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Technical Note

Efficacy of Respiratory Control under Local Anesthesia during Endovascular Therapy in the Tortuous Vertebral Artery with the Use of Respiratory Dislocation of the Aortic Arch

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Purpose: Endovascular therapy (EVT) through the tortuous access route is increasingly performed in neurovascular procedures. In the posterior circulation through the vertebral artery (VA), ischemic complications, including vessel dissection and cerebral vessel infarction, are sometimes observed, especially during navigation of the guiding catheter, because of small vessel diameter and tortuous origin. We describe an adjunctive technique for passing the guiding catheter safely to the tortuous VA and reducing ischemic complication using respiratory displacement of the aortic arch.
Case Presentations: The guidewire is advanced to the origin of the VA until it is caught in the tortuosity. Then we instruct the patient to take a maximum deep inspiration and hold his or her breath. In this manner, the aortic arch and side branches are dislocated to the caudal direction, which reduces the tortuosity of the VA origin and facilitates passage of the guidewire. Here, we discuss three representative cases which demonstrate that our techniques are effective in navigating the catheter to the tortuous VA.
Conclusion: In the EVT of a patient who has a tortuous VA, respiration control under local anesthesia, maximum deep inspiration, and breath holding induce the respiratory dislocation of the aortic arch. This enables safe navigation of the guiding catheter, reduces the likelihood of interruption in blood flow, and helps avoid dissection and ischemic complications during EVT.

Keywords ▶ vertebral artery, tortuous, guiding catheter

Introduction

With the development of devices and techniques for neuroendovascular treatment, the indications for the endovascular therapy (EVT) are increasing. The access route from the puncture site to the target vessel is often tortuous, especially in elderly patients, in whom arteriosclerotic changes are commonly advanced.[1)] This tortuosity leads to inefficient catheter handling, insufficient treatment, premature cessation of the procedure, and intraprocedural complications.

With regard to navigation of the guiding catheter, the vertebral artery (VA) is narrower than the carotid artery, and the guiding catheter can interrupt blood flow or can lead to iatrogenic dissection are easily observed. In EVT, adjunctive techniques for navigating the tortuous VA are few in comparison with navigating the carotid artery.

In the posterior circulation, iatrogenic dissection is easily observed.[2)] In this report, we introduce our technique of respiratory control when patients are under local anesthesia during EVT so that the guiding catheter is safely and easily inserted through the tortuous VA. By this technique, the tortuosity of the VA is stretched, and the guiding catheter is easily navigated during the EVT.

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Fig. 1 DSA. (**A**) The left subclavian artery during normal breathing. (**B**) The left subclavian artery when the patient was holding his breath after maximum deep inspiration. The first segment of the VA became less tortuous during breath holding. DSA: digital subtraction angiography; VA: vertebral artery

Case Presentations

Details of the technique

This method is effective in cases in which the origin of the VA appears tortuous on digital subtraction angiography (DSA) and safe navigation of the guidewire is difficult.

First, the guidewire is advanced to the origin of VA just proximal to where the guidewire is caught in the tortuosity. Then the patient is instructed to take a maximum deep inspiration and hold his or her breath. This causes the aortic arch and side branches to be displaced in the caudal direction, which, in turn, stretches out the VA, and the guidewire and guiding catheter can then be passed easily through the VA.

Case 1

In a 54-year-old man, a 6-Fr. guiding catheter was inserted into the left VA. The origin of the left VA was too tortuous for the guidewire to pass through; it was caught in there, and there was concern about VA dissection (**Fig. 1A**). The patient took a maximum deep inspiration and held his breath, and the VA was stretched out, becoming less tortuous (**Fig. 1B**). The guidewire and guiding catheter were then easily passed through the VA (**Video 1**; the videos are available online.). No stoppage of blood flow was observed after passage of the guiding catheter and during the coil embolization, and the EVT was completed without any complication.

