Type 1 Perimedullary Arteriovenous Fistula with Subarachnoid Hemorrhage: Utility of Contrast-enhanced 3D Gradient-echo Technique

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Purpose: In patients with perimedullary arteriovenous fistula (AVF) with subarachnoid hemorrhage (SAH), knowledge of lesion location is necessary to select the appropriate approach for catheter spinal angiography. We evaluated the utility of 3-dimensional (3D) fast imaging with steady-state precession (FISP) sequence for detecting type 1 perimedullary AVF with SAH.

Materials and Methods: We evaluated 4 patients (2 men, 2 women, aged 53 to 68 years, mean age, 59.25 years) with type 1 perimedullary AVF who presented with SAH and underwent conventional spin-echo MR and contrast-enhanced 3D FISP imaging. Two neuroradiologists assessed detection of vascular lesions and delineation of their relationships to the adjacent vessels. Catheter angiography was used as the reference standard and compared with the MR findings.

Results: Perimedullary AVF was located at the medullocervical junction in 2 patients, cervical spine in one, and thoracic spine in one. For all patients, use of contrast-enhanced 3D FISP in addition to conventional MR imaging improved lesion detection and delineation of the relationship between the lesion and surrounding vessels.

Conclusion: Contrast-enhanced 3D FISP imaging was useful for detecting and delineating type 1 perimedullary AVF with SAH.

Keywords: 3D GRE imaging, MRI, Spinal AVM

Introduction

Perimedullary arteriovenous fistula (AVF) is a relatively rare form (8 to 19\%) of spinal arteriovenous malformation (AVM),\textsuperscript{1,2} most commonly affects the conus medullaris or cauda equina,\textsuperscript{3-5} and has been reported at the brain stem, medullocervical junction, and cervical or thoracic levels of the spine.\textsuperscript{5-8} Irrespective of location, perimedullary AVFs present with either chronic, insidious, progressive myelopathy or sudden, catastrophic, subarachnoid or intramedullary hemorrhage.\textsuperscript{5,9,10} Perimedullary AVF with subarachnoid hemorrhage (SAH) is a rare but acute clinical condition that requires prompt management with critical care.\textsuperscript{5}

Although conventional angiography is widely accepted for evaluating SAH, previous studies have reported failure of initial 4-vessel cerebral angiography to demonstrate cause of SAH in approximately 15\% of patients,\textsuperscript{11,12} and spinal AVM was found to be one of several causes of angiographically negative SAH.\textsuperscript{11} Patients with uncommon vascular lesions with accompanying SAH usually undergo magnetic resonance (MR) angiography, computed tomographic (CT) angiography, and MR imaging of the brain and spine to detect the cause of SAH, but detecting the causative vascular lesion using these noninvasive techniques may be limited.\textsuperscript{13} Catheter spinal angiography remains the gold standard, but it is invasive and associated with extensive catheter manipulation, high radiation...
doses, and large volumes of iodinated contrast material.\textsuperscript{14–17}

Time-resolved contrast-enhanced MR angiography and MR digital subtraction angiography have been reported useful for evaluating the hemodynamic information of AVM and AVF of the spine, but their range of cranio-caudal field of view (FOV) is limited.\textsuperscript{14–17} Therefore, their utility may be restricted if lesion location is not suspected.

Contrast-enhanced 3-dimensional (3D) gradient-echo (GRE) imaging using 3D fast imaging with steady-state precession (FISP) sequence has been reported useful in evaluating organic lesions of the spine.\textsuperscript{18} The large cranio-caudal FOV of 3D GRE imaging permits screening of the entire spine with high spatial resolution.\textsuperscript{18} To our knowledge, this technique has not been systematically investigated for detecting perimedullary AVF. Therefore, we evaluated the usefulness of contrast-enhanced 3D FISP for detecting and depicting perimedullary AVF with SAH.

Materials and Methods

We evaluated 4 consecutive patients (2 men, 2 women; aged 53 to 68 years, mean, 59.25 years) with perimedullary AVF accompanied by SAH who underwent conventional MR and post-contrast 3D FISP imaging of the spine as part of their clinical evaluation before referral for spinal angiography. SAH was located at the spinal to posterior fossa subarachnoid space in three and posterior fossa subarachnoid space in one.

All patients underwent catheter angiography after MR imaging, and spinal perimedullary AVFs were determined according to Merland’s classification.\textsuperscript{19} All lesions were confirmed by surgery. Our institutional review board approved this retrospective study, and all patients or their relatives gave written informed consent prior to MR examination.

**MR imaging protocol**

MR examinations were performed with a 1.5-tesla superconducting unit (Magnetom Vision; Siemens, Erlangen, Germany) using a circular polar phased-array spinal coil. For spinal screening, we performed T\textsubscript{1}-weighted (repetition time [TR], 500 ms; echo time [TE], 12 ms; number of excitation [NEX], one) spin-echo, T\textsubscript{2}-weighted (TR, 3500 ms; effective [TE\textsubscript{eff}], 96 ms; NEX, one) fast spin-echo, contrast-enhanced T\textsubscript{1}-weighted, and 3D FISP imaging within the sagittal plane. All sagittal images were acquired with a rectangular FOV to obtain finer spatial resolution in the phase-encoding direction. The spin-echo images were obtained with 3-mm thickness and 0.3-mm intersection gap. The parameters for the 3D FISP sequence were: TR, 35 ms; TE, 6 ms; one excitation; 1.0-mm section thickness; and 70° flip angle. Image acquisition time of 3D FISP sequences was 6 min 34 s.

