Contrast-enhanced radicular veins on MR of the lumbar spine in an asymptomatic study group.

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Contrast-Enhanced Radicular Veins on MR of the Lumbar Spine in an Asymptomatic Study Group

John I. Lane, Kelly K. Koeller, and John L. D. Atkinson

PURPOSE: To determine whether radicular enhancement occurs in asymptomatic persons and, if so, to provide insight into the mechanism of such enhancement. **METHODS:** Thirty asymptomatic volunteers were studied with gadolinium-enhanced MR (0.1 mmol/kg) of the lumbar spine. The precontrast axial T1-weighted sequences were reviewed for the entry section phenomenon of flow-related enhancement. If present, the sequence was repeated in combination with a superior saturation pulse in an attempt to eliminate this phenomenon. All studies were reviewed to document the incidence of radicular enhancement and determine its association with the entry section phenomenon. **RESULTS:** The entry section phenomenon was observed in 16 of 30 volunteers with successful elimination obtained in all cases. Eighteen of the volunteers demonstrated radicular enhancement; 16 of the 18 enhancing roots were associated with the entry section phenomenon. **CONCLUSIONS:** Radicular enhancement occurs commonly in asymptomatic volunteers. This phenomenon most likely represents the enhancement of prominent radicular veins. We urge caution in interpreting this finding as abnormal in the symptomatic population with degenerative disk disease.

Index terms: Radiculitis; Veins, magnetic resonance; Spine, magnetic resonance

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The phenomenon of lumbar nerve root enhancement has been observed in both symptomatic and asymptomatic patients with and without prior back surgery (1–4). The clinical significance of such enhancement remains in question, given the conflicting results obtained in the studies published to date. Several authors have ascribed this enhancement to a breakdown in the blood-nerve barrier in the setting of an active radiculitis (1–3). However, a recent study has proposed that, in some cases, this phenomenon represents intravascular enhancement of radicular veins that travel adjacent to one or more nerve roots of the cauda equina (4). If this theory is correct, radicular enhancement should occur normally in people with large radicular veins and no clinical evidence of radiculitis. To test this hypothesis, we endeavored to study asymptomatic volunteers with contrast-enhanced MR of the lumbar spine.

Subjects and Methods

We recruited 30 volunteers from the active-duty military population at our institution, after receiving approval to conduct this study from our institutional review board. Exclusion criteria for participation consisted of any episode of back pain that had limited or prevented normal daily activity within the 4-year period before this study. All volunteers were healthy and had no significant medical history.

The imaging protocol consisted of a sagittal T1-weighted sequence (500/20/2 [repetition time/echo time/excitations]) followed by an axial T1-weighted sequence (833/16/2) obtained contiguously from the level of the inferior endplate of L-2 through the superior endplate of S-1. All exams were performed on the same 1.5-T system using a 20-cm field of view, 4-mm section thickness, and

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From the Departments of Radiology, Neuroradiology Section (J.I.L., K.K.K.) and Neurosurgery (J.L.D.A.), Naval Hospital, Oakland, Calif.

Address reprint requests to John I. Lane, MD, Department of Radiology, Naval Hospital, 8750 Mountain Blvd, Oakland, CA 94627-5000.

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Fig 1. Normal radicular enhancement along the course of the right S-1 nerve root.

A, Entry section from a T1-weighted (833/16/2) axial sequence demonstrates hyperintense focus (*long arrow*) along ventral aspect of cauda equina at the L-2 level representing FRE. Note tip of conus (*short arrow*).

B, Entry section from T1-weighted (833/16/2) axial sequence, which was repeated in combination with a superior saturation pulse, successfully eliminated the entry phenomenon. Note tip of conus (*short arrow*).

C and *D*, T1-weighted axial images after contrast administration demonstrate continuous enhancement (*arrows*) following the course of the right S-1 nerve root.

