CASE REPORT

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The usefulness of three-dimensional fusion imaging of spinal arteriovenous malformation by a workstation connected to angiography systems

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ABSTRACT

Digital subtraction angiography (DSA) is the most useful technique for diagnosing spinal arteriovenous malformations (AVM). In recent years, with the improvement of imaging capabilities, the usefulness of three-dimensional (3D) imaging by fusing various modalities has been recognized. The use of 3D fusion imaging with a workstation connected to an angiography system has been reported in many cases of intracranial disease, but less frequently for spinal AVM. In this article, we describe two illustrative cases of spinal AVM in which 3D fusion imaging was useful for treatment. Although 3D fusion images using the system have the disadvantage that only a maximum of two images can be fused, it provides spinal surgeons with useful information for preoperative evaluation in a small amount of time.

Keywords: spinal vascular malformations, spinal arteriovenous shunt, dural arteriovenous fistula, spinal arteriovenous malformation, 3D fusion image

Abbreviations:
3D: three-dimensional
DSA: digital subtraction angiography
AVM: arteriovenous malformations
SAH: subarachnoid hemorrhage
ASA: anterior spinal artery
AVF: arteriovenous fistula
VA: vertebral artery
TAE: transcatheter arterial embolization
NBCA: N-butyl-2-cyanoacrylate
TOF: time-of-flight
MRI: magnetic resonance imaging
CTA: CT angiogram

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INTRODUCTION

Three-dimensional (3D) rotational angiography, which can visualize small blood vessels, is now established as a standard method for the diagnosis of spinal vascular malformation.[1-5] Furthermore, there is also a known image creation method for better understanding vascular anatomy by fusing two three-dimensional images on a workstation connected to an angiography device.[6-9] This method provides surgeons with a solid understanding of the vascular architecture and anatomy of the lesion, allowing for effective preoperative planning and improved outcomes. However, this method is commonly reported as being used for the diagnosis of cerebral arteriovenous malformations, but few for spinal arteriovenous malformations.

In this article, we discuss the usefulness of 3D fusion imaging by presenting two illustrative cases.

CASE PRESENTATIONS

Case 1

The patient was a 58-year-old man. He presented with a sudden headache and consulted a former doctor. Imaging examination revealed subarachnoid hemorrhage (SAH) and aneurysms at the anterior spinal artery (ASA); therefore, the patient was transferred to our hospital. CT angiography and time-of-flight MR angiography (TOF MRA) at our institution could not confirm the details of the vascular lesions (Fig. 1 A–D). Cerebral angiography revealed an arteriovenous fistula (AVF) at the craniocervical junction and two aneurysms on the ASA (Fig. 2). The AVF was fed independently by the spinal pial artery from the ASA and the right C-2 radicular artery. Two-color 3D–3D fusion images illustrated the blood flow from these feeders and were

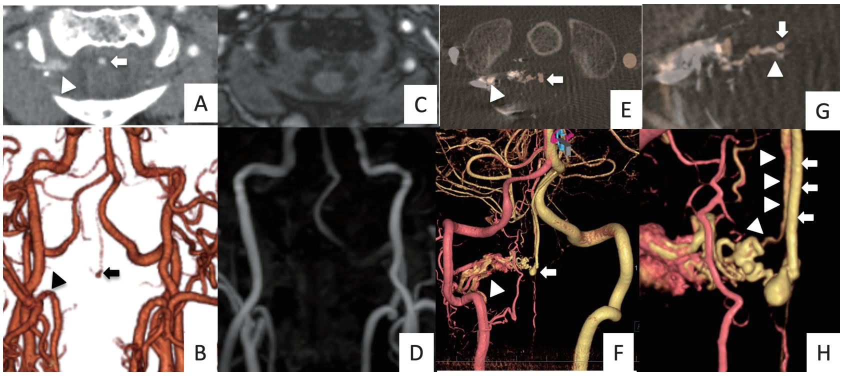

Fig. 1 CT angiography, time-of-flight MR angiography, and rotational DSA images (Case 1)

Fig. 1A–1B: Axial image of CT angiography showed an aneurysm anterior to the spinal cord (arrow) and abnormal vessels (arrowhead) around the right vertebral artery (A). The 3D-CTA image showed the dilated anterior spinal artery (ASA) to the aneurysm, but the shunt point and surrounding blood vessels around the right vertebral artery were not visualized in detail (B).

Fig. 1C–1D: Time-of-flight MR angiography did not show any abnormal vessels (C, D).

