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Case Report

Endovascular Repair of an Aortic Arch Aneurysm in a Patient with a Hypoplastic Left Vertebral Artery Terminating into the Posterior Inferior Cerebellar Artery

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We present a 76-year-old male with an aortic arch aneurysm and a hypoplastic left vertebral artery (VA). Endovascular repair with left subclavian artery (SCA) closure was planned. The right VA was dominant, while the left VA was hypoplastic, barely connected to the basilar artery, and appeared to terminate at the posterior inferior cerebellar artery (PICA). The VA sizes and flow patterns during ultrasonography confirmed these findings. Therefore, we performed endovascular repair with left SCA reconstruction to prevent ischemia of the PICA perfusion area. After the operation, he experienced no difficulty with brain perfusion.

Keywords: thoracic endovascular aortic repair, aortic arch aneurysm, posterior inferior cerebellar artery

Introduction

For thoracic endovascular aortic repair (TEVAR) of an aortic arch aneurysm with a stent graft, revascularization of the branches of the aortic arch may be required if there is intentional occlusion of the branches, to obtain an adequate proximal sealing zone.[1,2] However, researchers reported that simple occlusion is possible for the left subclavian artery (SCA) in many cases. This is possible if there is a good connection between the right and left vertebral arteries (VAs) and basilar artery, and there are no anatomical variations that would compromise perfusion to the brain, spinal cord, heart, or left arm.[3,4] However, the VAs exhibit anatomical variations in many cases.[5,6] Therefore, VA anatomy must be evaluated by preoperative diagnostic imaging. In the present case, we evaluated the anatomy of the cerebral vessels in detail using ultrasonography[7] in addition to computed tomography (CT) and magnetic resonance imaging (MRI).

Case

A 76-year-old male with a previous history of hypertension, cerebral infarction, and emphysema was referred to our hospital. Three years ago, a transient ischemic attack resulted in a right hemiparesis. The symptoms improved thereafter. He developed hoarseness without any apparent cause, 6 months ago. A visit to a local physician showed a tumor in the upper lobe of the left lung on a standard X-ray film; consequently, he was referred to our hospital for further examination. Laboratory data showed only slight elevation of FDP, which maybe occurred due to the aneurysm. The rest of the data were normal. CT showed an aneurysm at the distal portion of the left SCA on the lesser curvature of the aortic arch across from the origin of the left SCA. The maximal diameter was 65 mm (**Fig. 1**). Considering his condition, we planned TEVAR.

However, the distance from the distal edge of the left common carotid artery (CCA) to the proximal edge of the aneurysm on the lesser curvature of the aorta was <15 mm. Even if TEVAR with closure of the left SCA was planned, the proximal sealing zone would be too short to receive sufficient sealing using a stent graft. However, the distance from the distal edge of the left CCA to the proxi-

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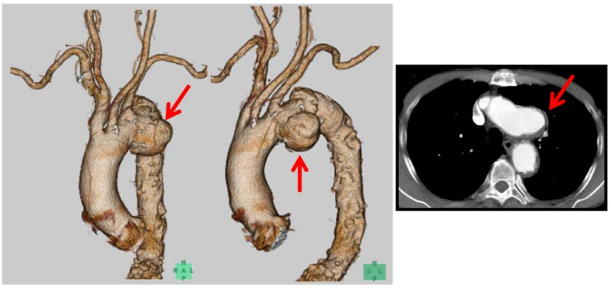

Fig. 1 Thoracic aortic aneurysm on preoperative computed tomography images.
There was an aneurysm in the distal portion of the left subclavian artery (SCA) on the lesser curvature of aortic arch across from the left SCA. The maximal diameter was 65 mm (arrow). The size of the brachiocephalic artery, right SCA, right common carotid artery (CCA), left CCA, and left SCA were 15, 12, 9, 9, and 10 mm, respectively.

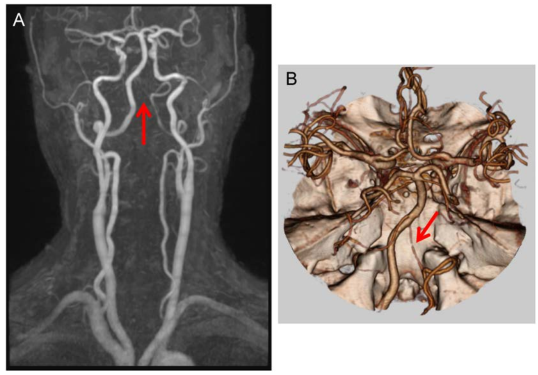

Fig. 2 Vertebral arteries and basilar artery on preoperative imaging.
The left vertebral artery (VA) was significantly hypoplastic compared with the right VA. The left VA demonstrated a connection with both the basilar artery and the posterior inferior cerebellar artery. However, the VA connection with the basilar artery was very small and exhibited a severe stenosis in the middle (arrow).
A: magnetic resonance imaging, **B:** computed tomography

