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Interactive spinal computed tomography angiography–guided spinal digital subtraction angiography and embolization for thoracolumbar epidural arteriovenous fistulas: illustrative case

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BACKGROUND Spinal digital subtraction angiography (sDSA) is the gold standard for examining spinal arteriovenous fistulas; however, thorough sDSA evaluations of spinal arteriovenous fistulas require a long procedure, which may increase the radiation exposure time.

OBSERVATIONS A 72-year-old man presented with progressive myelopathy due to a spinal epidural arteriovenous fistula. Spinal computed tomography angiography (sCTA) showed an epidural arteriovenous fistula fed by the left L3 segmental artery. To prepare for sDSA, the sCTA images were modified to mark the segmental artery bifurcations from T5 to L5 with multicolored markers. These modified sCTA images were loaded onto the multiwindow DSA display. The sCTA images were interactively modulated during sDSA. This sCTA-guided sDSA identified 18 segmental arteries within 47 minutes. The total radiation exposure was 1,292 mGy. Subsequently, transarterial embolization resolved the epidural arteriovenous fistula with clinical improvement.

LESSONS Three-dimensional sCTA can provide detailed anatomical information before sDSA. Modified sCTA images with segmental artery bifurcation marking can provide interactive guidance on multipanel DSA displays. sCTA-guided sDSA is useful for accurate catheterization and reduction of procedure time.

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KEYWORDS computed tomography angiography; digital subtraction angiography; spinal epidural arteriovenous fistula

Spinal epidural arteriovenous fistulas and rare arteriovenous shunts are observed in the thoracolumbar region, and they manifest as back pain, progressive radiculopathy, and myelopathy.[1] Surgical treatments for spinal epidural arteriovenous fistulas include direct surgery interrupting drainage veins, endovascular embolization of arteriovenous shunts, and a combination of direct surgery and endovascular mbolization.[1] Preoperative examinations include gadolinium-enhanced magnetic resonance imaging (MRI), spinal computed tomography angiography (sCTA), and spinal digital subtraction angiography (sDSA).[2–5] sDSA is the gold standard for evaluating spinal epidural arteriovenous fistulas,[6] and it can identify feeding arteries, which are often bilateral and multilevel.[1,3,7,8] However, thorough angiographic evaluation of the bilateral multilevel spinal segmental arteries increases procedure time and radiation exposure dose. Here, we present a technical note on sCTA image-guided sDSA. Composited sCTA images on a multiwindow DSA display can facilitate the angiographic procedure. We present a case of spinal epidural arteriovenous fistula treated using sCTA image-guided sDSA technique.

Illustrative Case

History and Examination

A 72-year-old man presented with bilateral toe numbness lasting for more than a year and reduced walking ability. The patient also had bowel and bladder incontinence and impotence. Thoracic and lumbar MRI revealed thoracolumbar spinal cord edema and multiple vascular

ABBREVIATIONS 3D = three-dimensional; MRI = magnetic resonance imaging; sCTA = spinal computed tomography angiography; sDSA = spinal digital subtraction angiography.

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flow void signs (Fig. 1). sCTA was performed for further evaluation of the arteriovenous shunt. Subsequently, sDSA was performed.

