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Yamakawa, Akira ; Fujita, Atsushi ; Tanaka, Jun ; Kohta, Masaaki ; Hosoda, Kohkichi ; Kohmura, Eiji

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Technical Note

Transarterial Embolization for Spinal Dural Arteriovenous Fistula Assisted by a Balloon Placed at a Different Level of a Segmental Artery: A Case Report

Akira Yamakawa, Atsushi Fujita, Jun Tanaka, Masaaki Kohta, Kohkichi Hosoda, and Eiji Kohmura

Objective: We report a case of a spinal dural arteriovenous fistula (s-dAVF) involving feeders from multiple intervertebral levels. Transarterial glue embolization was performed with controlling the blood flow from a feeder other than the one through which n-butyl-2-cyanoacrylate (NBCA) was injected using a balloon placed at a different level of a segmental artery. With this technique, complete occlusion was achieved with satisfactory penetration of NBCA.

Case Presentation: A 57-year-old male presented with progressive gait disturbance and bladder bowel dysfunction. DSA revealed an s-dAVF fed by the right 6th, 7th, and 8th intercostal arteries (ICAs). During injection of NBCA from the radicular artery of the 6th ICA, the blood flow was controlled by occluding the feeder from the right 7th ICA with NBCA and a balloon placed at the orifice of the feeder from the right 8th ICA. Complete occlusion of the fistula was achieved by the balloon-assisted injection of NBCA.

Conclusion: NBCA injection with flow control using a balloon placed in a feeder from a different segmental artery was useful for the treatment of an s-dAVF fed by multiple segmental arteries.

Keywords▶ spinal dural arteriovenous fistula, transarterial embolization, balloon assist, image fusion

Introduction

Spinal dural arteriovenous fistula (s-dAVF) is the most frequent vascular anomaly of the spinal cord, reportedly accounting for 60%–80% of such vascular anomalies.[1,2] The annual incidence of s-dAVF is 5–10 of 1,000,000 people.[3] While the occlusion rate by direct surgical disconnection of the fistula is high,[4] the complete occlusion rate by endovascular embolization varies from 25% to 75%.[5,6] For complete occlusion of an s-dAVF by transarterial embolization (TAE), n-butyl-2-cyanoacrylate (NBCA) must sufficiently penetrate from the shunt to the drainer through a wedged microcatheter. Good control of the progression of glue into the shunt is reliant upon the control of blood flow from vessels other than the target vessel into which the NBCA is injected.

We herein report a case of an s-dAVF involving feeders from multiple intervertebral levels. To determine the optimal treatment strategy, we used 3D-DSA fusion images obtained by multiple segmental arterial injection. Based on the findings of fusion images, we could perform curative embolization with controlling the blood flow of one feeder with glue and another with a balloon. To the best of our knowledge, no previous reports have described a TAE with flow control using a balloon placed in a segmental artery of a different level.

Case Presentation

The patient was a 57-year-old man with a history of lumbar intervertebral disc herniation, for which he had undergone herniectomy at the ages of 30 and 46 years. He noted weakness of the bilateral lower extremities from early August 201X. He became unable to walk and developed an urination disorder in October. He was referred to the Neurology

Department of Neurosurgery, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan

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Corresponding author: Akira Yamakawa. Department of Neurosurgery, Kobe University Graduate School of Medicine, 7-5-2 Kusunoki-Cho, Chuo-Ku, Kobe, Hyogo 650-0017, Japan
Email: ayamakawa66@yahoo.co.jp

