Case Report

Carotid-Vertebral or Carotid-Subclavian Transpositions in Supra-Aortic Steno-Occlusive Diseases When Endovascular Therapy Is Unfeasible or Unsuccessful

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Background and purpose: Despite advances in endovascular therapies, some patients experience vertebral artery stenosis or subclavian artery occlusion and may not benefit from less-invasive angioplasty/stenting. This study described 4 cases in which carotid-vertebral transposition (CVT) or carotid-subclavian transposition (CST) was adapted when endovascular treatment was unfeasible or unsuccessful.

Presentation: Case 1: A 65-year-old woman presented with severe stenosis of the right vertebral artery ostium, dysplastic left vertebral artery, and aneurysmal dilatation of proximal right subclavian artery and brachiocephalic trunk. Case 2: A 23-year-old woman had severe stenosis at the first portion of left vertebral artery caused by Takayasu’s arteritis. Because endovascular intervention was unfeasible, CVTs were performed in cases 1 and 2. Case 3: A 73-year-old man presented with total occlusion of the proximal right subclavian artery and severe stenosis of the right internal carotid artery. Case 4: A 58-year-old man experienced complete occlusion of the left subclavian artery and severe stenosis of the left common carotid artery. Duplex ultrasonography showed reverse flow in the vertebral
artery in keeping with vertebral steal syndrome. Endovascular treatment was unsuccessful because the wire did not cross the occlusion of the subclavian artery. CSTs were performed with concurrent ipsilateral carotid endarterectomy in cases 3 and 4.

Conclusion: The present case series demonstrated that CST and CVT were effective treatment modalities for subclavian or vertebral artery lesions. Although endovascular stenting and angioplasty have been advocated as first-line management, CST and CVT should be considered as the remedy when endovascular intervention is unsuccessful or unfeasible.

Key words: Vertebral stenosis – Subclavian occlusion – Vertebral steal syndrome – Carotid-vertebral transposition – Carotid-subclavian transposition – Carotid endarterectomy – Carotid stenosis

The supra-aortic arterial lesion is commonly involved in the subclavian or vertebral artery as single or concurrent disease. Obstruction of the subclavian artery can cause symptoms of vertebral steal syndrome, vertebrobasilar insufficiency, and upper extremity ischemia. Stenosis of the vertebral artery can result in ischemia in the vertebrobasilar territory when the opposed vertebral artery is absent or hypoplastic. The aim of the treatment is to normalize permanent antegrade blood flow to the subclavian or vertebral artery and to eliminate the source of embolism, thereby eliminating vertebrobasilar ischemia and arm hypoperfusion and relieving the symptoms.

There are several methods of treating symptomatic subclavian or vertebral lesions. Surgical revascularization is attempted via carotid-subclavian transposition (CST) or carotid-vertebral transposition (CVT). CST and CVT have been reported to be the safe and effective procedures for the reconstruction of the subclavian or vertebral artery and to provide excellent long-term patency, stroke protection, and symptomatic relief.1,2 In recent years, endovascular interventions including balloon angioplasty and intraluminal stenting have mostly replaced a direct open surgical procedure because of their less-invasive solution and lower risk of major morbidity and death.3,4 There remains instances in which angioplasty and stenting are technically unfeasible or have previously failed, making open surgical procedures of CST or CVT necessary for these specifically selected patients. We described 2 cases of vertebral artery stenosis treated with CVT when endovascular therapy is inappropriate and 2 cases of proximal subclavian artery occlusion treated with CST when endovascular intervention is unsuccessful.