Spinal CTA-guided Spinal DSA

Three-dimensional (3D) sCTA imaging data were transferred to a medical imaging workstation (Synapse Vincent, Fujifilm). sCTA revealed a spinal epidural arteriovenous fistula fed by the left L3 segmental artery. Vascular images of the T5–L5 segmental arteries and spinal dural arteriovenous fistulas were also reconstructed after bone subtraction. Subsequently, colored dot signs were placed at the bifurcation of the segmental artery from T5 to L5. The main feeder to the spinal epidural arteriovenous fistula was the peripheral branch of the left L3 segmental artery (Fig. 2). This dot-marked 3D sCTA imaging data were transferred to a workstation for sDSA (Azurion, Philips). Dot-marked sCTA images were observed on the multiwindow DSA display. The angles of the sCTA images were adjusted along with that of the sDSA. The dot signs of sCTA guided catheter introduction for 18 bifurcations of the right T8–L3 and left T7–L4 segmental arteries. The Adamkiewicz artery, which was not revealed on CTA, was identified with selection of the right T11 segmental artery (Fig. 2 and Video 1). The right L2 and left L2 and L3 segmental arteries were fed into the epidural arteriovenous fistula (Fig. 3). The total dose area product was 355.754 Gy/m^2, and the exposure cumulative dose area product was 283.387 Gy/m^2. The number of exposure series and images, including rotational DSA of two segmental arteries and a single series of cone-beam CT, were 47 and 1,933, respectively. The total fluoroscopy time was 46 minutes 7 seconds. The fluoroscopy cumulative dose-area product was 72.367 Gy/m^2. The total air kerma dose was 1,292 mGy. The volume of contrast material was 190 mL.

FIG. 1. Preoperative radiological images. **A:** Sagittal short tau inversion recovery MRI sequence shows spinal cord edema from the T6 to T12 level. The conus medullaris is also edematous. Multiple flow voids are identified. **B:** Sagittal CTA image shows vascular enhancement on the ventral and dorsal surface of the thoracolumbar spinal cord.

VIDEO 1. Clip showing that spinal computed tomography angiography images were used as a guidance during spinal digital subtraction angiography. Click here to view.

Six days after the sDSA, transarterial embolization of the spinal epidural arteriovenous fistula was performed. As an intraoperative guide, preoperative rotational sDSA images related to the epidural spinal arteriovenous fistula were merged with the dot-marked 3D sCTA. A 5-Fr, 55-cm Flexor Ansel guiding sheath was inserted into the right femoral artery. The left L3 segmental artery was selected using a 4-Fr C2 Cobra catheter (Terumo Clinical Supply Co., Ltd). A TACTICS microcatheter (Technocrat Corporation) was guided to the segmental artery with a 0.025-Fr, 260-cm Radifocus guidewire (Terumo Corporation). A DeFrictor Nano catheter (Medico's Hirata Inc.) was introduced just before the shunting point through the left L3 dorsal segmental artery using an ASAHI CHIKAI 10 (Asahi Intecc Co., Ltd.). We validated the selection of the dural arteriovenous shunt, and the rotational sDSA image demonstrated no arterial feeding to the spinal cord. The venous pouch was filled with 0.5 mL of 20% n-butyl-2-cyanoacrylate. There were no ischemic, hemorrhagic, or neurological complications associated with the procedure. The sensory disturbances and motor weakness of the lower extremities improved. MRI 3 months after the endovascular surgery revealed resolution of flow voids and spinal cord edema (Fig. 4).

Discussion

Observations

Thoracolumbar epidural arteriovenous fistulas are fed by bilateral and multiple segmental arteries.[1,7,9] Thus, a preoperative detailed vascular anatomical examination is essential to treat complex and difficult arteriovenous fistulas.sDSA is the gold standard for evaluating thoracolumbar epidural arteriovenous fistulas;[1,4,7,9] however, thorough examinations of thoracolumbar arteriovenous fistulas using sDSA require individual catheterization of multiple segmental arteries.[10] Furthermore, fluoroscopy time, radiation exposure, and amount of contrast agent are often increased.[11] Aortography can be helpful in decreasing fluoroscopy time, radiation exposure, and amount of contrast agent because segmental arteries can be detected using aortography.[12] However, aortography should be repeated for the upper thoracic lesion and the sacral lesion. Paradoxically, radiation exposure and the amount of contrast agent required can increase consequently. Hypoplasia or arteriosclerosis of the segmental artery and a common bifurcation of the bilateral segmental arteries may not be completely identified on two-dimensional aortography images alone.

