

## Cerebral protection during retrograde brachiocephalic artery stenting using a single filter and increased subclavian steal phenomenon: illustrative case

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**BACKGROUND** Cerebral protection during brachiocephalic artery (BCA) stenting is important. However, the maneuver is sometimes challenging because both the internal carotid artery (ICA) and vertebral artery (VA) should be protected. Herein, the authors present an alternative cerebral protection technique involving filter protection for the ICA and hemodynamic protection for the VA during retrograde BCA stenting.

**OBSERVATIONS** A 64-year-old man with a thoracic aortic aneurysm presented with cold sensation and numbness in his right arm due to BCA stenosis. Endovascular stenting under cerebral protection was planned. Cerebral protection was attempted through the brachial access. Despite the successful placement of the filter in the ICA, selective catheterization of the VA failed. Furthermore, repeated transfemoral catheterization of the BCA was unsuccessful. Concerning a thoracic aortic aneurysm injury, the authors performed retrograde BCA stenting using a transbrachial approach. Hemodynamic protection of the VA was provided by increasing the subclavian steal phenomenon that resulted in successful recanalization of the BCA.

**LESSONS** Retrograde BCA stenting performed while protecting the ICA with a filter and the right VA by increasing the subclavian steal phenomenon was successful. This simple technique is feasible, especially in patients with steno-occlusive lesions of the BCA concurrent with the dominant vertebral/vertebral collateral pathway.

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**KEYWORDS** cerebral protection; brachiocephalic artery stenosis; stenting

Brachiocephalic artery (BCA) stenosis is a relatively rare pathology manifesting as vertebrobasilar insufficiency, upper limb ischemia, and cerebral ischemia.<sup>1,2</sup> Endovascular stenting is an effective and safe treatment technique for BCA stenosis; however, embolic complications in the anterior and posterior circulation remain a significant concern.<sup>3-7</sup> The requirement for cerebral protection during internal carotid artery (ICA) stenting is well established,<sup>8</sup> and protection of both the ICA and the vertebral artery (VA) during BCA angioplasty and stenting is carried out using double filters or balloon catheters.<sup>9-13</sup> However, the protection of both the ICA and VA is occasionally challenging because the patient's vascular anatomy inhibits the navigation of the guidewire, which can hinder the placement of embolic protection devices.

Herein, we report a case of successful stenting for BCA stenosis under cerebral protection with a filter in the ICA and an increase in the subclavian steal phenomenon by inflated pressure cuff of the unaffected upper limb.