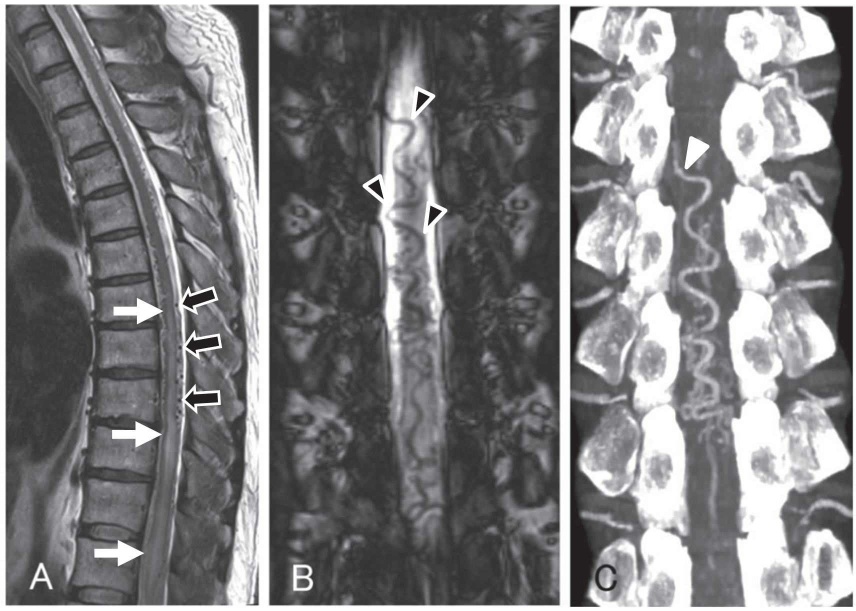

Fig. 1 Thoracic mid-sagittal (**A**) and coronal (**B**) images of T2-weighted MR images show a hyperintensity area (**A**, white arrows) which starts at the level of the Th7 vertebral body and continues to the conus medullaris. Note serpiginous flow voids (**A**, black blank arrows) and the tortuous dilated perimedullary vein (**B**, black blank arrow heads) on the dorsal surface of the spinal cord. A coronal reconstruction of contrast-enhanced CT maximum intensity projection image (**C**) shows dilated radicular vein (**C**, white arrow head) which starts at the level of the Th7 root.

Department of our hospital from a local doctor. He was then referred to our department because an s-dAVF was suspected on spinal cord MRI.

Neurologic findings on admission

Upon admission, the patient was alert with no abnormalities in the cranial nerves or upper extremities. Manual muscle testing (MMT) revealed a bilateral lower extremity muscle strength of 4/5 and a bilateral quadriceps femoris muscle strength of 3/5. He also exhibited dysbasia and was restricted to a wheelchair. Deep sensibility was reduced bilaterally below the umbilicus (4/10 compared with the upper extremities), and the Romberg sign was positive. The bilateral patellar and Achilles tendon reflexes were reduced. Reflex incontinence was noted, self-controlled defecation was difficult, and bowel movements were induced by intermittent enemas. Blood test results were unremarkable.

Neuroradiological examinations

Sagittal T2-weighted images of thoracolumbar spinal MRI (**Fig. 1A**) showed an area of hyperintensity in the spinal cord caudal to the Th7 level (**Fig. 1A**, white arrows) and flow voids (**Fig. 1A**, black blank arrows). Coronal images (**Fig. 1B**) showed a dilated and tortuous drainer on the dorsal aspect of the spinal cord (**Fig. 1B**, black blank arrows). Coronal maximum intensity projection (MIP) images of CTA (**Fig. 1C**) showed a dilated and tortuous spinal vein from the right side at the Th7/8 level (**Fig. 1C**, white arrow head). Involvement of feeders from the right 6th and 8th intercostal arteries (ICAs) was suspected, and an involvement of the right 7th ICA was also considered. From these findings, we diagnosed a thoracic s-dAVF (Aminoff-Logue scale G4, M2) and scheduled TAE in the same session with diagnostic angiography.

