Usefulness of 3D DSA-MR Fusion Imaging in the Pretreatment Evaluation of Brain Arteriovenous Malformations

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Rationale and Objectives: For the evaluation of patients scheduled for the treatment of brain arteriovenous malformations (AVMs), accurate anatomical information is essential. The purpose of this study was to assess the usefulness of three-dimensional (3D) digital subtraction angiography (DSA)-magnetic resonance (MR) fusion imaging for the pretreatment evaluation of AVMs.

Materials and Methods: The study population consisted of 11 consecutive patients (7 males, 4 females; age 10–72 years; mean 45 years) with brain AVMs. All prospectively underwent pretreatment MR imaging (MRI), MR angiography (MRA), and two-dimensional (2D) and 3D DSA. The 3D DSA and MR images were semiautomatically fused with fusion software on a workstation. In the delineation of AVM nidus, feeder, drainer, and relationship between AVM and the adjacent brain structures, two radiologists independently evaluated MRA and MRI, three-dimensional (3D) DSA, and MRI, and 3D DSA-MR fusion images using a 4-point scoring system. The referring neurosurgeons were asked whether the information provided by 3D DSA-MR fusion images was helpful for treatment decisions.

Results: For all four items, the delineation was significantly better with the 3D DSA/MRI or 3D DSA-MR fusion images than the MRA/MRI images. Although the delineation for the nidus, feeder, and drainer were not significantly different between the 3D DSA/MRI and 3D DSA-MR fusion images, 3D DSA-MR fusion imaging were significantly better for the relationship between AVM and the adjacent brain structures than 3D DSA/MR imaging ($P = .0047$). The information provided by 3D DSA-MR fusion images was helpful for treatment decisions in all cases.

Conclusion: 3D DSA-MR fusion images are useful for the pretreatment evaluation of brain AVMs.

Key Words: 3D DSA; MRI; fusion imaging; brain AVM.

At the pretreatment assessment of brain arteriovenous malformations (AVMs), the precise relationship between the nidus, feeders, and drainers and the adjacent hematoma and/or brain structures must be recognized. Intra-arterial two-dimensional (2D) digital subtraction angiography (DSA) is the standard reference procedure for the diagnosis and follow-up of brain AVMs because of its high temporal and spatial resolution (1,2). However, it does not provide three-dimensional (3D) information on the vasculature and adjacent brain tissues. On conventional magnetic resonance imaging (MRI) and MR angiography (MRA), including source and multiplanar reconstruction images, the intracranial vasculature and brain tissues are visualized; therefore, these techniques are valuable for the pretreatment and follow-up evaluation of brain AVMs (1–5).

Image fusion techniques consisting of the registration of different kinds of images are widely used for diagnostic purposes and pretreatment planning (6–8). The fusion of 3D DSA and MR images yields useful information on the vasculature (eg, perforating arteries, aneurysms) and brain tissues (9–11). Although it is expected to be useful for the evaluation of brain AVMs, the report regarding the utility of 3D DSA-MR fusion imaging in patients with brain AVMs is limited (12). The usefulness of this technique for the pretreatment evaluation of brain AVMs has not been systematically investigated. The purpose of this study was to

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systematically assess the usefulness of 3D DSA-MR fusion imaging in conjunction with 2D DSA for the pretreatment evaluation of brain AVMs.

MATERIALS AND METHODS

Subjects

In this prospective study, 3D DSA and MR images were fused in 11 consecutive patients with brain AVMs (7 males, 4 females; age 10–72 years; mean 45 years) as part of their pretreatment evaluation (Table 1). The AVM location included the frontal lobe (n = 3), frontoparietal region (n = 3), temporal lobe (n = 2), parietooccipital region (n = 2), and basal ganglia (n = 1). In 10 patients, AVM was the primary diagnosis; the other patient manifested residual AVMs postoperatively. The eloquent area of the brain was involved by AVM in 4 patients; 10 manifested parenchymal hemorrhage. After evaluation of the imaging results, 9 patients underwent surgical resection and 2 endovascular embolization. Prior written informed consent for MRI studies was obtained from all patients or relatives. Our study was approved by the institutional review board of our institution.