### Illustrative Case

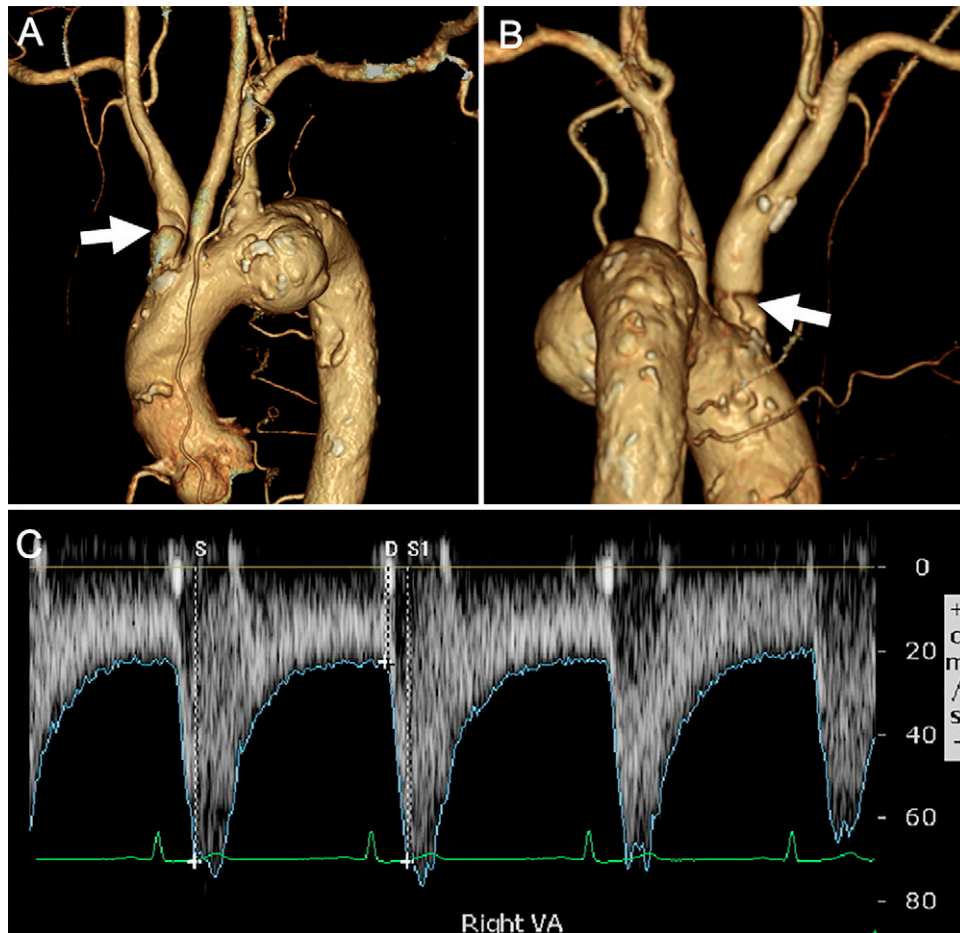
A 64-year-old man with a history of hypertension, diabetes mellitus, and acute myocardial infarction was referred to our hospital with cold sensation and numbness in his right arm. The physical examination revealed weak pulsation in the right brachial and radial arteries. The blood pressure gradient in the upper extremities was 120 mm Hg. Computed tomography angiography (CTA) showed severe stenosis of the BCA and a thoracic aortic aneurysm measuring

**ABBREVIATIONS** BCA = brachiocephalic artery; CCA = common carotid artery; CTA = computed tomography angiography; ICA = internal carotid artery; VA = vertebral artery.

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**FIG. 1.** Anteroposterior (A) and posteroanterior (B) CTA showing severe stenotic lesion of the BCA (white arrow) and thoracic aortic aneurysm at the aortic arch. Preoperative Doppler ultrasonography (C) of the right VA shows retrograde blood flow.

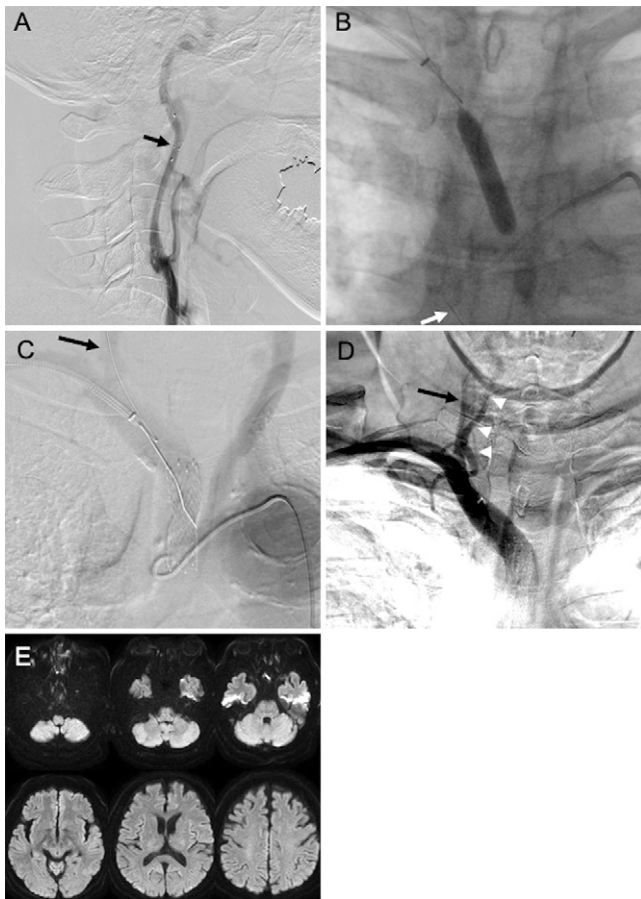
4 cm in diameter (Fig. 1A and B). Carotid ultrasonography revealed retrograde blood flow in the right VA (Fig. 1C). We decided to perform endovascular stenting to alleviate the symptoms.