Fig. 1E–1H: The native volume that fused two rotational DSA images of the bilateral vertebral arteries, showed not only the aneurysm (arrow) but also the shunt point and surrounding blood vessels around the right vertebral artery in detail (arrowhead) (E, F). As an example, we were able to distinguish between the dilated ASA (arrows) and the anterior spinal vein that had been dilated as a drainer (arrowheads) (G, H).

represented in different colors (Fig. 1 E and F). Both feeders drained into the epidural venous plexus and refluxed into the intradural anterior spinal vein (Fig. 1 G and H, Fig. 2). Based on these findings, we diagnosed an epidural AVF with a pial feeder.

We first performed an endovascular treatment. We attempted to approach the ASA aneurysms from the left vertebral artery (VA), which was thought to be the rupture point; however, the

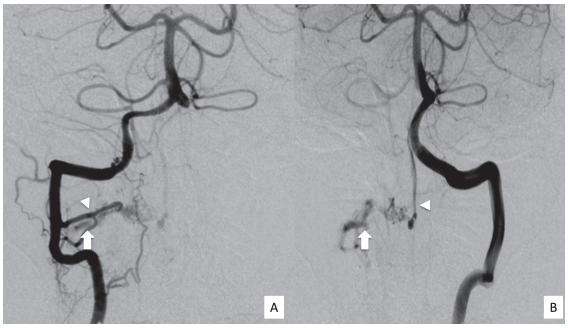

Fig. 2 Cerebral angiography at our hospital (Case 1)
Right VA angiogram (A), anteroposterior view showing the AVF fed by the C-2 radicular artery (arrowhead), with engorgement of the epidural venous plexus from the high-flow shunt (arrow). Left VA angiogram (B), anteroposterior view showing a dilated ASA (arrowhead) and pial artery supplied to the AVF, with engorgement of the epidural venous plexus (arrow) and backflow to the anterior spinal vein.

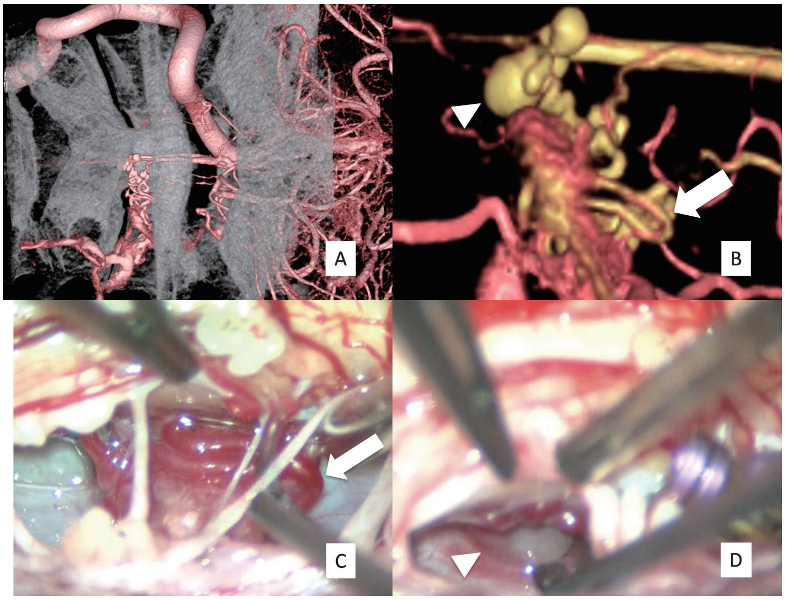

Fig. 3 A comparison of preoperative 3D fusion images and intraoperative findings (Case 1)
The fusion image of the left vertebral angiography (VAG) and the bone of the spine (A) clarifies the localization of the lesion and is vital for determining the extent of bone removal. The lesion can be grasped three-dimensionally from the fusion images of the left and right VAGs (B). Two aneurysms were found on the ASA. The location of the feeder from the pial branch of the ASA (arrow) and the aneurysm on the ASA (arrowhead) was as examined preoperatively (B–D).

aneurysms could not be reached. Next, we approached the right VA and performed transcatheter arterial embolization (TAE) of the radicular artery using N-butyl-2-cyanoacrylate (NBCA). As a result, the blood feeder from the right C-2 radicular artery was occluded, but the feeder from the spinal pial artery to the shunt remained. Following this endovascular treatment, surgical treatment using the posterior approach was performed. 3D-3D fusion images are useful for preoperative planning. Fusion of the cervical vertebrae and left vertebral arteriography allowed us to determine the extent of bone removal necessary to reach the shunt lesion (Fig. 3A). Following a suboccipital craniotomy and C1 and C2 laminectomies, the dura mater was opened, and the C2 dorsal root was cut. The same vascular structure that was confirmed preoperatively in the 3D image was confirmed in the surgical field (Fig. 3B and C). The feeder from the spinal pial artery was temporarily clipped (Fig. 3D). Although clipping the aneurysms was impossible, intraoperative DSA confirmed that the shunt and the two aneurysms had disappeared and the feeder was cut. No recurrence of AVF was observed on cerebral angiography 10 months after surgery.

