Emergency Retrograde Left Common Carotid Artery Stenting after Thoracic Endovascular Aortic Repair with Regional Cerebral Oxygen Saturation Monitoring: Report of Two Cases

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Objective: Two cases in which emergency retrograde stenting were performed for occlusion of the left common carotid artery orifice that occurred during thoracic endovascular aortic repair are reported.

Case Presentations: In males in their 70s with thoracic aortic aneurysm, oxygen saturation dropped in the left cerebrum immediately after deployment of the thoracic aortic stent graft under general anesthesia. The stent graft obstructed the orifice of the left common carotid artery, and recanalization was achieved by direct puncture of the cervical left common carotid artery and placing a balloon expandable stent at the orifice of the left common carotid artery. No postprocedural neurologic deficits were observed.

Conclusion: Retrograde stenting of the orifice of the left common carotid artery is effective for thoracic aortic stent graft migration, and regional cerebral oxygen saturation is an important index. The cases are worth reporting as neurointerventionist may also be required to perform the procedure, which is usually performed by vascular surgeons.

Keywords: common carotid artery, stent, thoracic aortic aneurysm, regional cerebral oxygen saturation, thoracic endovascular aortic repair

Introduction

Since thoracic endovascular aortic repair (TEVAR) using a self-expandable covered stent for thoracic aortic aneurysm, which is performed by cardiovascular surgeons, began to be covered by insurance in Japan in 2008, it has rapidly spread due to its low invasiveness and applicability to older and high-risk patients. Basically, TEVAR is indicated for thoracic aortic aneurysms distal to the left subclavian artery because stent migration into the aneurysm or persistence of blood flow into the aneurysm may occur unless a landing zone of at least 15–20 mm can be secured on both the cardiac and peripheral sides of the stent graft (Fig. 1A). If the proximal landing zone is insufficient, the stent is often deployed more proximally by sacrificing the left subclavian artery. In this event, it is common practice to secure the blood flow of the left upper extremity by constructing an axillary–axillary artery bypass using a vascular graft and to prevent the retrograde blood flow from hitting the external wall of the stent graft by occluding the left subclavian artery at its orifice (debranching) (Fig. 1B). In the two cases presented here, immediately after TEVAR with debranching of the left subclavian artery for aortic arch aneurysm, the proximal end of the stent graft also occluded the orifice of the left common carotid artery. The neurosurgery department was consulted, and emergency retrograde stenting of the left common carotid artery orifice was performed from the cervical region, and favorable outcomes were obtained.
Case Presentations

Case 1
The patient was a 79-year-old male with histories of hypertension, angina pectoris, scleroderma, and gastric ulcer. An enlarging thoracic aortic aneurysm (distal arch) was detected by thoracic CT (Fig. 2A), and the patient was referred to the department of cardiovascular surgery of our hospital. Since the lesion was a saccular aneurysm with a maximum short diameter of 52 mm accompanied by mural thrombosis, it was judged to be an indication for TEVAR.

A non-invasive measurement system of mixed blood oxygen (INVOS, Covidien Minneapolis, MN, USA) was attached, and general anesthesia was introduced. Since the distance between the proximal end on the greater curvature side of the neck of the thoracic aortic aneurysm and the left subclavian artery was 5 mm, axillary–axillary artery bypass (Advanta PTFE graft, 7 mm; Atrium Medical, Hudson, NH, USA) was performed after systemic heparinization, and a proximal landing zone 15 mm or longer was secured from immediately below the common carotid artery on both the greater and lesser curvature sides by embolizing the orifice of the left subclavian artery with AMPLATZER vascular plugs 4, 16 mm (AGA Medical, Minneapolis, MN, USA). The right inguinal region was incised, the right common femoral artery was exposed, and, after performing a purse-string suture, a 24 Fr. sheath (GORE DrySeal; W.L. Gore & Associates, Flagstaff, AZ, USA) was inserted. A thoracic aortic stent graft 40 mm × 15 cm (GORE CTAG; W.L. Gore & Associates) was advanced to the ascending aorta (Fig. 2B and 2C), and the CTAG was deployed immediately below the left common carotid artery. The regional oxygen saturation (rSO₂) of the left brain was 66% before deployment of the stent but decreased to 48% immediately after stent deployment. Since delayed contrast enhancement was observed in the left common carotid artery on aortography (Fig. 2D), the neurosurgery department was consulted. On repeated aortography, the left common carotid artery was nearly occluded (Fig. 2E). To avoid ischemic complications of the brain, retrograde stenting of the orifice of the left common carotid artery was selected. The cervical region was incised at the anterior margin of the left sternomastoid muscle, the left common carotid artery was exposed, a purse-string suture was performed, and a 7 Fr. short sheath was inserted toward the aorta. When a 0.035 inch guidewire (Radifocus; Terumo, Tokyo, Japan) was advanced retrogradely, it passed near the flare of the stent and easily reached the aorta. A balloon expandable stent (Express LD stent system 7 mm × 37 mm; Boston Scientific, Natick, MA, USA) was set with its distal end protruding out of the aorta and placed by inflating the balloon to a nominal pressure (8 atm). The rSO₂ increased rapidly to 68% from immediately after balloon deflation, and the delay of contrast enhancement of the left common carotid artery disappeared on aortography (Fig. 2F). While slight type 1a endoleak was noted, touch-up using a tri-lobe balloon was not performed in consideration of adverse effects on the chimney stent. The sheaths in the left common carotid artery and right common iliac artery were removed, the puncture site was closed by purse-string suture, and surgery was ended by closing the incision. After emergence from anesthesia, no neurologic deficits were noted, complete thrombosis of the thoracic aortic aneurysm was confirmed by contrast-enhanced CT (Fig. 3), and the patient was discharged to home on the 9th postoperative day with an uneventful course.