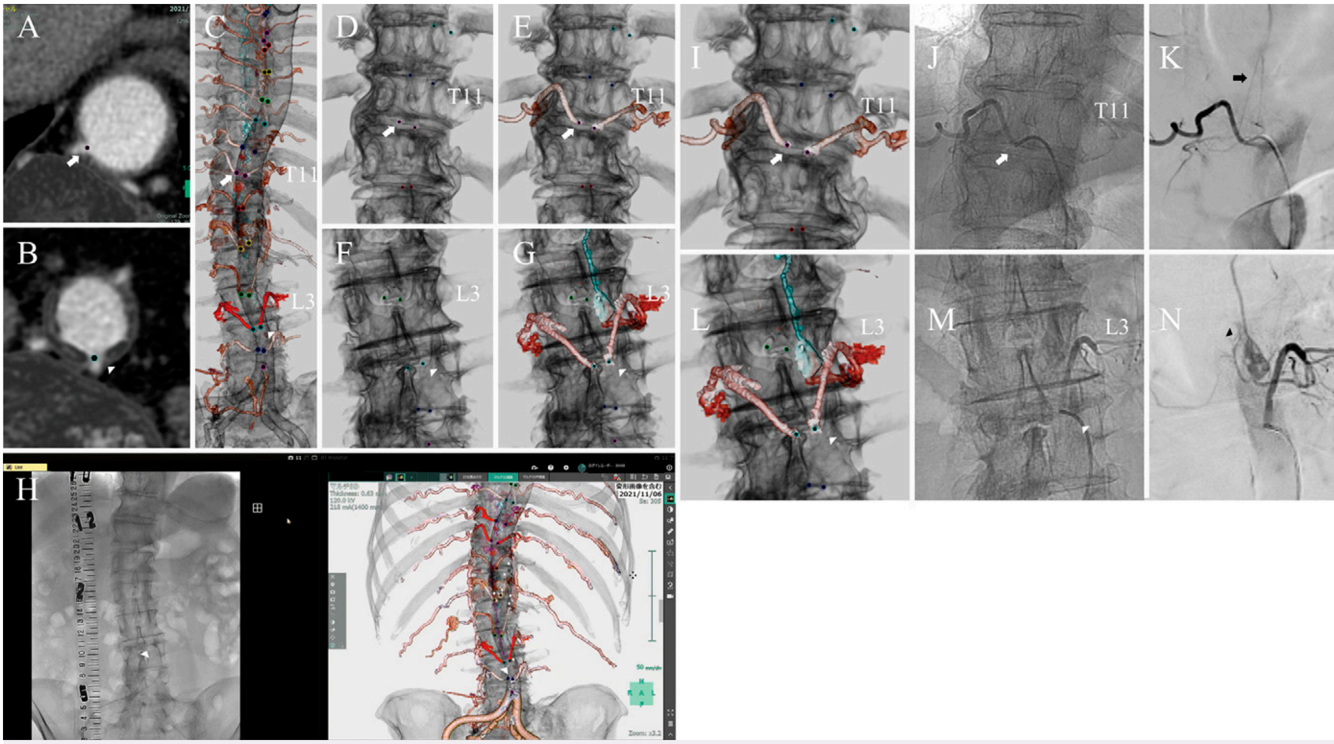

FIG. 2. Preoperative preparation using CTA and sDSA images in representative segmental arteries. *White arrows* indicate the bifurcation of the right T11 segmental artery; *white arrowheads*, the left L3 segmental artery; *black arrow*, artery of Adamkiewicz; *black arrowhead*, epidural arteriovenous fistula. The bifurcation of the segmental arteries from the aorta is marked on axial CTA images **(A and B)**. **C:** The markers for bifurcations are merged with vascular and spine images. The markers and segmental arteries are shown in different colors. **D and E:** The pointed bifurcation and structure of the right T11 radicular artery are fused with the vertebral structures. **F and G:** The feeder and drainer of the spinal epidural arteriovenous fistula were reconstructed and fused, respectively. The same method was applied to all segmental arteries. Fusion and intraprocedural images. **H:** The sDSA was performed, referring to the fusion image. **I–K:** The intraprocedural and fusion images were shown on the screen. sDSA shows canulation and angiography of the right T11 segmental artery. The right T11 segmental artery was selected based on the fusion image and the bony structure. The artery of Adamkiewicz branches from the right T11 radicular artery. **L–N:** sDSA showing canulation and angiography of the left L3 segmental artery. The left L3 segmental artery was selected based on the fusion image. An epidural spinal arteriovenous fistula was also identified. The same method was applied to all segmental arteries.