E, Partition of 1.8 mm at the L-3 level from a 2-D time-of-flight sequence (39/9, 40° flip angle) performed with a walking inferior saturation pulse. Note flow-related enhancement at location of right S-1 nerve root within cauda equina (*arrow*).

a 220 × 256 matrix. The most cephalad section from this axial sequence was reviewed for evidence of flow-related enhancement (FRE) within the cauda equina. If this entry section phenomenon was observed, the sequence was repeated after placement of a superior saturation pulse at the L-1 level, an attempt to eliminate hyperintense signal produced by the inflow of unsaturated protons entering the imaging volume from caudally draining radicular veins. All volunteers received intravenous injection of gadopentatate dimeglumine (0.1 mmol/kg) and had another T1-weighted axial sequence as previously described. One subject who demonstrated radicular enhancement returned at a later date for a two-dimensional time-of-flight sequence (39/9, 40° flip angle). All studies were reviewed independently by two neuroradiologists (J.I.L., K.K.K.).

Results

The 30 volunteers were 29 men and 1 woman, with a mean age of 25 years (range, 20 to 34). FRE was noted in 16 (53%) of the 30 subjects. A superior saturation pulse eliminated FRE in all cases (Figs 1 and 3). Radicular enhancement was observed in 18 (60%) of the 30 cases. Sixteen of the 18 cases of radicular enhancement were associated with the entry section phenomenon. The distribution of radicular enhancement among the 30 volunteers is shown in Fig 2. There was no interobserver variability regarding the presence of FRE or root enhancement.

The most common pattern of enhancement (eight cases) was a small midline focus that could be followed caudally from the L-2 level along the distribution of the filum terminale to

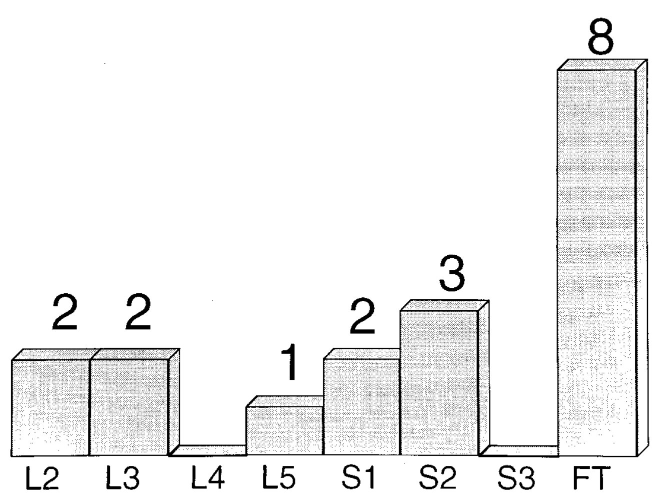

Fig 2. Distribution of radicular enhancement. Numbers on top of columns represent number of cases of radicular enhancement observed along respective root level. FT indicates filum terminale.

Fig 3. Normal radicular enhancement along the course of the left S-2 nerve root.

A, Entry section from a T1-weighted (833/16/2) axial sequence demonstrates hyperintense focus (*arrow*) along ventral aspect of cauda equina at the L-2 level representing FRE. Note tip of conus (*short arrow*).

B, Entry section from T1-weighted (833/16/2) axial sequence, which was repeated in combination with a superior saturation pulse, successfully eliminated the entry phenomenon. Note tip of conus (*short arrow*).

C and *D*, T1-weighted axial images after contrast administration demonstrate continuous enhancement following the course of the left S-2 nerve root (*arrows*).

its insertion at S-1. In two such cases, this midline enhancement terminated at the L-3/L-4 disk level. Radicular enhancement was noted along the distribution of a lower lumbar or sacral nerve root in the remaining cases. In four cases of radicular enhancement, axial images below L-5 were not obtained because of the limitation in the number of sections imposed by the standard repetition time used in the protocol. The exact root level was approximated, given its position within the thecal sac on the most caudal image in these cases. In several instances, radicular enhancement could not be followed into the nerve root sleeve; instead, the enhancement terminated immediately proximal or distal to the origin of the sleeve.

