Objective: An important point for consistent success in transvenous embolization (TVE) for dural arteriovenous fistulas (AVFs) is considered to be the identification of, and accurate guiding of the catheter to, the shunt point. We performed TVE using cone-beam CT and 3D roadmap function and evaluated its effectiveness and problems.

Methods: In 12 procedures of TVE performed in eight patients with dural AVF, we identified the shunt point by cone-beam CT performed intraoperatively using a diluted contrast agent and guided the microcatheter using 3D roadmap function. Only the shunt point was embolized in patients with a localized shunt point.

Results: The shunt point could be identified by cone-beam CT in all eight patients, and the shunt point was found to be localized in three patients. The shunt point was approached using intraoperative 3D roadmap function in six patients. 3D images of the affected sinuses and bones were superimposed on fluoroscopic images in four and two patients, respectively. The 12 procedures could be completed without complications in a mean procedure time of 300 minutes with a mean volume of contrast agent of 203.9 mL and a mean radiation dose of 3133 mGy.

Conclusion: Cone-beam CT using a diluted contrast agent is considered to have facilitated the identification of the shunt point, and the use of 3D roadmap function to have made decreases in the use of the contrast agent and radiation exposure possible. It also facilitated the confirmation of the arrival of the microcatheter at the shunt point.

Keywords ▶ dural arteriovenous fistula, transvenous embolization, cone-beam CT, 3D roadmap

Introduction

We consider the determination of, and accurate guiding of the catheter to, the shunt point to be key for consistent implementation of transvenous embolization (TVE) for dural arteriovenous fistula (AVF). To realize them, the use of the latent angiographic technologies, particularly, cone-beam CT, and 3D roadmap function are considered useful.

Cone-beam CT provides CT-like images by the use of a rotating C-Arm. High-resolution cone-beam CT, which has excellent spatial resolution, is useful for the identification of the shunt point. 3D roadmap function superimposes 3D images prepared by techniques such as 3D rotation angiography onto the fluoroscopic display. In conventional roadmaps obtained by projecting two dimensional (2D) DSA images, it was necessary to perform DSA with each change in the angle of fluoroscopy. Since 3D roadmap function enables the 3D projection image to track the movements of the C-Arm even when the angle of fluoroscopy is changed, it has made repetition of DSA unnecessary and reductions in the radiation exposure and use of the contrast agent possible.

In this study, we evaluated the effectiveness and problems of these functions in patients who underwent TVE for dural AVF at our department.

Subjects and Methods

In all, 12 procedures of TVE were performed in eight patients with dural AVF between January 2014 and June 2015.
Using the angiography system Allura Clarity FD20/20 (Philips Medical Systems, Best, The Netherlands), TVE was carried out with the intraoperative use of high-resolution Xper CT (HRCT) and dynamic 3D roadmap function (Philips Medical Systems).

As a standard procedure, contrast-enhanced imaging was performed first to identify the shunt point. A catheter was placed in the blood vessel that was most advantageous for visualization of the arteriovenous shunt of the dural AVF, and HRCT was performed while continuously injecting a three-fold dilution of the contrast agent at a rate of 2 mL/sec over 22 seconds. The imaging conditions were as follows: frame rate, 30 frames/second; scan time, 20 seconds; images, 620 images; size: 8 inches. The original data obtained were transferred to a 3D workstation (XtraVision, Philips Medical Systems), 3D reconstitution was performed using the Xper CT software (Philips Medical Systems), and the shunt point was identified in the maximum intensity projection (MIP) image. The shunt point was determined as the site of density change of the contrast agent in the artery.