Case 2

During stent-assisted coil embolization in a 68-year-old woman, a 6-Fr. guiding catheter was inserted into the left VA, which was the dominant side of the VA and the right VA was hypoplastic. However, the origin of the left VA was tortuous. The patient took a maximum deep inspiration and held her breath, and the guiding catheter was easily and safely advanced into the left VA (**Video 2**). Afterwards, blood flow was stagnated; this problem was alleviated only when the patient performed maximum deep inspiration and held her breath. Therefore, to continue the procedure, the patient repeated maximum deep inspiration and breath holding every 3 minutes; this ensured blood flow and prevented thromboembolization (**Video 2**). The procedure was completed without any complication.

Case 3

The patient was a 77-year-old woman. DSA showed that the origin of the right VA was too tortuous to pass the guidewire safely (**Fig. 2A**), but after the patient took a maximum deep inspiration and held her breath, the vessel

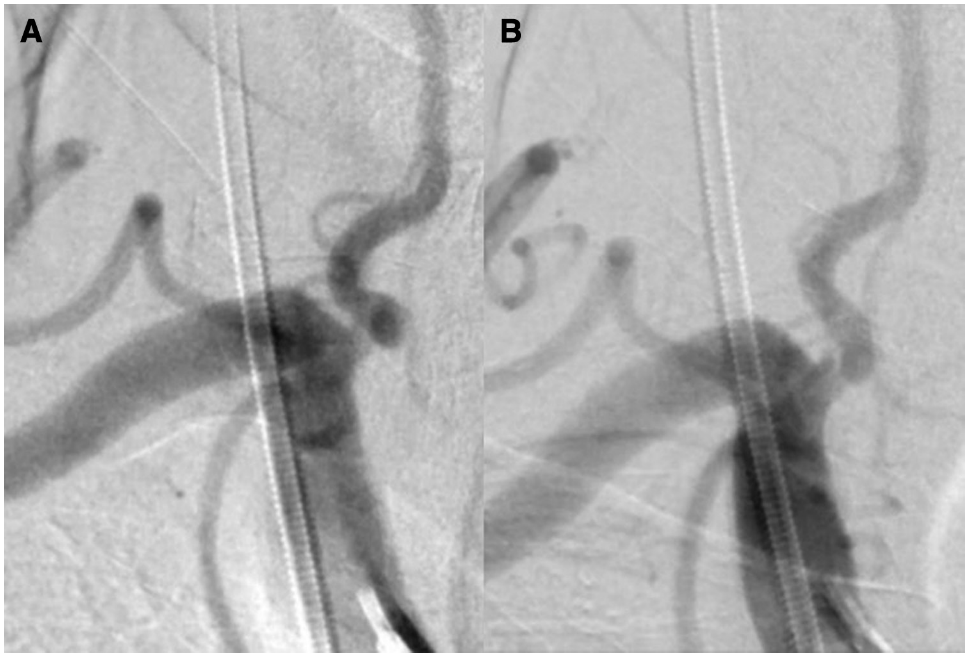

Fig. 2 DSA. (**A**) The right subclavian artery during normal breathing. (**B**) The right subclavian artery when the patient was holding her breath after maximum deep inspiration. The first segment of the VA became less tortuous during breath holding. DSA: digital subtraction angiography; VA: vertebral artery

stretched out, and the guidewire was passed easily and safety through the vessel (**Fig. 2B**).

Discussion

With the development of devices for neuroendovascular treatment, the indications for EVT are increasing. Accordingly, the use of EVT in situations involving tortuous access routes is increasing. Even in such situations, EVT is often the first or only option in the posterior circulation because of the difficulties in performing direct surgery.