Case 2

The patient was an 81-year-old woman who presented with a subarachnoid hemorrhage. A cerebral angiography revealed a perimedullary AVF in the cervical spine. The AVF is fed by the right radicular artery, accompanied by a feeder aneurysm, and drains into the radicular vein (Fig. 4A). The angiogram from the left VA also confirmed the depiction of the ASA via the radicular artery (Fig. 4B). The two-color 3D–3D fusion image clearly confirmed the fenestration of the

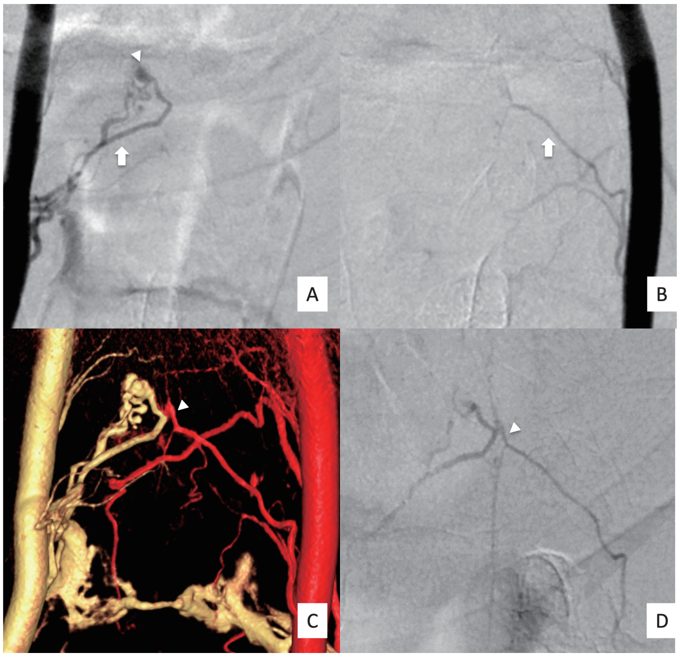

Fig. 4 The cerebral angiography of perimedullary AVF at the cervical spine (Case 2)
Right vertebral angiography (VAG) revealed the AVF is fed by the right radicular artery (arrow) accompanied with the feeder aneurysm (arrowhead) and drained into the engorged radicular vein (A). Left VAG also confirmed the depiction of the ASA via the radicular artery (arrow) (B). The two vessels 3D–3D fusion image clearly confirmed the fenestration of the ASA (arrowhead) (C). During the endovascular treatment, a catheter was inserted into the radicular artery and angiography was performed (D), the fenestration of the ASA was confirmed, as in the two vessels 3D–3D fusion image (arrowhead).

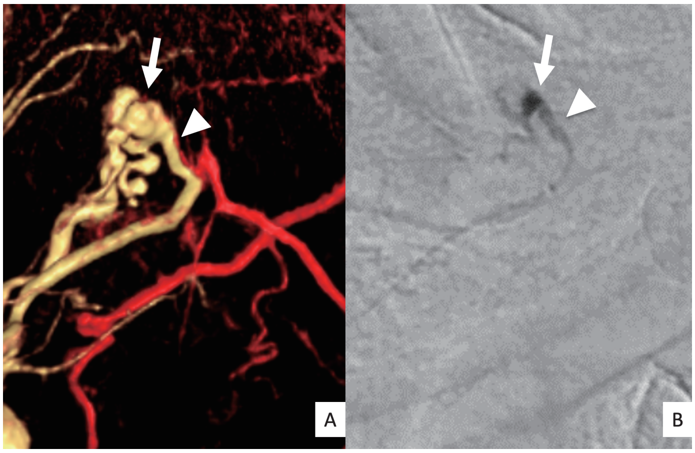

Fig. 5 DSA images during embolization procedure (Case 2)
Preoperative 3D-3D fusion images (A) allowed us to determine the appropriate catheter position during endovascular embolization. (B) It was accompanied by an aneurysm near the perimedullary AVF (arrow). To prevent flow back from the artery, 33% NBCA was injected from a sufficient distance from the ASA (arrowhead).

ASA (Fig. 4C). This helped in determining the proper catheter position during endovascular embolization.

Endovascular treatment was administered. First, a catheter was inserted into the radicular artery, and angiography was performed (Fig. 4D), and the fenestration of the ASA was confirmed as in the two-color 3D–3D fusion image. Furthermore, the catheter was advanced to the pial artery near the feeder aneurysm. The injection of 33% NBCA was started at a sufficient distance from the ASA to prevent the flow back into the ASA (Fig. 5). Aneurysm and shunt occlusion were achieved, and the ASA was preserved.