The use of sDSA to diagnose a spinal arteriovenous fistula was described in pediatric and adult cases;[13–16] thus, combined radiological diagnostic modalities with sDSA, such as CTA, 3D rotational angiography, and magnetic resonance angiography, have been reported (Table 1).[4,13–19] Although a possible reduction of radiation exposure in sDSA using an assistant radiological modality preceding sDSA was mentioned in previous reports, they did not describe the detailed information related to radiation exposure in sDSA such as Air Kerma and dose-area product (total, DSA, and fluoro). Only in the report by Guatam et al. was the radiation exposure dosage in pediatric cases described.[4,14,17–19]

Unlike the techniques mentioned above, we used sCTA images as an intraprocedural guide to effectively and easily detect bifurcations of the segmental arteries. The pre-sDSA requirements are simple: bifurcations of the segmental arteries are marked with different colored dots on the axial images of the sCTA. The dots and vascular bifurcation images are then fused with the translucent spine images of the sCTA images. During sDSA, the bifurcation-dotted sCTA images can be merged from the perspective images of sDSA. A bifurcation-dotted mark on the sCTA artery and spine image can guide catheter introduction into the preferred segmental artery for performing sDSA effectively.

The spinal level of multiple segment arteries is discriminated using different colored dots for easy recognition by the examiners. This simple and novel sCTA-guided sDSA can be beneficial for both patients and physicians. For patients, the accuracy of sCTA guidance can minimize sDSA procedure time, radiation exposure dose, and total amount of contrast agent. Intraarterial aortography can be omitted because merged sCTA images can guide the location of the arterial bifurcation. For physicians, sCTA can reveal the anatomy of the aorta and segmental artery prior to sDSA, such as the pathway of the aorta, location of the segmental artery bifurcations, and stenosis and/or common bifurcation of the segmental arteries. The physician can also examine the anatomical relationship between the dotted bifurcation and spinal architectures, such as pedicles, vertebral bodies, and vertebral endplates, which is useful for accurately canulating a catheter to the bifurcation.

This technical case report is limited to a single case, and it does not involve a group comparison or prospective analysis. The usefulness of this method should be evaluated in future studies. Additionally, because an application that can simultaneously merge sDSA images with bifurcation-dotted sCTA images during sDSA procedure is not available at our institute, we did not evaluate the usefulness of the intraprocedural fusion of the sDSA and bifurcation-dotted sCTA images; that requires further research. It should also be evaluated whether our method of using sCTA images as intraprocedural guide in sDSA can reduce radiation exposure.