Spinal angiography

After induction of general anesthesia, 7 French (Fr) sheaths were placed in the bilateral femoral arteries and systemic heparinization was established by administration of 3000 units of heparin with continued intravenous infusion at 1000 units/hour. Diagnostic angiography was performed using a 4 Fr Cobra (Medikit Co., Ltd, Tokyo, Japan). Transit 2 (Cordis, Johnson & Johnson, Fremont, CA, USA) was inserted into the right 6th (**Fig. 2A** and **2B**), 7th (**Fig. 2C**), and 8th (**Fig. 2D**) ICAs, and selective angiography and 3D-DSA were carried out. On 3D-DSA of the right 6th ICA, the right 7th ICA was also visualized via the anastomosis. Therefore, fusion images were constructed from this image and the 3D-DSA image of the right 8th ICA using the software of the workstation (syngo InSpace 3D/3D fusion;

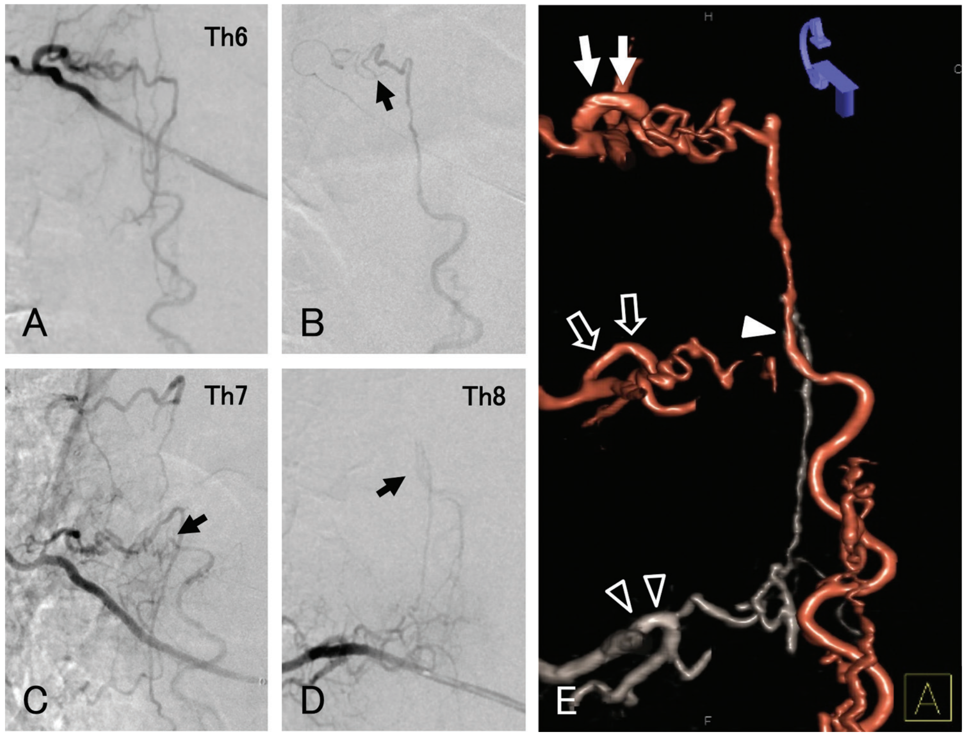

Fig. 2 Right Th6 (**A**), Th7 (**C**), and Th8 (**D**) intercostal artery angiogram shows a spinal dural arteriovenous fistula. Note the radicular arteries from right Th6 (**B**, micro-injection from radicular artery), Th7 (**C**, arrow), and Th8 (**D**, arrow). A dual fusion vessel image constructed from 3D-DSA of Th6 (red, Th7 intercostal artery is also seen through intercostal longitudinal anastomosis) and Th8 (gray) intercostal arteries (**E**) shows the shunting point (white arrow head) and feeders from three Th6-8 segmental arteries. White arrows, blank arrows, and blank arrow heads show right dorsospinal branches of Th6, Th7, and Th8 right intercostal arteries, respectively.

Siemens AG, Forchheim, Germany) and displayed as one volume (**Fig. 2E**). We identified an s-dAVF fed by the radicular arteries and arising from the right 6th–8th ICAs (**Fig. 2E**, white solid arrows, white blank arrows, white blank arrowhead). The s-dAVF had a shunt point near the right 7th thoracic spinal nerve root (**Fig. 2E**, white arrowheads) and drained into the perimedullary vein. No spinal arteries branching from the right 6th–8th ICAs were noted. The Adamkiewicz artery was confirmed by angiography of the left 10th ICA, and it was not related to the s-dAVF.

