral angiography 1 week after reoperation (Fig. 6B). Sufficient fluid replacement and administration of Eril and Ozagrel

Endovascular treatment (First): Under general anesthesia, the right femoral artery was punctured, and a 6 Fr Roadmaster was placed in the distal right VA. The aneurysm was confirmed on DSA (Fig. 5A). As embolization of the aneurysm using an Echelon 10 catheter was difficult, the strategy was changed to overlapping stents using an expandable LVIS Jr. Echelon 10 guided to the right P2 using a GT 12 guidewire and a 3.5×18 mm LVIS Jr. expanded in the right P1 over the BA, followed by placing a 3.5×23 mm LVIS Jr. so as to cover the first stent at a high position of the aneurysm (overlapping stenting) (Fig. 5B). The barrel technique was applied as much as possible when each LVIS was expanded. The aneurysm was slightly visualized in the arterial late phase on DSA (Fig. 5C), but surgery was completed expecting thrombosing by the flow diverter effect. During surgery, systemic heparinization, 300 mg of aspirin, and 300 mg of clopidogrel were loaded through a nasogastric tube, and 80 mg of Ozagrel Sodium was intravenously administered after stenting. DAPT with 100 mg of aspirin and 75 mg of clopidogrel was continued from the day following surgery, but a residual aneurysm (Fig. 5C) was noted. Thus, additional stenting using an LVIS Jr. (triple) was performed 14 days after the onset.

Aneurysm or vascular dissection was detected on MRA or cerebral angiography (Fig. 4B and 4C). Thus, antihypertensive therapy targeting systolic blood pressure <140 mmHg was performed. On cerebral angiography (3D-DSA), performed on day 5 after the onset (Fig. 4D and 4E), an approximately 1.7 mm posterior wall BBA of the basilar trunk (at the SCA bifurcation level) was detected. Due to the fact that coil embolization of the aneurysm was considered difficult, it was treated only with double-overlapping LVIS Jr. stents.

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were continued for 2 weeks after the first surgery to prevent cerebral vasospasm. No cerebral vasospasm or hydrocephalus developed after surgery. On cerebral angiography after 6 months, no recurrence of aneurysm, in-stent restenosis, or in-stent thrombosis was noted, and drug therapy was reduced to SAPT. No recanalization was noted 10 months after surgery (Fig. 6B and 6C), and the patient was rated mRS 1 and followed up at the outpatient clinic.

### Discussion

BBAs are intracranial aneurysms that develop in the ICA anterior wall and non-bifurcation regions of the BA, and they account for 0.3%–1.0% of all intracranial aneurysm cases and 0.9–6.5% of ruptured aneurysm cases. They are false aneurysms that are covered only with tunica adventitia and thin fibrous tissue. Ruptured BBAs spontaneously enlarge, and the recurrence and mortality rates are high regardless of the method of treatment. BBAs of the basilar trunk are rarer, and most cases are discovered with SAH.