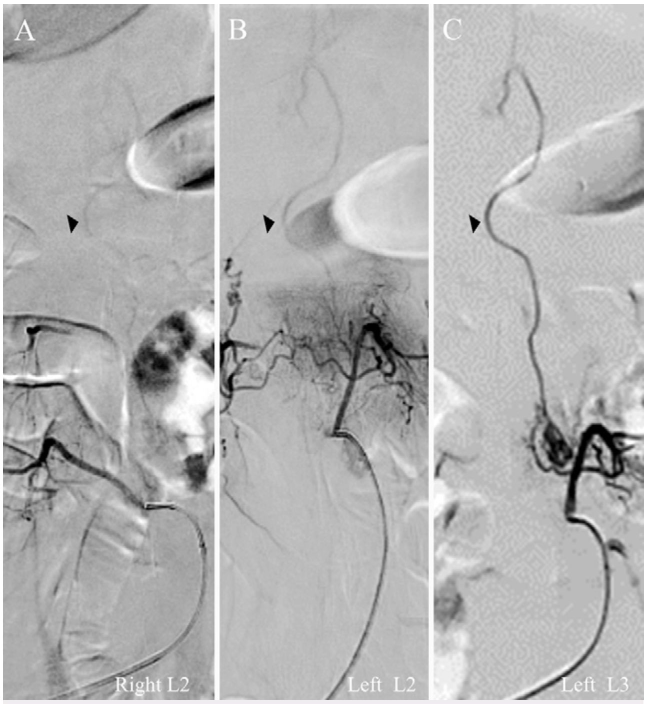

FIG. 3. The epidural arteriovenous fistula is fed by the right L2 (**A**) and left L2 (**B**) and L3 (**C**) segmental arteries and is drained into the radiculomedullary vein (*black arrowheads*).

In conclusion, three-dimensional sCTA can provide detailed anatomical information before sDSA. Modified sCTA images with segmental artery bifurcation marking can provide interactive guidance on multipanel DSA displays. sCTA-guided sDSA is useful for accurate catheterization and reduction in duration of the procedure.

Lessons

3D sCTA can provide detailed anatomical information prior to sDSA. Modified sCTA images with segmental artery bifurcation marking can be performed through interactive guidance on the multipanel DSA display. sCTA-guided sDSA is useful for accurate catheterization and reduction in duration of the procedure.

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FIG. 4. Postoperative radiological images. **A:** Sagittal short tau inversion recovery MRI sequence shows that the flow voids resolved and spinal cord edema decreased. **B:** Sagittal CTA image shows that vascular enhancement on the ventral and dorsal surface of the thoracolumbar spinal cord disappeared.

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TABLE 1. Summary of the diagnostic modalities combined with sDSA for spinal arteriovenous fistulae

Authors & Year	Diagnostic Modality	No. of Pts	Air Kerma in Gy (range)	DAP Total in Gy·cm^2 (range)	DAP DSA in Gy·cm^2 (range)	DAP Fluoro in Gy·cm^2 (range)
sDSA only						
Ropper et al., 2012[13]	sDSA only	29	2.96 ± 1.94 (0.72–6.43)	372.7 ± 267.8 (65.9–808.0)	NA	NA
Gautam et al., 2021[14]	sDSA only	24 (ped)	0.1869 (0.022–0.6098)	1188.8 (65.2–9130.6)	736.9 (42.5–2118.9)	96.5 (9.3–364.9)
Varghese et al., 2019[15]	sDSA only	7	1.4 (0.5–2.7)	186.7 (44.0–377.5)	NA	NA
Opitz et al., 2022[16]		58	N	299.55	NA	NA
MRA assist						
Saindane et al., 2015[17]	CE-TR MRA (+) sDSA	6	NA	NA	NA	NA
Luetmer et al., 2005[18]	MRA-localized AVF	13	NA	NA	NA	NA
CTA assist						
Yamaguchi et al., 2010[19]	IV CTA + sDSA	10	NA	NA	NA	NA
Yamaguchi et al., 2017[4]	4D IV CTA + sDSA	10	NA	NA	NA	NA
3DRA assist						
Ropper et al., 2012[13]	sDSA + 3DRA	8	3.44 ± 2.45 (0.55–6.75)	409.5 ± 318.6 (60.9–932.0)	NA	NA
CTA guided						
Current case	IV CTA + sDSA + 3DRA	1	1.292	355.754	283.387	72.367

3DRA = three-dimensional rotational angiography; AVF = arteriovenous fistula; CE-TR = contrast-enhanced time-resolved; DAP = dose-area product; IV = intravenous; MRA = magnetic resonance angiography; NA = not available; ped = pediatric; Pts = patients.

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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: Hashikata, Ishibashi. Acquisition of data: Hashikata. Analysis and interpretation of data: Hashikata, Maki. Drafting the article: Maki, Toda. Critically revising the article: Hashikata, Ishibashi, Toda. Reviewed submitted version of manuscript: Hashikata, Toda. Approved the final version of the manuscript on behalf of all authors: Hashikata. Study supervision: Toda.

Supplemental Information

Video

Video 1. https://vimeo.com/739648064.

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