Based on the classification of the AVM nidus location proposed by Johnston and Johnston (13), a cerebral AVM was defined as deep when it was located more than 2 cm below the parenchymal surface. All AVM lesions involving the basal ganglia or thalamus were regarded as deep, with cerebral AVMs at other locations as superficial. If the AVM crossed the borderline between these sites, it was assigned to both locations. Consequently, seven AVMs were considered as deep, two as superficial, and three as located at two sites. According to the Spetzler-Martin classifications of cerebral AVM (14), the AVM lesions were also classified as follows: grade of I, 2 patients; II, 6 patients; III, 2 patients; IV, 1 patient.

2D and 3D DSA

All patients underwent 3D DSA in conjunction with 2D DSA under local anesthesia. After catheterization of the internal and vertebral arteries via the femoral artery approach, biplanar intra-arterial 2D DSA (Allura Xper FD; Philips Medical Systems, Best, the Netherlands) was performed by a trained neuroradiologist and/or a neurosurgeon. Images were obtained with a 2048 × 2048 matrix and a 17-cm field of view (FOV). The temporal resolution of the images was 3 frames/s. For each projection, we manually injected a 6- to 10-mL bolus of undiluted iodinated contrast material with an iodine concentration of 300 mg/mL (Iopamidol 300 mgI/mL, Iopamiron 300; Bayer-Schering, Berlin, Germany).

We performed 3D rotational angiography using a frontal C-arm mounted flat-panel detector system (Allura Xper FD; Philips Medical Systems). The parameters were: 4.1-second rotation, rotation angle 240° with 2° increments resulting in 120 projections, rotation speed 55°/s, acquisition matrix 1024 × 1024, and frame rate 30 frames/s. The volume and injection rate of the nonionic iodinated contrast agent (Iopamidol 300 mgI/mL, Iopamiron 300; Bayer-Schering) were 20 mL and 4 mL/s (internal carotid artery) and 15 mL and 3 mL/s (vertebral artery). To reconstruct the 3D DSA images, we also obtained mask images. We then reconstructed and analyzed the filling run volume using a dedicated commercially available workstation (Philips Medical Systems). The 3D DSA images were reconstructed in a 512 × 512 × 512 matrix with an isotropic voxel size. To obtain 3D DSA-MR fusion images we used the volume rendering technique for 3D DSA image reconstruction.

MR Imaging and MR Angiography

All MR imaging studies were performed on a 3T scanner (Achieva 3.0T; Philips Medical Systems) using eight-channel head coils. The imaging sequences included three-plane scout localizers, axial spin-echo T1-weighted (repetition time [TR]/echo time [TE]/number of signal-intensity acquisitions (NSA) 450 ms/10 ms/L, matrix 320 × 320), turbo spin-echo T2-weighted (TR/TE/NSA 4060 ms/80 ms/L, turbo factor 9, matrix 512 × 512), fluid-attenuated inversion recovery (TR/TE/NSA/TI 9000 ms/120 ms/L/2500 ms, turbo factor 15; matrix, 352 × 352), and postcontrast T1-weighted and 3D turbo field echo (TFE) (TR/TE/NSA 450 ms/10 ms/L, matrix 320 × 320) images. The FOV was 23 cm on all conventional MR images.

Before the contrast-enhanced MRI studies, we performed 3D time-of-flight MRA to evaluate the brain AVMs. The parameters were: TR/TE/NSA 20 ms/3.5 ms/L, flip angle 20°, FOV 20 × 20 cm, matrix 512 × 512, effective voxel size 0.39 × 0.39 × 0.5 mm, parallel imaging factor 2, acquisition time 4 minutes, 48 seconds. Cephalad saturation pulses were applied to eliminate venous blood signals. The maximum-intensity-projection (MIP) and volume rendering techniques were used for the 3D display of MRA images. Coronal and sagittal images acquired with the multiplanar reconstruction (MPR) method were also reconstructed for the observers' interpretation.

3D DSA-MR Fusion

Based on the spatial overlap of the intracranial major arteries (eg, the carotid bifurcation) on the 3D DSA and 3D or 2D MR images, under the guidance of one experienced neuroradiologist, one experienced technologist semi-automatically fused the images using commercially available image fusion software (Philips Medical Systems) on a workstation (Fig 1). Details on the image-based 3D-3D registration or 2D-3D registration have been described elsewhere (15). Slab thickness of the fused images was set at 10 mm to 20 mm. The time required to acquire the fusion images was a few minutes. Fusion accuracy was confirmed by assessing the spatial relationship between the vessels and the AVM nidus, bone, and brain tissues. Depending on the contrast between the AVM and the brain tissues or hematoma, conventional MR or