3D-DSA, CTA, and high-resolution MRI are useful for the diagnosis of BBAs, but these BBAs are unlikely to be identified on the initial examination because of the size and SAH, and hence the diagnosis is often delayed. In the patients discussed in this study, the aneurysms could not be identified by cerebral angiography on admission, but they were definitely diagnosed by 3D-DSA on day 10 in Case 1 and day 5 in Case 2. Significant SAH was noted in the posterior cranial fossa on head CT on admission, which suggested the importance of repeating imaging (especially 3D-DSA) in consideration of the vascular abnormality of the posterior circulation. For treatment, direct surgery, occlusion of the parent vessel, and endovascular treatment are performed. For direct surgery of BA trunk BBAs, neck clipping is technically difficult because of the absence of aneurysm neck and thin wall. Mooney et al. applied neck clipping in four patients (the thin layer of the aneurysm was strengthened with cotton to minimize the risk of slipping clips in two patients) and achieved long-term efficacy. The remaining case required stenting of the residual aneurysm by endovascular treatment after clipping, but no recurrence occurred in any of the four patients throughout the 4-year imaging follow-up and 6-year clinical follow-up. Rouchaud et al. reported a systematic review and meta-analysis of endovascular treatment of 258 patients with ruptured BBAs, including those of the ICA and BA (in particular, a comparison between deconstructive techniques, such as internal trapping and parent vessel occlusion, and reconstructive techniques, such as coiling, SACE, overlapping stents, and flow diverter), in which 73% of the patients were females, their mean age was 47.6 years old, 19.3% were Hunt and Hess Grade IV or V, and the mean aneurysm size was 2.4 mm. The immediate occlusion rate was significantly higher in the deconstructive group (77.3%) than in the reconstructive group (33%). In the reconstructive group, the medium-long-term complete occlusion rate was significantly higher in the flow diverter (90.8%) than in the non-flow diverter (69.7%) group, and the retreatment rate was significantly different (6.9% in the former and 27.1% in the latter). Out of 57 cases of BBAs that could be searched for in PubMed, 8 (14%) were BBAs of the BA, and treatments with SACE and a flow diverter were performed in most of the recent cases. However, treatments with SACE and a flow diverter are not indicated for ruptured BBAs in Japan. Simple coiling in the aneurysm was considered difficult also for the present cases on the basis of the characteristics of BBAs. Overlapping SACE was performed after explaining the possibility of switching to SACE and the risk of perioperative complications to the patients and their families before surgery, after obtaining sufficient informed consent and approval by the Ethics Committee of the hospital. We consider that overlapping stents may be used as an alternative method of flow diversion for the following reason: LVIS stents are braided stents, and the metal coverage is higher than that of laser-cut stents and exhibits a high flow diverter effect. The metal coverage of LVIS Blue is higher than that of LVIS Jr. Wang et al. used computational fluid dynamics (CFD) analysis to compare the flow diverter effect of LVIS stents with those of Enterprise stents and Pipeline devices. The flow diverter effect of a single sheet of LVIS stents was higher than that of overlapping stents comprised of double Enterprise stents and smaller than that of a single sheet of Pipeline devices. However, the flow diverter effect of overlapping stents comprised of double-LVIS stents was significantly higher than that of a single Pipeline device. Thus, we selected the overlapping stents using LVIS stents.

Case 1 involved anterior wall BBA of the BA-SCA bifurcation. The possibility of parent vessel (VA–BA) dissection could not be ruled out. Thus, first, LVIS Blue with high metal coverage was placed while jailing a microcatheter for coil embolization so as to partially cover the region where dissection was of concern. Subsequently, considering the fragility of the BBA at a high position, coil embolization...
was performed using a 2.5 × 4.0 cm nano-Target 360, coils with a size not deviating from the stent and a relative soft 3D shape, and the second LVIS Blue was placed so as to cover the rest of the region where the parent vessel (VA–BA) dissection was of concern and overlapped only in the local region at a high position of the aneurysm. However, retrospectively, because BBAs are small, when the jailing technique used is similar to that used in SACE of normal large aneurysms, the microcatheter is fixed, which increases the risk of rupture during coil embolization. Thus, it may have been desirable to employ the jack-up technique in which coil embolization is performed after partially expanding the stent, and then the stent is fully expanded, as employed in Case 2.