DISCUSSION

Recent advances in imaging techniques have made it possible to visualize vascular lesions with MRA and CTA. The probability of identifying the site of spinal dural AVF has been reported to be 70–88% with dynamic MRA and 58–90% with 3D-CTA.[10] Moreover, 4D-CTA has been reported to further increase the localization rate of spinal dural AVFs.[10] These techniques are very useful in understanding the overall picture of spinal shunt disease and its relationship with surrounding tissues. However, in order to ensure normal blood flow to the spinal cord and prevent spinal cord ischemia during surgery, it is necessary to understand the detailed vascular structure. The spinal shunt disease has a very fine vascular structure compared to vascular malformations in other parts of the body. Therefore, complex shunt lesions with little blood flow cannot be well depicted by CTA or MRA (Fig. 1). For these reasons, DSA is still the gold standard with a fine depiction of spinal arteriovenous malformations. DSA image can be obtained that a catheter is placed close to the vascular lesion and contrast agent is injected for a detailed image of the blood vessels in that area. In complex vascular malformation lesions, it is necessary to combine several images to evaluate the lesion.

Multiple 3D rotational angiography fusion images are the accurate and reliable method to evaluate the vascular architecture of spinal arteriovenous malformations, because by using 3D rotational angiography, it is easier to grasp the vascular structure than with 2D images. As previously reported, two-color 3D–3D fusion can provide accurate information, even for lesions with complicated small blood vessels, such as anterior communicating artery complex aneurysms or cerebral arteriovenous malformations.[6-9] This method also enables detailed depiction, even in cases of spinal arteriovenous malformations.

The 3D fusion imaging using a workstation connected to an angiography system was created based on rotational angiography images. From the images obtained by conventional angiography, both the mask and contrast data were automatically transferred to the workstation (syngo X-Workplace; Siemens Healthcare GmbH, Forchheim, Germany). 3D subtraction images of the affected vessels were automatically produced on the workstation. The 3D-3D fusion process was carried out on a clinical workstation (syngo Inspace 3D–3D fusion). Two 3D images with the information of the native mask volumes, consisting of unsubtracted bony anatomy information, were used to create a 3D-3D fusion image. The two native mask volumes were automatically co-registered using the software. Manual adjustments were required if the automatic fusion was not satisfactory. The 3D-DSA volumes were then automatically fused and visualized. The window level settings and color of objects can be changed to achieve optimized visualization.

Visualization of the vascular lesion is not sufficient for the diagnosis and treatment of spinal AVMs. A good understanding of the anatomy of the vascular lesion and the soft tissue, including the spinal cord or dura mater and spinal bones, is required. By using 3D-3D fusion images of DSA as shown in the presented cases, accurate visualization of vascular lesions and spinal bone is possible, but soft tissues such as the spinal cord cannot be visualized. Takai et al proposed a method to describe all structures in a single 3D image using 3D computer graphics (CG) based on the fusion of 3D rotational angiography and postmyelographic CT or MRI.[11,12] This method provides more information to surgeons than the method presented here. However, this method has some drawbacks. The alignment of the spine changes depending on the position of the patient; therefore, manual adjustment is required to fuse each image. Manual adjustments for different modalities can make it difficult to create accurate 3D images, and in some cases, require a lot of time and skill to create it.

In contrast, 3D-3D fusion imaging using a workstation connected to an angiography system can be created more easily. To investigate how long it would take to create a 3D-3D fusion image using our method, one cerebrovascular surgeon who often used this software and three spine surgeons who had never used this software created the same images. We measured the time required to create a 3D-3D fusion image of Case 2. This case had an anomaly called fenestration of the anterior spinal artery, which made it easy to determine whether the 3D image was accurately created. The endovascular surgeon and three spinal surgeons were able to produce a two-color 3D-3D fusion image. It took 1 minute 58 seconds for the endovascular surgeon and 6 minutes 13 seconds, 3 minutes 58 seconds, and 3 minutes 43 seconds for spine surgeons. They were of a sufficiently short time and did not affect other clinical tasks. Although this method has limitations in that it is only possible to fuse two images, such as vessel to vessel or vessel to bone, the 3D images can provide the information needed for intraoperative strategies. In light of the above, for the purpose of diagnosis and preoperative evaluation of vascular malformations of the spinal cord, it is recommended to first create a 3D fusion image as shown in this study, and if the lesion is still difficult to evaluate, to create a 3D CG image by fusing multiple modalities.

CONCLUSION

The 3D-3D images created by a workstation connected to an angiography system are easy to create for surgical planning. These images are potentially useful in cases of spinal vascular malformations.

CONFLICT OF INTEREST

We declare that we have no conflict of interests.

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