Iatrogenic dissection of cerebral vessels occurs in 0.39% of diagnostic or interventional cerebrovascular procedures, and 72% of these occur in the VA.[2] There are two possible reasons for this. First, this is because of its smaller diameter in comparison with vessels of the anterior circulation; large-caliber guiding catheters can easily cause interruption of blood flow or intimal injury of the arterial wall.[3] Second, the route of VA is fixed by the transverse foramina, and mobility of the VA is limited. This anatomical feature makes it easy to perform iatrogenic dissection by the catheter.[4]

In the navigation of the guiding catheter to the anterior circulation, the adjunctive techniques are considered when the access route is too tortuous to navigate guiding catheter easily. Direct puncture of the carotid artery,[1] manual compression of the guidewire at the neck of the carotid artery,[5] combination use of the goose neck snare catheter,[6] and flow navigation or anchoring by balloon guiding catheter[7] were previously reported as effective, but these techniques could not be adapted to treatment in the posterior circulation. In the navigation of the guiding catheter to the tortuous VA, effective adjunctive techniques previously reported were few compared with the anterior circulation. Approach from the upper extremity, including radial or brachial artery, was reported to be effective in some cases.[8] It is effective in cases where the angle from the distal side of the subclavian artery to the VA is gentle. The stability of the guiding catheter may be superior via the femoral artery approach. However, tortuosity of the VA itself is not effective. Our technique reported here is one of the few effective techniques for the tortuous posterior circulation in which navigation of the guiding catheter is difficult, and this is the first report of the use of respiratory dislocation of the aortic arch and side branches in EVT. Moreover, this technique is not complex technically, and no additional devices are needed. This is effective in cases where the VA itself is tortuous. Although it involved some complex device systems and procedure, "buddy wire technique" was reported to be useful in the tortuous posterior circulation.[9] In this technique, large-caliber guiding catheter was placed in the subclavian artery, and stiff wire was navigated to the brachial artery through the guiding catheter as the buddy wire to stabilize

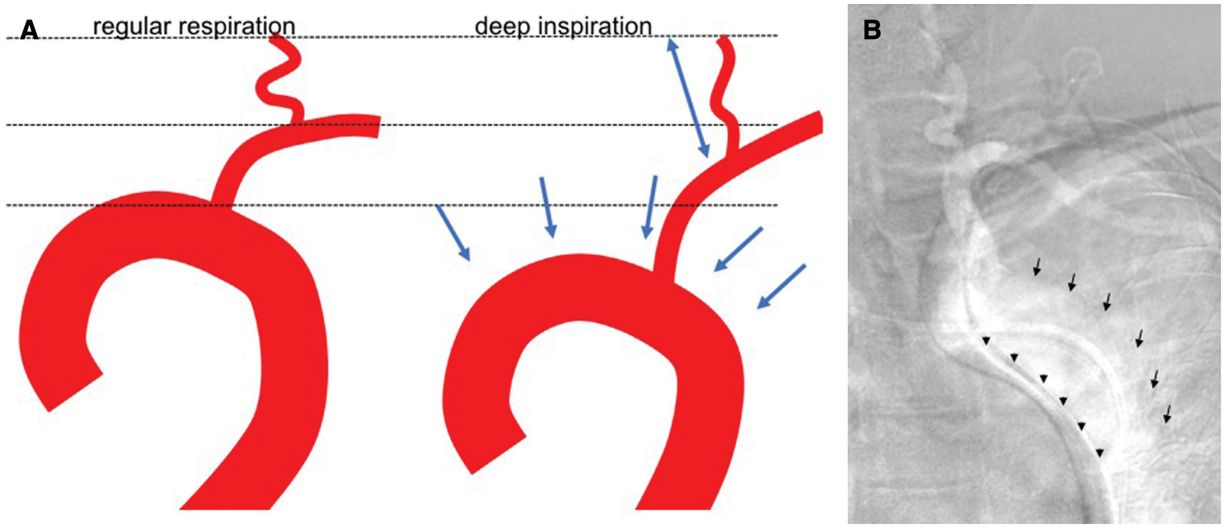

Fig. 3 (**A**) Schema of the aortic arch, subclavian artery, and VA. Expansion of the lung by deep inspiration causes dislocation of the aortic arch in the caudal direction. Because the distal side of the VA is attached to the transverse foramina, the VA is stretched and becomes linear. (**B**) DSA showing the difference in the outer side of the aortic arch between regular breathing (arrows) and breath holding after maximum deep inspiration condition (arrowheads). The aortic arch is dislocated in the caudal direction by expansion of the lungs. DSA: digital subtraction angiography; VA: vertebral artery

the guiding catheter. Next, only the microcatheter or small-caliber distal access catheter was navigated to the tortuous VA. This is effective in cases where the VA itself is tortuous, and it seems difficult to navigate the guiding catheter to the VA. However, in the situation that navigation of the guiding catheter to the VA is possible, our technique may be superior to the buddy wire technique with respect to subsequent procedural stability because the guiding catheter is placed in the distal position.