Endovascular treatment

3D-fusion DSA images revealed that this lesion consisted of feeders from three different segmental arteries; thus simplification of the feeder-shunt-drainer structure was necessary to allow for the curative TAE. NBCA was scheduled for injection via the radicular artery of the right 6th ICA because a microcatheter could be wedged in this feeder (**Fig. 2B**). During injection of the NBCA, we aimed to control the blood flow from right 7th and 8th ICAs by occluding a proximal portion of radicular arteries with NBCA and a balloon. Because the dorsospinal branch of the right 7th ICA arise sharply, navigation of the balloon was considered difficult. Therefore, the radicular artery from the right 7th ICA was occluded with NBCA at a proximal portion. Flow control was subsequently achieved by placing a balloon at the orifice of the dorsospinal branch of the right 8th ICA. A 7 Fr Axcess JR4.0 (Asahi Intecc Co., Ltd, Aichi, Japan) and a 4 Fr Cerulean (Medikit Co., Ltd) were placed coaxially in the right 6th ICA on the proximal side of the bifurcation of the ventral and dorsospinal branches, and a Marathon (Covidien, Irvine, CA, USA) was placed in the radicular artery (**Fig. 2B**, arrow). A similar system was also placed in the right 7th ICA, and from the Marathon placed in the radicular artery (**Fig. 3A**, arrow), the feeder was closed with 50% NBCA (**Fig. 3B**). The system inserted in the right 7th ICA was relocated in the right 8th ICA, and we confirmed the point at which the radicular artery converged from this site onto the shunt (**Fig. 3C**, arrow). A SHOURYU 4.0 mm × 10 mm (Kaneka Medix Corp., Osaka, Japan) was then placed at the orifice of the radicular artery (**Fig. 3D**, arrow). After inflating the balloon, angiography