Second, contrast-enhanced imaging was performed to visualize the approach route for TVE on the fluoroscopic image. 3D rotation angiography was performed while continuously injecting the contrast agent via the same catheter over 5 seconds at a rate of 1.5–3 mL/sec depending on the vessel diameter. The imaging conditions were as follows: frame rate, 30 frames/second; scan time, 4 seconds; images, 120 images; size, 13 inches. The timing of delineation of the affected venous sinus of the dural AVF was confirmed by conventional angiography for its optimal visualization, and, consequently, imaging was performed with a delay time of 2–4 sec. As described above, 3D reconstitution was performed, and the images were projected onto the fluoroscopic image on XtraVision using 3D roadmap function. The images projected by 3D roadmap function were basically those of the affected venous sinus. In the two procedures for dural AVFs of the cavernous sinus, treatment via the inferior petrosal sinus (IPS) was intended, but the IPS to be used as the approach was occluded. Therefore, bone window setting Xper CT images were reconstituted into 3D images, contrast was adjusted for clear visualization of the jugular foramen and petro-occipital fissure, and the images were projected onto the fluoroscopic image. The microcatheter was guided using these landmarks as the positions of the jugular bulb and IPS.

After the arrival of the microcatheter at the shunt point, HRCT was performed again using a three-fold dilution of the contrast agent, and whether or not the catheter could be guided to a site near the shunt point was confirmed. Then, if the shunt was localized, only the shunt was embolized (target embolization) as much as possible.

### Results

Table 1 shows details of the 12 procedures of TVE performed in the eight patients. Four procedures were performed under general anesthesia, and eight procedures under local anesthesia. During the procedure, HRCT was performed while injecting the contrast agent via the feeding vessel, and the shunt point could be identified in all patients. The shunt point was present diffusely in the affected venous sinus in five patients but was localized in three of the eight patients.

In six patients, the shunt points were approached using 3D roadmap function during the procedure. The 3D images of the affected sinus and bones were projected onto the fluoroscopic images in four and two patients, respectively. In all six patients, the 3D images automatically tracked in the fluoroscopic images with changes in the fluoroscopic angle. In patients who underwent the procedure under local anesthesia, since blurring of the image due to body movements was also automatically corrected, the number of imaging sessions could be markedly reduced. Target embolization rather than embolization of the entire affected venous sinus was possible in three patients in whom the shunt point was localized.

In the 12 procedures, the mean procedure time was 300 minutes, the mean volume of the contrast agent used was 203.9 mL, and the mean dose of radiation was 3133 mGy. Two representative cases are presented.

### Case 1

A 58-year-old man noted congestion of the left eye about 1 month before his visit to a local ophthalmologist. Since the condition did not respond to treatment, he consulted the neurosurgery department of a local hospital and underwent MRI. As dilation of the left superior ophthalmic vein was detected, he was referred to our hospital. Angiography revealed a dural AVF with influx from the meningohypophyseal trunk of the right internal carotid artery and middle meningeal artery, accessory meningeal artery, and artery of foramen rotundum of the left external carotid artery into the left cavernous sinus. The left superior ophthalmic vein, which ran anteriorly from the left cavernous sinus, was the only outflow vessel, and no drainage to the bilateral IPS was observed (Fig. 1A).
A 6F shuttle sheath (Cook Medical, Bloomington, IN, USA) was placed in the left internal jugular vein. At this point, Xper CT data obtained by bone window settings were 3D reconstructed, a 3D roadmap was prepared using the jugular foramen and petro-occipital fissure as landmarks of the IPS, and a 4F Cerulean G catheter (Tokai Medical, Aichi, Japan) and a Headway 17 microcatheter (Microvention Terumo, Tustin, CA, USA) were guided to the left IPS (Fig. 1B). Since the IPS was markedly organized, the devices were advanced to the posterior half of the left cavernous sinus via the basilar plexus. Since the shunt point was localized at the posterior end of the cavernous sinus, the microcatheter was temporarily turned from the posterior to the anterior half of the cavernous sinus, reversed there, and inserted to the shunt point located at the posterior end. By HRCT scans obtained while injecting a three-fold dilution of the contrast agent from the external carotid artery, the microcatheter was confirmed to be placed at the shunt point, and this site was selectively embolized using a total of nine coils, resulting in obliteration of the shunt (Figs. 1C, 1D, and 1E). Congestion of the left eye was resolved 1 week after the procedure.

