MR Angiography of Spinal Vascular Disease: What about Normal Vessels?

Spinal vascular disease encompasses a spectrum of lesions for which MR imaging findings may vary from subtle or nonspecific (dural arteriovenous fistula, arterial ischemia) to obvious (juvenile arteriovenous malformation). Frequently, affected patients have myelopathy with nonspecific symptoms and signs. Because MR imaging is the primary means of noninvasive screening for vascular lesions and determining who will require invasive catheter angiography for definitive diagnosis and possible treatment, it is important that the subtle findings be detected and the complexities be clarified as much as possible by the MR study. The key to differentiating vascular lesions from nonvascular inflammatory, neoplastic, degenerative, and posttraumatic conditions is obviously the identification of vessels with abnormal morphology and hemodynamics. The presence of flow voids and linear contrast enhancement on spin-echo images is helpful but inconsistent, except in the case of high-flow arteriovenous malformations (AVMs). The two main goals of spinal MR angiography as an adjunct to routine MR imaging have been to improve the visibility of the millimeter-sized intradural vessels and to differentiate abnormal from normal vessels. The article by Binkert et al in this issue of the *AJNR* (page 1785) represents a valuable step toward attaining these goals, but considerable work remains to be done.

The authors have used gadolinium-enhanced, fast gradient-recalled echo (GRE) 3D MR angiography to characterize and categorize 12 vascular lesions prospectively: six spinal cord AVMs, three spinal dural arteriovenous fistulas (AVFs), and three spinal or paraspinal tumors. The fast GRE method generates a 3D data set (7/2.3 [TR/TE]; voxel size, $\sim$1 mm^3 after zero-fill interpolation) in 24 seconds. In previous gadolinium-enhanced 3D MR angiography studies (1), a single-acquisition GRE data set (40–50/8–10 [TR/TE]; voxel size, $\sim$0.5 mm^3) or a phase-contrast (PC) data set (29/11 [TR/TE]; voxel size, $\sim$2 mm^3) required several minutes. Compared with the PC method, the fast GRE method provides better delineation of the AVM nidus and of the draining veins of both AVMs and dural AVFs. It is unclear whether the fast GRE method improves the visibility of the feeding arteries of AVMs. Maschalchi et al (2) found the PC method to be superior, but their fast GRE technique differed from that of Binkert et al in several ways. In general, the fast GRE method does not appear to improve the detection of draining veins of dural AVFs compared with the GRE method, although no direct comparison has been done. The earlier GRE method, however, did not delineate the arteriovenous shunt, which was observed in two of the three cases presented by Binkert et al. Although the level of the fistula often may be determined from the course of the draining vein alone, the display of the fistulous communication would provide added confidence in diagnosis and lesion localization. There are no published series of spinal cord AVMs evaluated with the GRE method. Thus, with respect to AVMs and dural AVFs, the contrast-enhanced fast GRE angiography method represents an overall improvement over previous studies. For vascular tumors, there is insufficient data for comparison. Yet, what about the display of normal spinal vessels? How well are they shown by the fast GRE method?

The largest normal intradural vessels, measuring 1 to 2 millimeters, are found in the thoracolumbar region. These include the anterior and posterior median veins (usually one predominates) and the anterior spinal artery, which are located on the cord surface, as well as the great anterior and posterior medullary veins and the (great medullary) artery of Adamkiewicz, which course between the cord and the dura. Only the GRE method with long repetition and echo times has been shown to display relatively long segments of the intradural vessels in normal subjects. These vessels, which were located in the thoracolumbar region, proved to be almost exclusively veins. The normal anterior spinal artery and artery of Adamkiewicz were not shown, nor were they observed on MR angiograms of patients with dural AVFs. Explanations of why normal arteries have been relatively ''invisible'' on previous MR angiography studies include smaller vessel size and faster pulsatile flow compared with the intradural veins. In the article by Binkert et al, no examples of normal intradural vessels were shown, nor do the authors indicate whether normal arteries were detected in the cases of dural AVF or extradural tumor.

The value of MR angiography in assessing the spinal vasculature for the presence of vascular disease or ''merely'' for locating certain vessels, such as the artery of Adamkiewicz, would be greatly increased if normal arteries could be detected in addition to the veins. This is no mean feat. The anterior spinal artery lies adjacent to the anterior median vein, and the diameter of the artery is typically smaller than that of the dominant posterior or anterior median vein. Furthermore, the time delay between intradural arterial and venous phases of gadolinium enhancement is almost certainly smaller than the estimated carotid-jugular delay of about 7 to 8 seconds (3). To distinguish the artery will likely require novel approaches to k-space sampling, such as elliptical centric view ordering or modified keyhole-like techniques, which retain

some spatial resolution while meeting the demands for temporal resolution necessitated by the gadolinium bolus method (3). These approaches will also require synchronization of the 3D data acquisition with the peak of arterial enhancement by using either real-time triggering or a ''test dose'' technique similar to that used by Binkert et al.

Only by establishing the MR angiographic appearance of normal vessels, veins, *and* arteries, can we begin to define ''abnormal'' with greater confidence. Variations in the size, trajectory, location, number, and extent of visible vessels that differ significantly from the normal appearance may then be used to identify abnormal vascular patterns. (This presumes that the variability in spinal cord blood supply and drainage is not so great as to preclude differentiation.) Building on the work of Binkert et al, improvements in 3D MR angiography that permit detection of both normal and abnormal vascular patterns should increase the accuracy of MR imaging in screening for vascular lesions and facilitate the planning and execution of subsequent invasive procedures. In addition, a greater range of MR angiography applications, including pre-, intra-, and postoperative monitoring of spinal vessels or the status of spinal vessels in degenerative, ischemic, or post-traumatic conditions, then may be considered.

BRIAN C. BOWEN
Member, Editorial Board

References

1. Bowen BC, Pattany PM. **MR angiography of the spine.** *Magn Reson Clin North Am* 1998;6:165–178
2. Mascalchi M, Cosottini M, Ferrito G, Quilici N, Bartolozzi C, Villari N. **Contrast-enhanced time-resolved MR angiography of spinal vascular malformations.** *J Comput Assist Tomogr* 1999;23:341–345
3. Huston J III, Fain SB, Riederer SJ, Wilman AH, Bernstein MA, Busse RF. **Carotid arteries: maximizing arterial to venous contrast in fluoroscopically triggered contrast enhanced MR angiography with elliptic centric view ordering.** *Radiology* 1999; 211:265–273