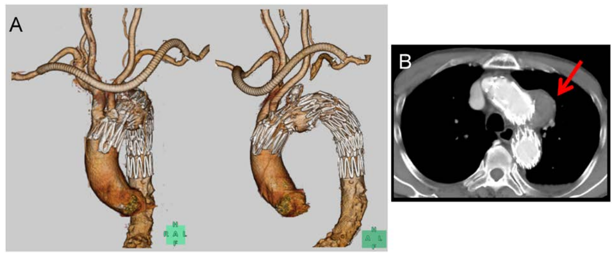

Fig. 3 Postoperative computed tomography images.
The stent grafts were deployed from the ascending aorta to the descending aorta. The aneurysm was isolated with no endoleak (arrow). The brachiocephalic artery and left common carotid artery were enhanced via fenestrations in the stent graft. The left subclavian artery and vertebral artery were enhanced by the right to left axillar artery bypass.

mal edge of the aneurysm on the aortic wall was 22 mm, which was within the manufacturer's recommendations for use of the Najuta stent graft™ (Kawasumi Laboratories, Inc., Tokyo, Japan). Therefore, we chose a Najuta stent graft™, which demonstrates fenestrations for arch branches to obtain a sufficient proximal sealing zone.[8]

In this case, MRI and CT showed that the left VA was significantly hypoplastic compared with the right VA. Although the left VA demonstrated a connection with the basilar artery and posterior inferior cerebellar artery (PICA), the part of the left VA that connected with the basilar artery was very small and exhibited a severe stenosis in the middle. We speculated that most of the blood flow from the left VA went into the PICA (**Fig. 2**). Based on ultrasonography, the diameter of the left and right VA was 2.8 mm and 4.2 mm, respectively. The mean flow velocity in the left and right VA was 17.0 and 22.9 cm/sec, respectively. Based on the criteria for classifying VAs, ultrasonography confirmed that the VA essentially terminated at the PICA (hereafter referred to as a PICA end pattern).[7] According to these findings, reconstruction of the SCA was planned to maintain blood flow in the PICA.

Under general anesthesia, endovascular repair of the arch aneurysm was performed. At first, a bypass was created from the right axillar artery (AxA) to the left AxA with an 8-mm expanded polytetrafluoroethylene vascular prosthesis (ePTFE). After that, two stent grafts were deployed from the ascending aorta to the descending aorta. A Zenith TX2 stent graft™ (Cook Medical LLC., Bloomington, IN, USA) was deployed in the thoracic aorta from the distal portion of the left SCA to the descending aorta. Then, a Najuta stent graft™ was deployed from the ascending aorta to the distal arch, partially overlapping the previous stent graft. Finally, plug embolization of the left SCA was added with an AMPLATZER vascular II plug™ (Abbott Laboratories, Abbott Park, IL, USA) placed via the left AxA. On the final digital subtraction angiography images, the aneurysm was isolated by the stent grafts with no endoleak. Both the brachiocephalic artery and left CCA were enhanced via the fenestrations of the Najuta stent graft™, and the left SCA and VA were enhanced by the right to left AxA bypass.

On the 7th postoperative day (POD), CT was performed. The aneurysm was isolated by the stent grafts without endoleak (**Fig. 3**). Since there was a prolonged inflammatory reaction based on laboratory data, the patient was discharged on the 16th POD.

Discussion

Blood flow to the brain is normally supplied by both carotid arteries and VAs. These arteries are connected at the base of skull, which is called the circle of Willis. The right and left VAs are confluent in the brain stem area and connect to the basilar artery. Therefore, even if a new obstruction occurs in one of the VAs, the blood supply would be maintained by this vascular system.[9] However, if there are some anatomical abnormalities or previous obstructive lesions, this compensating system for blood flow in the brain might not be present or functioning.

When a stent graft is used to perform TEVAR of an aortic arch aneurysm and intentional occlusion of the left SCA is necessary to obtain an adequate proximal sealing zone, blood flow in the left SCA will be maintained due to collateral flow via the right VA in many cases. However, in some cases, revascularization of the left SCA is recommended. Asymmetry of the VAs due to anatomical variation is one of the reasons why revascularization of the left SCA may be needed. In cases of left VA dominance, revascularization of the left SCA should be performed to maintain blood flow to the brain stem area; however, it would usually not be required in cases of right VA dominance.[5,6]

Termination of the left VA in the PICA is also an important anatomical abnormality that may require revascularization of the left SCA.[4,10] In patients who exhibit a PICA end pattern, even though the left VA is hypoplastic (right dominance), the blood flow in the PICA is only supplied by the left VA. Therefore, if the left VA is obstructed by a stent graft during TEVAR, the cerebral tissue supplied by the PICA would be damaged. An infarct in this area is called the Wallenberg syndrome.