**Case 2**

A 60-year-old man was emergently transported to our hospital due to seizure and disturbance of consciousness. MRI T2-weighed imaging showed hyperintensity in the left temporal lobe, and MRA showed abnormal signals in the left transverse sinus. Angiography demonstrated a dural AVF with influx from the left occipital artery mastoid branch and left middle meningeal artery into the left transverse sinus (Fig. 2A). The left transverse sinus was an isolated sinus both ends of which were occluded on the cardiac and confluence sides and showed reflux into cortical veins of the left temporal lobe, occipital lobe, and cerebellum. By HRCT scans obtained by selective injection of a diluted contrast agent via the left occipital artery, the shunt point was found to be localized at the cardiac end of the isolated sinus (Fig. 2B).

A 6F shuttle sheath was inserted into the right internal jugular vein, and a 4F Cerulean G was guided to a point near the confluence as an intermediate catheter. A 3D roadmap was prepared from the 3D DSA images of the isolated sinus obtained by contrasting from the left occipital artery, and an Echelon 10 microcatheter (Medtronic, Irvine, CA, USA) was advanced toward the end of the isolated sinus on the confluence side. Since the wall of the isolated sinus was hard and could not be penetrated with a usual microwire,
the septum was pierced with a Treasure XS12 wire for penetration of chronic arterial occlusion (Asahi Intecc, Aichi, Japan), and access to the interior of the isolated sinus could be obtained. The microcatheter was guided to the cardiac end of the isolated sinus, coils were inserted from this site, and the shunt point alone was embolized using a total of 11 coils without embolizing the cortical veins, resulting in obliteration of the dural AVF (Figs. 2C and 2D).

**Discussion**

In all, 12 procedures of TVE were performed in 8 patients with dural AVF using cone-beam CT and 3D roadmap function. HRCT using a three-fold dilution of the contrast agent and 3D roadmap function were very useful for accurately identifying the shunt point and reducing the amount of the contrast agent used and radiation exposure.

Identification of the shunt point is the most important factor for successful TVE of dural AVFs. MRI is the first modality used for the diagnosis of dural AVF. Particularly, original MRA images, which delineate the affected sinuses receiving the shunt flow as high signal intensity regions, are of diagnostic value. However, MRA has limitations: its ability for the identification of the shunt point is limited due to insufficiency of spatial resolution, and visualization of the affected venous sinus is difficult if the shunt flow is slow. Therefore, angiography is still considered the golden standard for the examination of dural AVF. However, while angiography was performed for the identification of the shunt point using techniques such as stereoscopic imaging, selective arteriography, and 3D DSA, the relationship of the lesion with surrounding tissues, such as the cranium and dura mater, was occasionally difficult to evaluate as the modality basically visualizes blood vessels alone. Recently, angiographic systems have entered an era of the flat panel detector from the conventional image intensifier, and their usefulness has been enhanced as the technique called cone-beam CT, which provides CT-like images using an angiographic system, has become available in addition to usual imaging. By the angiographic system used in this study, we performed scanning for 20 seconds with contrast enhancement using two-fold or three-fold dilution of the contrast agent and sent the data.
of TVE, angiography is performed via a catheter placed in the feeding vessel, roadmap images are prepared from the angiographic data, and the microcatheter is advanced while superimposing the roadmap images on the fluoroscopic image, by acquiring a new roadmap image each time the direction of fluoroscopy is changed. This is expected to result in increases in the number of imaging sessions and the amount of the contrast agent used. In addition, in endovascular treatment under local anesthesia, contrast-enhanced angiography becomes necessary with each body movement that may occur with prolongation of the procedure.

With the 3D roadmap function used in this study, changes in the direction of fluoroscopic image associated with intra-procedural manipulation of the C-Arm are simultaneously tracked by the 3D image, making re-preparation of the roadmap at each change in the direction of fluoroscopic image unnecessary and reductions in the radiation dose and obtained to a 3D workstation for 3D image reconstitution. By observing serial thin-slice cross sections from three directions on the 3D workstation, the site of connection of the feeding artery and the shunt point could be identified as a point of change in the density of the contrast agent.