Before the intervention, aspirin (100 mg) and clopidogrel (75 mg) were administered for 2 weeks. With the patient under local anesthesia, a 4-Fr sheath was inserted into the femoral artery, and a 4-Fr diagnostic catheter was placed in the ascending aorta over a 0.035-inch Radifocus guidewire (Terumo) to navigate the proximal ascending aorta in order to avoid injury to the thoracic aortic aneurysm. A 7-Fr guiding sheath (Parent Plus 68, Medikit) was inserted into the right brachial artery and positioned near the origin of the common carotid artery (CCA) and the VA to navigate embolic protection devices in both the ICA and VA. Heparin was administered to achieve an activated clotting time  $>250$  s.

To navigate the distal protection device in the right ICA, a J-shaped 4-Fr Goodtech HT catheter (IMT 110, NIPRO) was placed at the proximal portion of the right CCA with the tip facing the distal CCA through the right brachial access. Subsequently, a 200-cm CHIKAI 14 microguidewire (Asahi Intech Co., Ltd.) was navigated into the right ICA through a J-shaped 4-Fr catheter, and a 165-cm CHIKAI extension wire (Asahi Intech Co., Ltd.) was connected to the end of the microguidewire. After removal of the J-shaped 4-Fr

catheter, a Spider FX 5.0-mm embolic protection device (Medtronic) was navigated into the right ICA via a microguidewire and deployed at the ascending cervical segment of the ICA (Fig. 2A). We then attempted to navigate the wire into the right VA through the brachial access. However, despite multiple attempts, selective catheterization of the BCA failed because of the acute angle between the subclavian artery and the right VA. Furthermore, several attempts to navigate a wire into the BCA via a transfemoral access catheter positioned distally to the thoracic aortic aneurysm were unsuccessful. Although we considered applying the pull-through technique by navigating the wire in a retrograde fashion through the brachial access and capturing via the transfemoral access, this maneuver was not attempted, because the wire may damage the thoracic aortic aneurysm. Therefore, we decided to perform retrograde angioplasty and stent placement using only a brachial approach.

Based on the findings of a previous study,<sup>14,15</sup> protection of the VA during this procedure was provided by increasing the subclavian steal phenomenon as follows. A pressure cuff on the left upper arm was inflated to maintain a pressure  $>30$  mm Hg over the systolic arterial pressure to increase anterograde blood flow in the left VA, which in turn would increase retrograde blood flow in the right VA. Under the cerebral protection of the ICA using the filter and that of



**FIG. 2. A:** The filter device (*black arrow*) was placed in the ICA. **B:** Under filter protection of the ICA and hemodynamic protection of the right VA, a predilatation balloon was inflated at the stenotic segment of the BCA. The *white arrow* indicates the tip of a guidewire turned back from the aortic valve. **C:** Control angiogram obtained after stent placement but before the pressure cuff on the left upper limb was deflated, showing no anterograde filling of the right VA despite the filling of the right CCA (*black arrow*). **D:** Control angiogram shows anterograde flow in the right VA (*white arrowheads*) and right CCA (*black arrow*), which became apparent after deflation of the pressure cuff on the left upper arm. **E:** Diffusion-weighted magnetic resonance images obtained 1 day after endovascular stenting show no ischemic lesions.

the right VA by increasing the subclavian steal phenomenon, a 200-cm CHIKAI 14 wire was retrogradely crossed through the stenotic segment of the BCA and turned over on the aortic valve to stabilize the wire. A 7 × 40-mm percutaneous transluminal angioplasty balloon (Sterling PTA, Boston Scientific) was navigated through a 200-cm CHIKAI 14 wire and inflated to cover the entire stenotic lesion (Fig. 2B). After predilatation with inflation at nominal pressure, a PROTÉGÉ 10 × 30-mm open-cell stent (Medtronic) was deployed to cover the entire stenotic lesion, although it was not allowed to bridge the ostium of the subclavian artery or the CCA. Sufficient dilatation of the BCA was achieved; therefore, post-dilatation was not performed. An aortic angiogram obtained before deflation of the pressure cuff of the left upper arm showed robust anterograde blood flow in the right ICA but no anterograde flow in the right VA (Fig. 2C). However, after the pressure cuff was