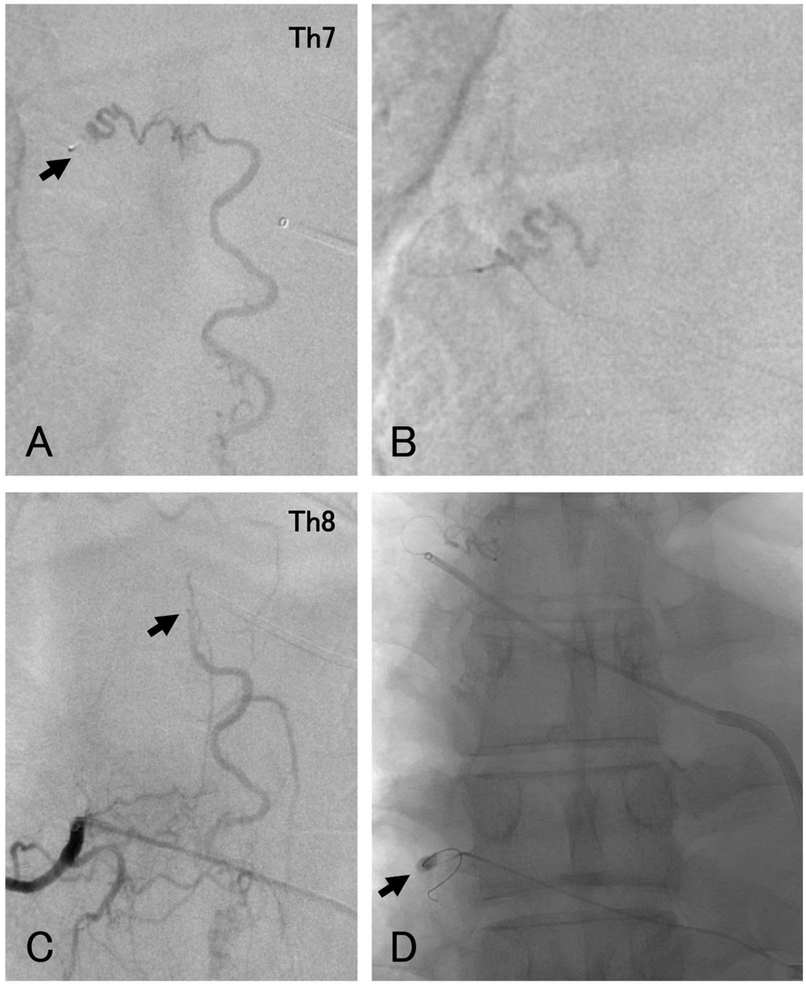

Fig. 3 Superselective microcatheter injection (arrow) of right Th7 radicular artery (**A**) shows spinal dural arteriovenous fistula. Injection of 50% NBCA from Th7 radicular artery (**B**) results in feeder occlusion. Right Th8 intercostal injection (**C**) obtained after Th7 radicular artery feeder occlusion clearly shows fistulas point (arrow) of the fistula. A non-subtracted image (**D**) shows inflated balloon (arrow) placed in the dorsospinal branch of right Th8 intercostal artery. NBCA: n-butyl-2-cyanoacrylate

was performed through the microcatheter placed in the radicular artery of the right 6th ICA and showed the disappearance of the laminar flow of the drainer. From this microcatheter, 14% NBCA was injected and slowly progressed into the shunt and drainer; it also refluxed into the radicular artery from the right 8th ICA (**Fig. 4**). Because the final angiography from the right 6th–8th ICAs confirmed complete obliteration of the shunt, the procedure was ended.

Postprocedural course

CTA performed 2 days after the procedure showed the NBCA cast in the shunt and proximal portion of the drainer and disappearance of the dilated and tortuous veins (**Fig. 5A**). The postprocedural course was uneventful; the muscle strength of the bilateral lower extremities improved to MMT 5-/5 on MMT, and the patient became able to walk without assistance. Deep sensibility also recovered, and the Romberg sign became negative. The patient was transferred to a rehabilitation hospital with a modified Rankin Scale (mRS) score of 2 on day 22 after the procedure. He was discharged to home after a 3-month rehabilitation period with slight impairment of deep sensibility but he was able to return to work. MRI performed 6 months after the procedure showed improvement in signal changes in the spinal cord and disappearance of the flow void (**Fig. 5B** and **5C**).

Discussion

To perform TAE of an s-dAVF consisting of multiple feeders from three segmental arteries, we selected a target

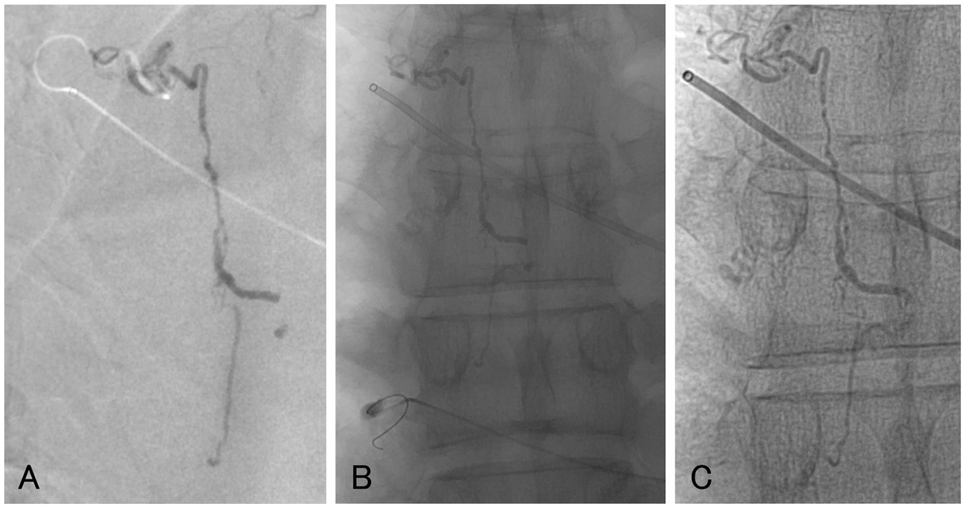

Fig. 4 DSA (**A**) and non-subtracted (**B**) images just after withdrawal of microcatheter during balloon-assisted injection of low concentrate NBCA from right Th6 radicular artery show that glue penetrates the shunting point and radicular vein with the reflux to the Th8 radicular artery. A non-subtracted image (**C**) shows the final cast of radiopaque NBCA. NBCA: n-butyl-2-cyanoacrylate