Case Presentation

Case 1

A 65-year woman with a medical history of hypertension and diabetes complained of dizziness and vertigo, described as a sense of spinning in relation to the surrounding environment for 10 years. Computed tomography (CT) angiography revealed an 83% stenosis at the origin of the right vertebral artery, a hypoplastic left vertebral artery, and an aneurysmal dilatation of the brachiocephalic trunk and the right proximal subclavian artery (Fig. 1A). Ultrasonography demonstrated a 10-mm-diameter aneurysmal dilatation of the right proximal subclavian artery, a brachiocephalic trunk with aneurysmal dilatation of 13.2 mm, and a high-grade stenosis of right vertebral artery origin with an atherosclerotic plaque at the vertebral artery orifice (Fig. 1B). The dilated right proximal subclavian artery and brachiocephalic trunk might progressively evolve into a true aneurysm. A stent-graft from the brachiocephalic trunk to the common carotid artery would be possible to cover the origin of the right subclavian artery and a carotid-subclavian bypass would probably be used for arm revascularization with the right subclavian artery oversewn distal to the aneurysms in the future. Thus, percutaneous transluminal stenting for vertebral artery stenosis was not considered as a treatment selection. An oblique skin incision was made along the anterior border of the sternocleidomastoid muscle, and the common carotid and vertebral arteries were exposed (Fig. 1C). CVT was performed to anastomose the distal vertebral artery to the common carotid artery in an end-to-side fashion with continuous 7-0 polypropylene sutures, with ligation of the proximal right vertebral artery (Fig. 1C). Duplex ultrasonography showed that blood
A 65-year-old woman presented with right vertebral artery stenosis and underwent successful CVT. (A) The preoperative CT angiography depicted severe stenosis of the right vertebral artery ostium (red arrowhead), a hypoplasia in the left vertebral artery (yellow arrowhead), and an aneurysmal dilatation of the right proximal subclavian artery and brachiocephalic trunk (white arrowhead). (B) The preoperative ultrasound examination showed a 10-mm-diameter aneurysmal dilatation of the right proximal subclavian artery.
flow velocity of the right vertebral artery increased from 10 to 61.2 cm/s postoperatively (Fig. 1D). The postoperative CT angiography confirmed the patent vascular anastomosis between the right vertebral artery and the common carotid artery (Fig. 1E). The symptoms of dizziness and vertigo completely disappeared after surgery. The patient had no postoperative complications.

Case 2

A 23-year-old woman was referred with vertigo and headache symptoms of 2-year duration. CT angiography showed an 80% stenosis at the first portion of the left vertebral artery (Fig. 2A), a 60% luminal narrowing in the left renal artery, and a near-total occlusion of the left distal subclavian and axillary artery. Ultrasonography showed diffuse intima-media thickening of the bilateral carotid artery wall (Fig. 2B). Blood pressure was 112/78 mm Hg supine in the right arm and not recordable in the left arm. Both the left brachial pulses were palpable. The patient was diagnosed with Takayasu’s arteritis. Biological inflammation significantly increased the likelihood of restenosis after endovascular stent insertion into the artery stenosis because of Takayasu arteritis. Endovascular angioplasty/stenting for supra-aortic branches in Takayasu arteritis was associated with a relatively high restenosis rate, especially for unstrict control of systemic inflammation. An end-to-side anastomosis was made between the left vertebral artery and the common carotid artery (Fig. 2C). Duplex ultrasonography showed that the flow velocity of the left vertebral artery was elevated from 51.5 to 66.5 cm/s 6 days postoperatively (Fig. 2D). The postoperative CT angiography confirmed excellent vascular patency between the left vertebral artery and the common carotid artery (Fig. 2E). The patient was free of vertigo and headache postoperatively. The postoperative course was uneventful.