Case 2
The patient was a 79-year-old male with histories of right lower lobe pneumonectomy due to lung cancer, chronic kidney disease, old myocardial infarction, angina pectoris,
and smoking (60 cigarettes/day for 55 years). He was diagnosed with aneurysm of the distal thoracic aortic arch by chest CT after surgery for lung cancer and was referred to the cardiovascular surgery department of our hospital. The lesion was a saccular aneurysm with a maximum short diameter of 50 mm and was judged to be an indication for TEVAR.

The distance from the proximal end of the neck of the thoracic aortic aneurysm on the greater curvature side to the left subclavian artery was 3 mm. Similar to Case 1, to obtain a proximal landing zone of 15 mm or longer, an axillary-axillary artery bypass was constructed, the orifice of the left subclavian artery was occluded with a vascular plug (Fig. 4A), and a stent (GORE CTAG 37 mm × 15 cm) was deployed immediately below the left common carotid artery via the right common femoral artery. The rSO₂, which was 62% before stent deployment, decreased to 57% after deployment. On aortography, visualization of

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**Fig. 2** Case 1. (A) Preoperative 3D-CTA shows thoracic aortic aneurysm. (B) Intraoperative AOG in cross-sectional view before intentional occlusion of the orifice of left subclavian artery. (C) AOG just before stent graft deployment shows that patency of axilla-axilla bypass using vascular prosthesis and detached vascular plug at the orifice of left subclavian artery. (D) AOG just after stent graft deployment shows proximal flare of stent graft covering the orifice of the left common carotid artery and causing flow delay. (E) AOG 10 minutes after stent graft deployment shows occlusion of the left common carotid artery. (F) Emergency retrograde stenting of the orifice of left common carotid artery restores antegrade flow of left common carotid artery. AOG: aortography

**Fig. 3** (A) Postoperative chest plain and contrast enhanced CT shows thrombosis of thoracic aortic aneurysm and no apparent endoleak to outer layer of the stent graft. (B) 3D-CTA shows positional relationship of stent graft and retrograde stenting of left common carotid artery.
the left common carotid artery was delayed for 2 seconds or more, and its orifice was stenosed (Fig. 4B). While preprocedural MRA showed cross flow via the anterior communicating artery, the risk of cerebral ischemic complications including embolism was high, and retrograde stenting of the orifice of the left common carotid artery was selected. The common carotid artery was exposed in the left cervical region, a purse-string suture was performed, and a 7 Fr. short sheath was inserted toward to the heart. When a 0.035 inch guidewire was advanced, it was bent into a hairpin curve against the external wall of the aortic stent. However, as it was advanced further, the more rigid part of the shaft of the guidewire entered the aorta, and the hairpin curve was released. An Express LD 8 mm × 37 mm was advanced, and the stent was placed by inflating the balloon at 8 atm (nominal pressure) at a position where the distal end of the stent protruded into the aorta (Fig. 4C). This was immediately followed by antegrade visualization of the left common carotid artery without delay, and the left rSO\textsubscript{2} increased to 67% (the right rSO\textsubscript{2} consistently remained at 62%). No postprocedural neurologic deficits were noted, there were no complications of the use of the contrast medium except mild exacerbation of kidney dysfunction, and the patient was discharged to home on the 11th postprocedural day. Postprocedural plain CT confirmed no change in the stent position.