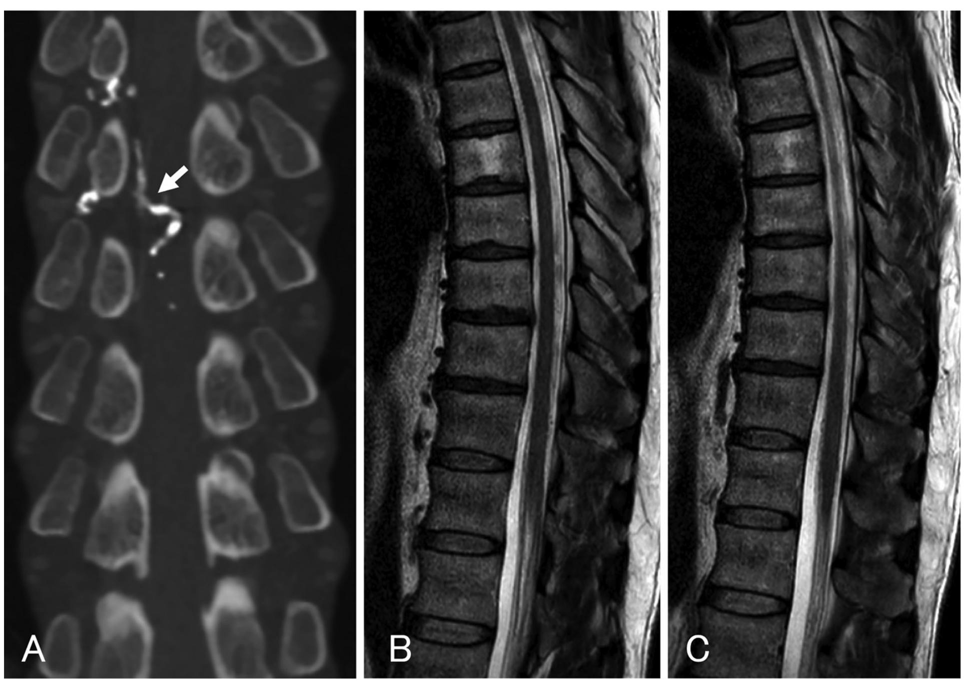

Fig. 5 A coronal reconstructed CT image (**A**) obtained the next day after embolization shows the cast of NBCA in the radicular vein (arrow). Sagittal images of T2-weighted thoracic MRI (**B** and **C**) obtained 6 months after embolization show the disappearance of flow voids and the improvement of abnormal signal change in the spinal cord. NBCA: n-butyl-2-cyanoacrylate

vessel through which NBCA would be injected and simplified the vascular architecture from the feeder to the shunt and drainer by occluding the other feeders with NBCA and a balloon. This led to satisfactory control of the blood flow during NBCA injection, penetration of the NBCA to the drainer, and complete embolization of the lesion.

As in endovascular treatment of the head and neck region, the use of 3D-DSA images in the treatment of an s-dAVF also provides detailed information about the vascular anatomy, which is advantageous for determination of the working angle.[7] It recently became possible to display a fusion image of two 3D-DSA images on a workstation.[8] In the present case, we fused 3D-DSA images of the right

6th ICA (the 7th ICA was also delineated via the anastomosis) and the right 8th ICA to clarify the vascular anatomy of the s-dAVF being fed from multiple intervertebral levels. This allowed us to delineate the relationship among the feeders from multiple segmental arteries, the shunt, the drainer, and the detailed information about the vasculature was useful for treatment planning. In a recent review of the literature on NBCA embolization of s-dAVF,[9] the occlusion rate reached 70%–90%, which is not inferior to the results of direct surgical disconnection of the fistula. In addition, Onyx (ev3 Neurovascular, Covidien, Plymouth, MN, USA), which is frequently used for embolization of intracranial dAVF, is also reported to be useful for TAE; however, it is currently suspected to be inferior to NBCA in terms of visibility and durability.[10] Therefore, NBCA is considered as the standard liquid material for embolization.