From the view point of the anatomy of the VA, approximately 95% of them originate from subclavian artery, and they entered the six transverse foramina.[10] The soft tissue in the first segment is somewhat mobile, but its route is fixed by its entry into the transverse foramina.[4] Therefore, arteriosclerotic changes were likely to accumulate in the prevertebral first segment of the VA and render it more tortuous. Navigating a catheter system through this position is one of the most important methods of avoiding iatrogenic dissection, and our technique is focused on this phase.

With regard to the mechanisms of our technique, our hypothesis is that when the lungs expand, the mediastinum, including the aortic arch, is pushed caudally during deep inspiration, and the subclavian artery and VA are pulled in the same direction simultaneously. Because the distal side of the VA is attached to the transverse foramina, the VA is stretched, and its course becomes almost linear (**Fig. 3A**). This phenomenon was observed in our actual patients (**Fig. 3B**). Dislocation of aortic arch and side branches depend on respiration were previously reported. Sailer et al. reported these vessels tend to move to anterior, medial, and caudal direction in the inspiration state compared to expiration state. In their report, dislocation is 8.9 ± 3.6 mm in aortic arch, 12.0 ± 4.1 mm in brachiocephalic artery, and 11.1 ± 3.9 mm in left subclavian artery.[11] Length of the VA of the prevertebral segment was reported as 38.8 ± 11.4 mm.[10] Therefore, the dislocation is comparable to approximately 1/3 length of the VA, it seemed to be enough dislocation to stretch the tortuosity of VA. Weber et al.[12] reported that there was threshold of respiratory thorax excursion to dislocation of the aortic arch, and tidal breathing is not sufficient to observe it, but maximum inspiration is needed. These reports support our hypothesis and efficacy of our technique.

Additionally, this displacement of the VA was observed even with the guiding catheter inside the VA after navigated the guiding catheter, and the interruption in blood flow by the guiding catheter was resolved by our technique. Therefore, continuation of the EVT procedure and reduction of the ischemic complication are also possible even in case of VA blood flow interruption.

This technique had some limitations. First, we performed our technique under local anesthesia and sedation by intravenous anesthesia, it is not clear that the same phenomenon could be observed under general anesthesia. However, we think same phenomenon could be observed under general anesthesia when gaining the inspiration volume enough to push down the aortic arch by controlling the ventilator. Second, there were some possibilities our technique was insufficient for patients who have constrictive lung disorder, since flexibility of the thorax is low during maximum deep inspiration.

Conclusion

In the EVT of a patient who has tortuous VA, respiration control under local anesthesia, holding maximum deep inspiration condition, induces the respiratory displacement of the aortic arch and side vessels. It enables safe navigation of the guiding catheter and reduces the incidence of blood flow interruption. It avoids dissection and ischemic complication during the EVT.

Supplementary Information

Video 1

Comparison of the VA tortuosity between regular breathing and deep inspiration (0”–8”) and movie of the navigating guidewire to the tortuous VA. A guidewire was caught in the tortuosity during regular breathing (8”–23”). However, tortuosity of VA origin was stretched by deep inspiration and the guidewire was easily passed through (23”–37”). VA: vertebral artery.

Video 2

Movie of navigating the guidewire to the tortuous VA (0”–23”), and ensuring the blood flow of the tortuous VA stagnated by the guiding catheter. It was alleviated when the patient performed maximum deep inspiration and held her breath (23”–37”). VA: vertebral artery.

Disclosure Statement

All authors declare no conflict of interest regarding this article.

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