HRCT is considered to be particularly useful for the identification of the shunt point of dural AVF, and there have been some reports to this effect.1–3) Hiu et al. evaluated 14 consecutive cases and reported that the shunt points that could not be identified by conventional angiography could be determined by cone-beam CT in seven patients.2) Aadland et al. reported a series of 14 cases of spinal dural AVF and the usefulness of cone-beam CT for the evaluation of the shunt point and relationships with surrounding tissues.3) After the identification of the shunt point, the next matter of importance is how fast and safely the microcatheter can be guided to the shunt point. In the conventional procedure of TVE, angiography is performed via a catheter placed in the feeding vessel, roadmap images are prepared from the angiographic data, and the microcatheter is advanced while superimposing the roadmap images on the fluoroscopic image, by acquiring a new roadmap image each time the direction of fluoroscopy is changed. This is expected to result in increases in the number of imaging sessions and the amount of the contrast agent used. In addition, in endovascular treatment under local anesthesia, contrast-enhanced angiography becomes necessary with each body movement that may occur with prolongation of the procedure.

With the 3D roadmap function used in this study, changes in the direction of fluoroscopic image associated with intra-procedural manipulation of the C-Arm are simultaneously tracked by the 3D image, making re-preparation of the roadmap at each change in the direction of fluoroscopic image unnecessary and reductions in the radiation dose and
the amount of use of the contrast agent possible. Instances of the use of 3D roadmap function for the treatment of cerebral aneurysms and cervical internal carotid artery stenosis have been reported.\(^4,5\) Not only 3D DSA images, but also MRA images have been used for 3D roadmapping, which resulted in virtual elimination of the use of a contrast agent for the procedure. In our series, 3D DSA images of the affected venous sinus were used in four patients, and 3D reconstituted images of bones by cone-beam CT were used in two patients. Since the affected venous sinuses could be visualized by MRA in the first four patients, the use of MRA images is also considered to have been sufficiently possible.

Limitations of 3D roadmap function include the image-tracking performance in body movements and displacement of blood vessels associated with manipulations including catheter insertion. In this study, shifts of images due to body movements were automatically corrected, and manual image correction was unnecessary, in the patients who received the procedure under local anesthesia. Exact correction may have been unnecessary in this study because the procedure was performed for relatively large lesions at sites such as the affected venous sinus and IPS. Since 3D roadmap function 3D matches the fluoroscopic and 3D image information about bones, theoretically, it can sufficiently cope with horizontal, vertical, and rotational body movements. However, when we applied this function to patients undergoing acute revascularization procedures, we had the impression that automatic correction was impossible in the event of large body movements such as those observed during restlessness. Since the accuracy of matching declines due to the lack of fluoroscopic information about bones during large body movements, the procedure is considered to be performed more safely in relatively cooperative patients under local anesthesia and in lesions with a fair size. In addition, 3D roadmap images of intracranial vessels and arteries not fixed to bone tissue, such as the cervical blood vessels, may largely deviate from their true positions by wire or guiding catheter placement. However, vascular displacement posed no problem in our series because the affected sinus is nearly immobilized by bone and dural tissues in TVE for dural AVFs.

The next limitation is that the exposure dose in cone-beam CT is relatively high. By the method described here, in particular, 3D DSA for the delineation of the approach for TVE was necessary in addition to HRCT for the determination of the shunt point. According to our dosimetry, one session of HRCT involved an exposure of 128.68 mGy. However, since 13-inch single-plane fluoroscopy involves an exposure of 5.5 mGy/min, one session of HRCT corresponds to about 23 minutes of single-plane fluoroscopy. This appears a considerable dose, but, in consideration of the situation before the introduction of this technique, that is, multiple sessions with frequent fluoroscopy were necessary to identify the shunt point, and, in addition, sinus packing that requires prolonged exposure was performed if the shunt point could not be exactly identified, the exposure by HRCT, which provides a large amount of information in one session, is considered acceptable. In our series, the mean dose was about 3 Gy, which is considered to be low for the relatively long mean duration of the procedure (300 minutes).

**Conclusion**

In conventional TVE for dural AVF, frequent radiography from multiple directions used to be necessary to identify and approach the shunt point, but the amount of use of the contrast agent and radiation exposure could be reduced by the use of new functions of the angiographic system. In addition, confirmation of the arrival of the microcatheter at the shunt point has been facilitated, and target embolization has become possible in patients with localized shunt points.

**Disclosure Statement**

The first author and coauthors have no conflicts of interest.

**References**