deflated, anterograde blood flow in the right VA became apparent (Fig. 2D). No debris was retrieved from the Spider FX device. The step-by-step procedure is shown in Video 1. Diffusion-weighted magnetic resonance imaging performed 1 day after stenting showed no ischemic lesions (Fig. 2E). The patient was discharged 7 days after stenting without preoperative symptoms, such as cold sensation and numbness of the right upper limb. Dual antiplatelet therapy was continued for 1 month after the procedure, and single antiplatelet therapy with aspirin was continued for 1 year. CTA and ultrasonography performed at the 3-month follow-up visit showed no restenosis, and the subsequent 8 months were uneventful.

**VIDEO 1.** Clip showing step-by-step procedure of the retrograde BCA stenting under a single filter and increased subclavian steal phenomenon. [Click here to view.](#)

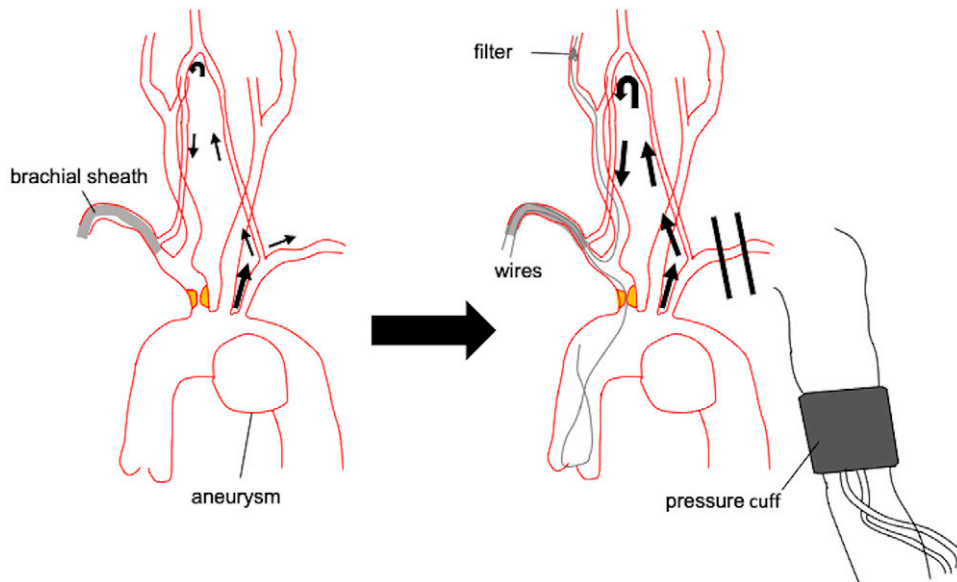
## Discussion

Cerebral protection of both the ICA and VA should be considered during BCA stenting. However, achieving full protection of the ICA and VA is sometimes challenging because of the tortuous vascular anatomy. The present case provides an alternative technique for embolic protection of the affected VA during BCA angioplasty or stenting when device-based protection was unsuccessful.

## Observations

In cases of symptomatic steno-occlusive lesions of the BCA, compression maneuvers of the unaffected upper arm increase ipsilateral anterograde VA blood flow and subsequent contralateral retrograde blood flow, resulting in increased subclavian steal phenomenon.<sup>14,15</sup> Therefore, a rise in reverse flow in the right VA can prevent embolus migration into the intracranial vessels before recanalization of the BCA. Furthermore, Doppler sonography showed that percutaneous transluminal angioplasty performed for subclavian artery syndrome resulted in a gradual reversal of retrograde flow in the affected VA that took 20 s to several minutes after recanalization for completion, rather than an immediate reversal, indicating a protective mechanism against cerebral embolism shortly after recanalization of the subclavian artery.<sup>16</sup> These findings may explain the reason for the persistent reverse flow in the right VA until the pressure cuff on the left upper arm was deflated in the present case (Fig. 3).