All sequences used an FOV of 20×50 cm and matrices of 192 to 256×512. We obtained T\textsubscript{1}-weighted spin-echo and 3D FISP sequences after intravenous injection of gadopentetate dimeglumine (0.1 mmol/kg of body weight). Reconstruction of 3D GRE images with a multiplanar reconstruction (MPR) technique yielded images in all 3 orthogonal planes.

**Catheter angiography**

Experienced radiologists performed catheter digital subtraction angiography (DSA) using a 1024×1024 matrix with a biplane DSA unit. All catheterizations were performed via a transfemoral approach using the Seldinger technique, and angiography was routinely accomplished with a standard diagnostic catheter. For spinal angiography, selec-

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**Table.** Summary of image assessments with conventional MR imaging and contrast-enhanced 3D gradient echo imaging

<table>
<thead>
<tr>
<th>Case/ Age (year)/ Sex</th>
<th>Location of the lesion</th>
<th>Feeders</th>
<th>Detection of the lesion*</th>
<th>Relationship to surrounding vessels*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>CMRI</td>
<td>CEGRE</td>
</tr>
<tr>
<td>1/68/M</td>
<td>Medullo-cervical junction</td>
<td>Branches from VA</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>2/53/M</td>
<td>Medullo-cervical junction</td>
<td>Branches from VA</td>
<td>±</td>
<td>++</td>
</tr>
<tr>
<td>3/56/F</td>
<td>Cervical spine</td>
<td>Branches from VA</td>
<td>–</td>
<td>++</td>
</tr>
<tr>
<td>4/60/F</td>
<td>Thoracic spine</td>
<td>PSA from RMA</td>
<td>+</td>
<td>++</td>
</tr>
</tbody>
</table>

Fig. 1. A 56-year-old woman (Case 3) with type 1 perimedullary arteriovenous fistula (AVF) of the cervical spine. (A) T2- and (B) T1-weighted images show a small area of flow void (arrow) anterior to the spinal cord at the C1 level. However, it is not clear whether it is an abnormal vessel. Detection and delineation of lesions were ranked poor. (C) Contrast-enhanced 3-dimensional (3D) fast imaging with steady-state precession (FISP) image reveals abnormal enhanced vessels (arrow) extending from the left vertebral artery (arrowhead). Detection and delineation of lesions were ranked excellent. (D) Left vertebral angiogram shows abnormal vessels (arrow) derived from the left vertebral artery. This lesion was confirmed by surgery and diagnosed as type 1 perimedullary AVF.

Discussion

Perimedullary AVFs are rare vascular malformations that can be categorized into 3 subtypes by diameter, flow magnitude, and number of feeding and draining vessels. Type I have small diameter, slow flow, and single fistulous communications, usually between the anterior spinal artery and moderately enlarged perimedullary veins; type II have intermediate size and flow velocity and generally more than one feeder, usually including a dilated anterior spinal artery and perhaps including one or 2 posterior spinal arteries; type III are giant lesions with typically high flow and high pressure shunts and a markedly enlarged venous drainage system. This subdivision is important because...
Spinal angiography and MR imaging are now most commonly used to identify perimedullary AVFs, but our results indicate that it is often difficult to identify exact lesion location with conventional MR imaging because residual SAH may be misleading as the causative lesion site on conventional imaging.

We found that findings of contrast-enhanced 3D FISP sequence were useful supplements to findings of conventional spin-echo MR imaging. Although we did not obtain accurate characterization of the feeder, fistula site, and draining vessel of the perimedullary AVF, use of contrast-enhanced 3D FISP images improved lesion detection and delineation of lesion relationship with adjacent vessels. These results indicate the usefulness of 3D FISP sequences for detecting and delineating type I perimedullary AVF with SAH. We believe the advantages of the 3D FISP sequences, including high contrast, high spatial resolution, multiplanar capability, suppression of fat signal, and depiction of the continuity of vascular structures, influenced our study results.

Our study was limited by the relatively long acquisition time and lower contrast between enhanced structure and adjacent nonenhancing brain and spinal structures using the 3D FISP sequence, but this may be overcome by using an MR unit with higher magnetic field, such as 3T. In addition, susceptibility artifacts may degrade images more severely with 3D FISP sequences, although we did not observe such artifacts in this series. Finally, our patient population was small.

Conclusions

In conclusion, contrast-enhanced 3D FISP sequence was useful for detecting type I perimedullary AVF with SAH, enabled screening of the entire spine with high spatial resolution, and was much better than conventional MR imaging for lesion detection and delineating lesion relationship to surrounding vessels.

References