Case 3

A 73-year-old male smoker with a history of hypertension and diabetes presented with right arm claudication for 9 months. CT angiography confirmed a complete occlusion of the proximal right subclavian artery at the length of 2.8 cm, a 75% stenosis of the right internal carotid artery, and a high-grade stenosis at the origin of the left vertebral artery (Fig. 3A). Vertebral artery stenosis was treated successfully by percutaneous transluminal angioplasty and stenting; however, the wire did not cross the right subclavian occlusion and always sided into the right common carotid artery (Fig. 3B). A skin incision was made along the anterior margin of the sternocleidomastoid muscle to the mastoid bone to facilitate surgical exposure of carotid bifurcation. Right carotid endarterectomy (CEA) was primarily performed with synthetic patch angioplasty (Fig. 3C). The right subclavian artery was transected from the brachiocephalic trunk and anastomosed to the common carotid artery in an end-to-side fashion (Fig. 3D). Duplex ultrasonography showed that blood flow velocity in the artery of the right upper extremity increased from 15 to 35 cm/s after surgery (Fig. 3D). The postoperative CT angiography confirmed the origination of the right subclavian artery from the common carotid artery, the patent right
internal carotid artery, and the endovascular stent graft placement in the left vertebral artery (Fig. 3E). The patient was free of right upper extremity ischemia postoperatively. The patient was discharged postoperatively without any complications.

Case 4

A 58-year-old male smoker complained of dizziness when moving his left arm for 6 months. CT angiography indicated a complete occlusion of the proximal left subclavian artery at a length of 2.7 cm and high-grade stenosis of the left common carotid artery (Fig. 4A). Ultrasonography demonstrated a 70% luminal narrowing of the left common carotid artery (Fig. 4B). Duplex ultrasound found low flow velocity in the left subclavian artery and the reversed flow in the left vertebral artery. The diagnosis of vertebral steal syndrome was established. Endovascular angiography/stenting had been tried but without success because the wire could not pass through the subclavian occlusion. Through an oblique incision made along the anterior margin of the left sternocleidomastoid muscle, the left subclavian artery was transected from the brachiocephalic trunk and anastomosed to the common carotid artery in an end-to-side fashion (Fig. 4C). The skin incision was extended toward the mastoid bone for surgical exposure of the carotid bifurcation. Concurrent left CEA was simultaneously performed for common carotid artery stenosis (Fig. 4C). Retrograde flow in the left vertebral artery was normalized into the antegrade direction postoperatively (Fig. 4D). Blood flow velocity significantly increased from 33.6 to 90.2 cm/s in the left subclavian artery postoperatively (Fig. 4E). The postoperative CT angiography confirmed successful CST and CEA (Fig. 4F). The symptom of dizziness completely disappeared after surgery. The patient had no postoperative complications.

Discussion

In 1964, Parrot et al. introduced the techniques of CST, whereby the subclavian artery was transected distal to the stenosis or occlusion and anastomosed to the side of the common carotid artery. Ehrenfeld et al. first performed CVT in 1969, in which the vertebral artery was anastomosed to the common carotid artery in an end-to-side fashion with the ligation of vertebral artery just distal to the stenosis. Subclavian artery occlusive disease may be asymptomatic or may produce disabling symptoms of arm ischemia or vertebrobasilar insufficiency. Treatment of subclavian artery occlusion is only indicated in symptomatic patients to improve quality of life. The vertebral artery lesion is considered to require treatment when there is at least 75% stenosis and the other vertebral artery is equally stenosed, hypoplastic, or absent.

CST and CVT have several advantages. Surgical exposure is performed through a transcervical incision and allows simultaneous CEA. Because of the absence of prosthetic material, graft-related complications are avoided. Because autogenous material with identical physicoelastic properties is used, compliance is ideal. With 1 single autogenous end-to-side anastomosis performed with running sutures, normal flow into the vertebral or subclavian artery can be restored. The anatomic features after transposition imitate the natural history. Embolic sources are simultaneously excluded.

CST has been reported to have 100% 5-year patency in 108 patients. Claudio et al. reviewed 511 patients who underwent CST from 1966 to 2000 and reported that patency rate was 98% and the rate of symptom relief was 99% at a mean follow-up of 5 years.