Discussion

Radicular enhancement has been described recently in association with clinical radiculopathy in patients both with and without prior surgery (2, 3). This enhancement has been considered evidence of a breakdown in the blood-nerve barrier induced by nerve root compression. The ability to detect such an alteration in the normal physiology of the nerve root poses some rather intriguing questions. What is the relationship between root enhancement and diskogenic pain? Could root enhancement have prognostic value in predicting which patients would benefit from surgical decompression? Unfortunately, correlation between radicular enhancement and the clinically determined level of radiculopathy has been inconsistent. One study of symptomatic patients without prior surgery noted a poor correlation between clinical symptoms and the level of root enhancement (4). In addition, Boden et al noted a high incidence of radicular enhancement in their series of asymptomatic patients studied in the immediate postoperative period (1). This lack of correlation between root enhancement and symptomatology requires a reevaluation of the interpretation of this phenomenon as a breakdown in the blood-nerve barrier.

We propose an alternative mechanism of enhancement: intravascular contrast within veins of variable caliber that accompany a lumbosacral root or filum terminale, providing venous drainage from the conus and cauda equina to the epidural venous plexus. Venous return within the epidural plexus proceeds by way of a superior or inferior route depending on the anatomic level. At or above L-2, the plexus is drained by the lumbar veins, which join the inferior vena cava transversely but also may continue their cephalad course into the azygous or hemiazygous system. Below L-2, the inferior route is characterized as descendant, with foraminal veins draining into the iliolumbar veins, which are tributaries of the common iliac veins (5).

Anatomists have described both large and small radicular veins of the cauda equina (6–10). The larger vessels, referred to as great radicular veins, vary in caliber from 0.5 to 1.2 mm and are few in number. They are usually found at the lower thoracic or upper lumbar level. In addition to its more common thoracolumbar location, a great radicular vein may be found accompanying a lower lumbosacral root, or filum terminale, in a significant percentage of the population (6). Opacification of these veins could explain the relatively high incidence of radicular enhancement encountered in this study of healthy volunteers. We previously noted that less than half of our cases of enhancement were associated with root compression, prompting us to theorize that enhancement in the absence of compression may represent contrast within a lumbosacral great radicular vein (4).

Small radicular veins (75 to 250 μm) are more numerous, being found at every spinal level within the endoneurium of the spinal root. In the presence of root compression, partial obstruction of several small radicular veins proximal to the point of compression might cause the appearance of root enhancement. We have noted that in all cases in which regression of the offending disk herniation was documented on a 3- to 6-month follow-up examination, there was also resolution of the radicular enhancement (4). Boden et al reported resolution of radicular enhancement in all patients within a 6-month period from the date of surgery (1). The results of both these studies demonstrate that radicular enhancement associated with compression or postoperative inflammation is often a transient phenomenon. Temporary impairment of venous outflow of these small veins can effectively explain the transient nature of the enhancement.

A variety of factors affect spinal venous hemodynamics including gravity, posture, and changes in thoracic and abdominal pressure. Below the level of the heart, the respiratory cycle plays the most significant role in driving caudal venous drainage by producing negative pressure during inspiration and promoting central flow into the inferior vena cava (5, 11). The hemodynamics of venous return in the supine position could theoretically be altered because gravitational forces favoring caudal flow would be negated. Additionally, in the reclining position the inferior vena cava is compressed against the lumbar lordosis, thereby increasing venous pressure that is transmitted into the valveless epidural venous plexus (5). This would also increase pressure within the valveless radicular veins draining into the epidural venous plexus. Our observation that caudal venous flow persists in the recumbant position confirms the dominant role of the respiratory cycle in driving caudal venous return.