Collateral circulation can develop to compensate the blood flow to the arm ipsilateral to the steno-occlusive BCA or subclavian artery in patients with symptomatic steno-occlusive lesions of the BCA or proximal subclavian artery.<sup>17,18</sup> The vertebra/vertebral collateral pathway bypasses obstruction by retrograde blood flow from the contralateral VA through the basilar artery into the affected VA. When the blood flow of the contralateral VA is insufficient to compensate for that of the affected arm, a carotid/basilar collateral pathway can also develop in case both BCA and subclavian artery stenosis occur. Furthermore, external carotid branches can anastomose with muscular branches of the VA and thyrocervical and costocervical trunks in cases of subclavian artery stenosis. However, in cases of steno-occlusive lesions of the BCA, external carotid collateral circulation is less likely to develop than the vertebra/vertebral collateral pathway because of the preexisting insufficiency of blood flow in both the external carotid artery and VA.<sup>15</sup> Therefore, a cerebral protection technique by compressing the unaffected brachial



**FIG. 3.** Illustrations demonstrating blood flow before and after the left brachial artery occlusion in the present case. After inflation of the pressure cuff on the left arm, increase in blood flow volume in the left VA enhances subclavian steal phenomenon.

artery seems to be feasible, especially in cases of dominant collateral flow supplied through the dominant vertebra/vertebral collateral pathway. However, the flow direction in the affected VA may vary depending on the anastomosis type. For example, the external carotid branches (occipital artery) anastomose with muscular branches of the VA through the suboccipital artery of Salmon arising from segment V3 of the VA.<sup>19</sup> In this scenario, the flow direction would be antegrade in the affected V4 segment but retrograde in the V3 or more proximal segment of the left VA. Therefore, the blood flow from the unaffected VA would interfere with the antegrade flow in the affected V4 segment, and retrograde flow in the proximal segment of the affected VA would not necessarily increase. This would probably reduce the protective effect after recanalization.

BCA stenting under full protection of the ICA and right VA requires two protection devices. In addition, because the landing zone for the guiding catheter is short, a guidewire for stent deployment is required to anchor the guiding catheter. In most studies, stenting was performed through a transfemoral approach, and a transbrachial/radial approach was employed to navigate a balloon or filter protection device or even a balloon guiding catheter.<sup>9,11–13</sup> Furthermore, when selective catheterization using transfemoral access is challenging, the pull-through technique is used, wherein the BCA lesion is crossed in retrograde fashion through the radial or brachial artery and captured via the femoral approach using a snare device.<sup>11–13</sup> However, because atherosclerotic lesions involving the peripheral vessels are frequently associated with steno-occlusive lesions of the BCA, the transfemoral approach may be restricted.<sup>20</sup> We did not perform transfemoral BCA stenting because of the unsuccessful attempts at catheterization across the BCA through the transfemoral access and concerns regarding the occurrence of thoracic artery aneurysm injury while performing the pull-through maneuver. In situations where transfemoral BCA stenting is restricted, retrograde BCA stenting using the present cerebral protection

technique is feasible because it can be performed with minimal complications compared with those that may arise during transfemoral antegrade stenting, such as embolus migration or aortic injury due to repetitive attempts of catheterization from the pathological aortic arch. Furthermore, BCA stenting under cerebral protection is possible with single-site access from either the radial or brachial artery.

### Lessons

Retrograde stenting was successfully performed while protecting the ICA using a filter and the right VA by increasing the subclavian steal phenomenon. This cerebral protection technique is useful, especially in patients with steno-occlusive lesions of the BCA with a dominant vertebra/vertebral collateral pathway.

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### Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

### Author Contributions

Conception and design: Akamatsu. Acquisition of data: Akamatsu, Yanagihara, Shibanaï, Kojima, Kashimura. Analysis and interpretation of data: Akamatsu. Drafting the article: Akamatsu, Yanagihara. Critically revising the article: Akamatsu, Yanagihara, Ogasawara. Reviewed submitted version of manuscript: Akamatsu, Shibanaï, Kubo, Ogasawara. Approved the final version of the manuscript on behalf of all authors: Akamatsu. Administrative/technical/material support: Fujimoto. Study supervision: Shibanaï, Kashimura, Kubo.

### Supplemental Information

#### Video

Video 1. <https://vimeo.com/714475364>.

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