In TAE using NBCA, it is necessary to wedge the microcatheter as much as possible and inject the glue to penetrate into the drainer beyond the shunt. To achieve this, it is optimal to modify the vascular architecture consisting of multiple feeders, shunt point, and drainer into a single feeder-single drainer pattern because such a simplified vascular architecture permits adequate control of the progression of NBCA and ensures its penetration into the drainer. While wedging of the microcatheter is most important, such a condition cannot always be attained. When wedging is impossible, techniques such as injecting NBCA after intentionally preparing a wedge using coils introduced through parallel microcatheters[5] and creating a wedge by placing a balloon catheter at the orifice of the feeder have been reported.[11] However, to ensure penetration of the injected NBCA to the drainer, it is also important to control the blood flow other than that from the target vessel; if this is not performed, unintended early polymerization of NBCA may occur before it reaches the drainer. Moreover, influx from other feeders may cause fragmentation of the NBCA cast, and these fragments may scatter in the spinal veins. It may cause the disturbance of venous return at the sites difference from the lesion or incomplete embolization due to insufficient penetration.

To perform TAE in our patient, we selected the radicular artery from the right 6th ICA as the target vessel for NBCA injection because it was visualized most clearly on preprocedural CTA and allowed for reliable wedging. We also controlled the blood flow by occluding the radicular artery from the right 7th ICA with NBCA and the orifice of the radicular artery from the right 8th ICA with a balloon. This resulted in simplification of the shunt and made the injection of NBCA highly controllable. NBCA could be injected to the drainer without fragmentation, and reflux into the balloon-occluded feeder. To our best knowledge, no previous reports have described the TAE for an s-dAVF with control of blood flow from other segmental arteries using a balloon. This procedure is considered to have the following advantages. With respect to control of blood flow into the shunt, our procedure is comparable with feeder occlusion; however, by controlling the blood flow using a balloon, the option of removing the balloon and adding TAE via the same vessel (radicular artery of the right 8th ICA in our patient) can be retained even if NBCA injection via the target vessel (radicular artery from the right 6th ICA in our patient) ends in incomplete occlusion. Once feeder occlusion has been performed using NBCA, additional embolization via the same vessel becomes difficult. However, the simultaneous use of a balloon ensures similarly effective control of blood flow and secures a second chance for additional treatment.

There were some technical limitations in our report. First, a balloon can rarely be inserted into small spinal vessels, particularly the radicular arteries. The balloon is used to occlude the orifice of the feeder, so it is necessary to carefully evaluate the position of balloon. In addition, depending on the site of occlusion, the intended effect of occlusion may not be obtained because of the presence of collaterals from other segmental arteries such as a retrocorponeal anastomosis. In our patient, to examine the occlusive effect of the balloon, we inflated the balloon placed in the dorsospinal branch of the right 8th ICA to occlude the orifice of the radicular artery and, in this state, we performed angiography via the microcatheter placed in the radicular artery arising from the right 6th ICA. Because the laminar flow of the drainer disappeared in this angiogram, we confirmed that intended flow control could be achieved. Another limitation is that the use of an intermediate catheter may be difficult because of the larger profile of the assist balloon compared with a microcatheter. In this situation, it may be difficult to navigate the balloon catheter to the intended position. Moreover, when using the transfemoral approach, blood flow of a vessel other than the vessel used for NBCA injection can be controlled by this balloon-assisted method; however, additional occlusion using NBCA as in our patient is necessary for three or more feeders.

Conclusion

For s-dAVF in which three segmental arteries were involved, we performed TAE under flow control from two radicular arteries other than the artery used for NBCA injection. Complete occlusion was achieved with satisfactory penetration by NBCA. Flow control using a balloon placed a different segmental artery was a useful technique for the treatment of an s-dAVF consisting of multiple segmental arteries.

Disclosure Statement

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

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