In our case, asymmetry of the VA was present on preoperative MRI and CT. Obviously, the left VA was hypoplastic compared with the right VA. Furthermore, the left VA demonstrated a connection with a small branch of the basilar artery, which exhibited severe stenosis in the middle. Therefore, we suspected that blood flow through this branch was very poor and would be the same as with a PICA end pattern of the left VA. If the connections between the arteries did not provide adequate collateral circulation, reconstruction of the left SCA would be indicated to avoid ischemia in the PICA perfusion area. However, based on only CT and MRI, judging whether our patient demonstrated a left VA that functioned as if it terminated into the PICA was impossible. Therefore, we thought an alternative method should be used to evaluate the VAs.

Saito et al. previously reported on the diagnostic criteria for the site of occlusion in the VAs using duplex color-coded ultrasonography in patients with an acute stroke, particularly those with medullary and brain stem infarction, by measuring VA blood flow velocities and diameters. A five-step decision tree is used to classify the VAs into 5 groups (VA origin occlusion, VA occlusion before branching into the PICA, symptomatic VA occlusion after branching into the PICA, asymptomatic, or hypoplastic occlusive VA after branching into the PICA [hereafter referred to as the "PICA end group"], no significant occlusion).[7] A case in the PICA end group would exhibit a positive flow signal, and detecting the end-diastolic flow velocity would be possible. While the mean flow velocity would be < 18 cm/s, the mean flow velocity ratio would be ≤ 1.4, and the diameter ratio would be ≤ 1.4. We thought that if these diagnostic criteria were used along with CT or MRI for the preoperative evaluation of the VAs, a PICA end pattern or similar condition of the left VA could be identified more accurately.

In this case, the VAs were clearly displayed using B-mode with color imaging, and blood flow velocity was successfully evaluated by pulse Doppler (1st step). The blood flow signals and end-diastolic flow velocities in the VAs could be detected using pulse Doppler (2nd step). The mean flow velocity in the left VA was 17.0 cm/sec (3rd step). The mean flow velocity in the right VA was 22.9 cm/sec. The mean flow velocity ratio was 1.35 (4th step). The diameter of the left VA was 2.8 mm, and the diameter of the right VA was 4.2 mm. The diameter ratio was 1.5 (5th step). If we pass these results through the decision tree,[7] we can see that this case would not be classified as being in the PICA end group, because the mean flow velocity ratio (4th step) was just below the cut off point. Accordingly, this case was classified as being in the no significant occlusion group.

However, with the exception of the mean flow velocity ratio, which was only 0.5 points less than the cut off value, all the other values met the requirements for a case in a PICA end group. Therefore, we believe that this case could be classified as being in the PICA end group, considering the existence of a connection between the left VA, the basilar artery (although it was poor), and the cut off values, which were determined using sensitivity-specificity curve analysis. Thus, we thought that reconstruction of the left SCA was desirable.

During the operation, when we deployed a Najuta stent graft™ with clamping of the right to left AxA bypass graft and closed the orifice of the left SCA, the systemic blood pressure did not change. The only change we observed was that the blood pressure in the left radial artery (RA) fell to <20 mmHg without pulsation. After declamping of the graft, the blood pressure in the left RA recovered to a level similar to systemic blood pressure. Usually, even if the orifice of the left SCA is closed with a stent graft, the systolic blood pressure in the left RA would be maintained at a level >50 mmHg when the systemic blood pressure was normal, due to the collateral flow through the VAs.[4] Our findings during left SCA occlusion suggested that the connection between the right and left VAs was very poor.

If we performed angiography of the arch branches and pressure measurement of the left SCA with occlusion, we would be able to confirm the anatomic abnormalities of

VAs and the need for revascularization of the left SCA in TEVAR. However, these procedures exhibit some risks of cerebral embolism and other complications, while an ultrasonographic examination exhibits no attendant risks. In this case, the anatomic abnormalities of VAs could not be confirmed directly by ultrasonography, but predicting the anatomic abnormalities and the necessity of revascularization based on CT scan or MRI was possible. Therefore, we thought this method was less invasive and useful for a supplemental examination.

There is a limitation of this research. The diagnostic criteria based on the sizes and flows of the VAs were useful just in this case. However, as this is only one case, the use of this type of information should be considered for many other cases.

Conclusion

For TEVAR of an aortic arch aneurysm with a stent graft, recognition of a left SCA with a PICA end pattern of the VA is necessary to avoid ischemia of the perfusion area. Combining ultrasonography with CT or MRI might be useful to evaluate conditions in the vascular system.

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Disclosure Statement

All authors have no conflict of interest.

Additional Note

We presented an overview of our manuscript at the 9th Conference of the German-Japanese Society of Vascular Surgery on August 20th, 2016, in Hiroshima, Japan.

Author Contributions

Study conception: KS
Data collection: KS, HT, SE, SM
Analysis: KS
Investigation: KS, HT, SE
Writing: KS
Critical review and revision: all authors
Final approval of the article: all authors
Accountability for all aspects of the works: all authors

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