**Discussion**

We encountered two patients in whom the orifice of the left common carotid artery was occluded due to proximal migration of the stent graft during TEVAR, immediately causing a decrease in the blood flow of the left common carotid artery. In both patients, ischemic complications of the brain could be avoided with retrograde placing of a balloon expandable stent via the cervical region in emergency. Also, the rSO\textsubscript{2} was a sensitive index of ischemia of the anterior circulation of the brain during TEVAR under general anesthesia and was useful for the assessment of the effect of retrograde stenting of the orifice of the left common carotid artery.

There have been few reports of retrograde stenting of the orifice of the left common carotid artery for migration of the stent graft after its placement\textsuperscript{2,3). Neurointerventionist may be requested to treat such a condition although the procedure is intrinsically a specialty of vascular surgeons, so they must have knowledge about the procedure as an emergency measure to prevent ischemic complications of
the brain (Fig. 5). Thoracic aortic aneurysm is an important disorder with a mortality rate exceeding 30% if it shows symptoms indicating impending rupture or rupture such as chest pain. While thoracotomy is a highly invasive procedure, TEVAR can also be performed for the treatment of aortic aneurysms located near a vessel branch with the use of surgical adjuvant techniques, and its area of application has widened to incidentally detect thoracic aortic aneurysms in elderly patients, which are increasing recently. CTAG is made of a nitinol open-cell stent and Gore-Tex (expanded polytetrafluoroethylene [PTEF]). In its placement, the PTEF thread attached to the deployment sleeve is extracted at hand, which induces instantaneous self-expansion from the graft center, but experience is needed for its positioning. In addition, since there is a risk of endoleak and stent displacement unless landing zones of 15–20 mm can be secured on the proximal and distal sides of the stent, the dilemma that stent deployment at as proximal a site in the aorta as possible is required even with debranching of the left subclavian artery can cause migration. Thus, conditions similar to those of our patients are highly likely to occur, and prompt judgment of therapeutic intervention is necessary for the prevention of cerebral ischemic complications.

The INVOS system, which with non-invasive and simple intraprocedural monitoring of the blood flow was possible, was useful for the prediction of cerebral ischemic complications in TEVAR and the evaluation of the effects of retrograde left common carotid artery stenting. As it provides consistent values under general anesthesia and permits comparison with the baseline value and evaluation of asymmetry, it has recently begun to be used widely in the field of cardiovascular surgery for the detection of cerebral ischemic complications. If neurologic deficits are first recognized after emergence from anesthesia without monitoring of the rSO₂, ischemic damage of the brain may have become irreversible. The rSO₂ was slightly higher than on the opposite side immediately after recanalization because of reperfusion of the occluded carotid artery. Post-stenting hyperperfusion syndrome is reported to occur frequently if the rSO₂ is 10% or more higher than the baseline value 3 minutes after recanalization, but the increase was less than 10% in both our patients, and hyperperfusion syndrome was not observed in either patient.

Express LD was prepared for exacerbation of the blood flow of the lower extremity after the placement of a 24 Fr. sheath in the common femoral artery during TEVAR rather than for common carotid artery occlusion. However, this balloon expandable stent has excellent operability and vascular compatibility and is already in wide use for stenotic lesions of the subclavian artery although it was originally developed for the iliac artery. We obtained satisfactory outcomes in our two patients by applying this device to the orifice of the left common carotid artery.

A stent placed in advance in a branch of a vessel for its preservation is called a chimney stent, but this technique involves the risk of type 1a endoleak. Moreover, since postdilatation using a tri-lobe balloon, which is usually added to improve the affixation of deployed aortic stents to the vascular wall, may cause occlusion of the chimney stent, it cannot be performed. If considerable endoleak persists, it makes the therapeutic effects on aortic aneurysm insufficient. Therefore, this technique should be used only as a salvage measure.

If the possibility of occlusion of the orifice of the left common carotid artery is considered high before the procedure, bypass grafting using a synthetic vessel between the bilateral common carotid arteries is an option, but this procedure, involving clamping of the carotid artery, may induce cerebral embolism.

Not only neurovascular treatment but also endovascular treatments in other fields are improving remarkably, and routine close collaboration among related departments is necessary for the prevention of severe complications.

## Conclusion

In the two cases reported here, we successfully avoided cerebral ischemia with retrograde placing of a balloon expandable stent by direct puncture of the cervical common carotid artery for occlusion at the orifice of the left common carotid artery that occurred during stenting of thoracic aortic aneurysm. This technique is useful as an option of emergency treatment for conditions that require prompt management with monitoring of values provided by the INVOS system.

## Disclosure Statement

Neither the first author nor any of the coauthors have any conflicts of interest.

## References

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