Fig. 3 A 73-year-old man presented with right subclavian artery occlusion and right internal carotid artery stenosis and experienced a successful CST and CEA. (A) The preoperative CT angiography depicted a total occlusion of the proximal right subclavian artery (red arrowhead), a high-grade stenosis of the right internal carotid artery (white arrowhead), and a severe left vertebral artery orifice stenosis (yellow arrowhead). (B) Endovascular stenting of the left vertebral artery stenosis was successfully performed (yellow arrowhead); however, the wire could not cross the right subclavian occlusion and always entered into the right common carotid artery (red arrowhead). (C) Intraoperative pictures demonstrated an end-to-side anastomosis of the right subclavian artery to common carotid artery (black arrowhead) and a right-sided CEA with synthetic patch angioplasty (white arrowhead). (D) Ultrasonic Doppler showed a substantially increased blood flow velocity in the artery of the right upper extremity after surgery. (E) The postoperative CT angiography showed successful transposition of the right subclavian artery to the common carotid artery (red arrowhead), a patent right internal carotid artery (white arrowhead), and an endovascular stent placement in left vertebral artery (yellow arrowhead). 1, external carotid artery; 2, internal carotid artery; 3, common carotid artery; 4, subclavian artery.
years. Endovascular stenting seems to be considerably less durable than CST, because a 3-year patency rate of 78% to 82.7% and a 5-year patency rate of 67% have been reported.\textsuperscript{13,14} Berguer et al\textsuperscript{15} reviewed 218 patients undergoing CVT and reported that the 5-year patency rate was 80% and the protection rate from stroke was 97%. An investigation involving 73 patients indicated that the 5-year patency rate was 87.3% after endovascular treatment of vertebral artery stenosis.\textsuperscript{16} Therefore, CST and CVT are safe and effective procedures associated with low risks and good long-term results.

More recently, less invasive endovascular techniques, including balloon angioplasty and intraluminal stenting, have become the first-line modalities for subclavian or vertebral artery lesions. When endovascular treatment is unsuccessful or impossible, CST or CVT should be emphasized as the primary or remedial modality for subclavian or vertebral revascularization. Beyond traditional indications for occlusive disease, CST is increasingly performed to allow for left subclavian artery revascularization in the setting of thoracic endovascular aortic repair (TEVAR).\textsuperscript{17} Endovascular embolization for posterior circulation aneurysms is occasionally prohibited by proximal vertebral artery occlusion or vessel tortuosity. CVT is a safe and efficacious technique providing a conduit for endovascular access to the posterior circulation.\textsuperscript{18} Moreover, an open surgical procedure carries better long-term durability and should be the preferred approach in low-risk patients.

**Conclusion**

Endovascular therapy for subclavian or vertebral artery disease has become the first-line medical

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Fig. 4 A 58-year-old man presented with left subclavian artery occlusion and left common carotid artery stenosis and experienced a successful CST and CEA. (A) The preoperative CT angiography depicted a total occlusion of the left proximal subclavian artery (red arrowhead) and high-grade stenosis of the left common carotid artery (white arrowhead). (B) The preoperative ultrasound examination showed severe left common carotid artery stenosis. (C) The intraoperative pictures demonstrated an end-to-side anastomosis of the left subclavian artery to common carotid artery (black arrowhead) and a left-sided CEA with patch angioplasty (white arrowhead). (D) Ultrasonic Doppler indicated that reverse flow of the left vertebral artery was normalized into the antegrade direction postoperatively. (E) Ultrasonic Doppler showed that blood flow velocity in the left subclavian artery was significantly increased postoperatively. (F) Postoperative CT angiography showed a successful transposition of the left subclavian artery to the common carotid artery (red arrowhead) and a patent left common carotid artery (white arrowhead). 1, common carotid artery; 2, vertebral artery; 3, subclavian artery; CCA, common carotid artery; VA, vertebral artery.
modality during the last few years. Open surgical procedures, including CST or CVT, are the preferred remedial methods of revascularization for patients with failed or unfeasible endovascular treatment.

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