Case 2 involved the posterior wall BBA of the BA-SCA bifurcation, and no parent vessel dissection was clearly noted, but only overlapping stents using an LVIS Jr. expandable in the 10 catheter were applied in the first surgery in consideration of the fragility of the parent vessel of BBA and concern for damage of the perforating branch of the posterior wall, with the aim of strengthening the parent vessel and a flow diverter effect on the aneurysm. Retrospectively, complete occlusion would have been achieved only by the first surgery if an LVIS Blue with higher metal coverage than that of LVIS Jr. was used for the overlapping stents because it increases the flow diverter effect. A residual aneurysm was detected, and reoperation was performed 2 weeks after the first surgery. However, there is room to discuss how long thrombosing should be waited for after surgery. In reoperation, based on the experience of Case 1, multiple overlapping stents were applied using the third LVIS Jr. employing the jack-up technique. LVIS Blue was not selected for the third stent because the amount of metal increases. An increase in the risk of stenosis of the parent vessel, in-stent thrombosis, and damage of the perforating branch of the posterior wall because of an increase in the metal amount of triple LVIS was considered. Case 2 involved a ruptured BBA of the BA-SCA posterior wall, and the perforating branch was present near this region. Coil embolization may have been a cause of postoperative infarction of the perforating branch in this patient, and the concomitant use of coils for the posterior wall aneurysm should have been avoided. The barrel technique was applied to improve the metal coverage when the LVIS stent was placed in each case while considering the burden on the parent vessel, and the aneurysm was covered with the overlapping stents at a high position of the aneurysm in combination with coil embolization using 3D-shaped relatively soft coils to reduce the burden on the aneurysm. These may have led to the prevention of rupture during surgery and improvement of the flow diverter effect, which would contribute to the final complete occlusion. However, excess application of the barrel technique may place a burden on the parent vessel, and the risk of vascular rupture increases in cases of vascular dissection, so this technique should be carefully applied.

In addition, for overlapping SACE, consideration is necessary for the procedure, stent selection, and perioperative antiplatelet/anticoagulant therapies. In Case 1, overlapping was applied to only the high position of the aneurysm, and reduction of the metal amount was considered as much as possible for the parent vessel because another dissection of the parent vessel was of concern. Thus, a stent with the same size as the first stent and a longer length was selected for the second stent. In the first surgery of Case 2, the stent was selected for the same reason as that in Case 1. In reoperation, a stent shorter than the second stent was selected for the third stent because thrombosing in the aneurysm by local coverage at the high position of the aneurysm was expected while considering the reduction of the amount of metal in the parent vessel. We also consider that the points of the LVIS stent described above can be overcome by careful operation, utilizing the characteristics of the LVIS stent: favorable visibility, resheathability, and ability to redo placement many times if necessary. For the overlapping stents in SACE, ischemic complications, such as in-stent thrombosis and in-stent restenosis-induced parent vessel stenosis, are of concern. On the other hand, the risk of rebleeding induced by anticoagulant/antiplatelet therapy increases in rupture cases. We continued antihypertensive therapy targeting systolic blood pressure <140 mmHg until complete occlusion of the aneurysm is confirmed after surgery, and we investigated the timing of reducing drugs from DAPT to SAPT by frequently confirming the presence or absence of aneurysm occlusion and in-stent thrombosis on cerebral angiography approximately every 2 weeks. These are discontinued when no ischemic symptom develops for 1 year.

**Conclusion**

It has been suggested that overlapping SACE in combination with double- or triple-LVIS overlapping stents placed in ruptured BBA of the BA using the barrel technique and coil embolization at the high position of the aneurysm is effective. However, the perforating branch bifurcates near
BA posterior wall aneurysms, in which attention should be paid to the damage of the perforating branch after surgery. Accumulation of cases and further investigations may be necessary to clarify the appropriate multiple overlapping stents of the basilar trunk in Japan. Overlapping stents using LVIS may be employed as an alternative method. Overlapping SACE in combination with double- or triple-overlapping LVIS stents using the barrel technique and coil embolization at a high position of the aneurysm may be effective, and it is desirable to select LVIS Blue for the stents as much as possible with the expectation of a flow diverter effect. However, for BA posterior wall BBAs, attention should be paid to the damage of the perforating branch after surgery. Accumulation of cases and further investigations may be necessary to clarify the appropriate multiple overlapping stents.

I Disclosure Statement

None of the first and co-authors have a conflict of interest to be disclosed in this report.

I References