The results of this study of asymptomatic volunteers raise serious doubts about the clinical relevance of radicular enhancement in the symptomatic population with degenerative disk disease. These results also do not support the contention that all cases of root enhancement represent a breakdown in the blood-nerve barrier. The theory of blood-nerve barrier breakdown does not explain the high frequency of FRE both in this study of asymptomatic volunteers and in our previous series of symptomatic patients (4). Slow flow within large veins of the cauda equina would explain the observation of FRE on the entry section, and intravascular enhancement of these vessels could produce an image indistinguishable from that of an enhancing nerve. Caudal flow within these vessels would explain the elimination of FRE after placement of a superior saturation pulse that was observed in all cases in which FRE was noted on the precontrast sequence. Scanning parameters were not altered during this study, and therefore the optimal parameters for the detection of FRE on a T1-weighted sequence were not determined. A 2-D time-of-flight sequence performed with an inferior saturation pulse was obtained in one subject with an enhancing root, demonstrating caudal flow (Fig 1).

Von Quast noted that some radicular veins exit the dura separately, which fact may explain our inability to follow radicular enhancement into the nerve root sleeve in many cases (12). To date, we have dissected seven cadaveric spines for the purpose of confirming the presence of these veins and have found a large lower lumbosacral great radicular vein in two cases (4).

Our observation that 60% of asymptomatic volunteers demonstrated radicular enhancement was surprisingly high, given the previously reported 25% incidence of lower lumbosacral great radicular veins in the largest human cadaveric series (7). If we exclude the cases of radicular enhancement observed cephalad to and including the L-3 level, this figure falls to 47%. This is still considerably higher than would be expected from both the cadaveric series and the symptomatic population studied with contrast-enhanced MR of the lumbar spine (4). However, a significant difference in the mean ages of these study populations should be noted. The mean age of the symptomatic population was 37 years (range, 9 to 84), compared with a mean age of 25 years (range, 20 to 34) in our asymptomatic group. The patency of lower lumbosacral great radicular veins might therefore be age-dependent. In a microtome study of 46 unselected cadaveric spines (mean age 67 years, range 36 to 91), Hoyland noted chronic thrombus within the venous channels of the intervertebral foramina in a "majority" of cases (13). If propagation of this thrombus extended proximally to involve the intradural compartment, this could effectively occlude these radicular veins and thus prevent intravascular enhancement in an older population.

In conclusion, the results of this study do not support the previously reported contentions that radicular enhancement is clinically significant and indicative of radiculitis in patients with degenerative disk disease. This phenomenon should be expected as a normal finding, especially in young patients, and probably represents intravascular enhancement of lower lumbosacral great radicular veins, which are present in a significant percentage of the general population.

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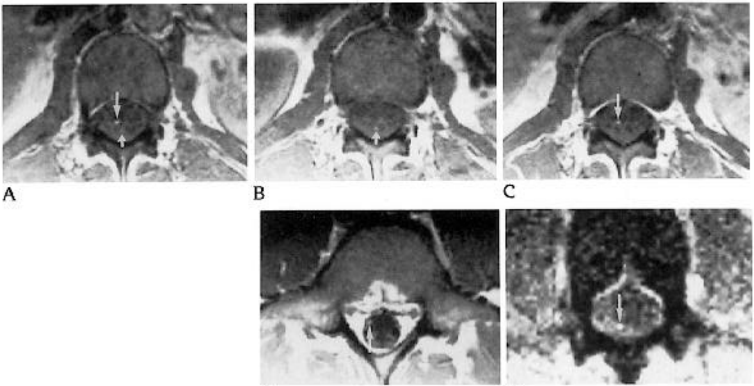

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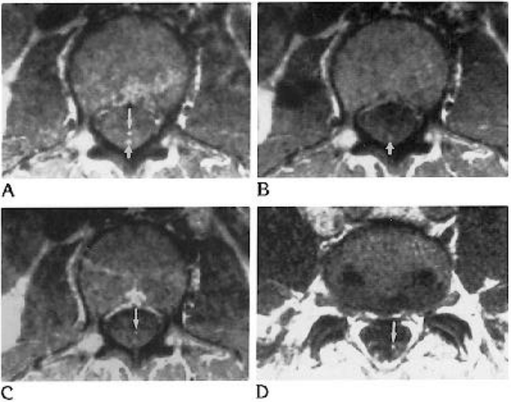
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