AJNR

MR Imaging of the Cervical Spine: Neurovascular Anatomy

Bonnie D. Flannigan, Robert B. Lufkin, Charles McGlade, James Winter, Ulrich Batzdorf, Gabriel Wilson, Wolfgang Rauschning and William G. Bradley, Jr.

AJNR Am J Neuroradiol 1987, 8 (1) 27-32
http://www.ajnr.org/content/8/1/27

MR Imaging of the Cervical Spine: Neurovascular Anatomy

Bonnie D. Flannigan[1,2]
Robert B. Lufkin[1]
Charles McGlade[1]
James Winter[1]
Ulrich Batzdorf[3]
Gabriel Wilson[1]
Wolfgang Rauschning[4]
William G. Bradley, Jr.[5]

High-resolution surface-coil MR imaging reveals intricate anatomic detail of the cervical spinal canal and its neurovascular contents. Appreciation of the normal neurovascular anatomy provides a scientific foundation for the detection of disease. Sagittal, axial, and oblique MR images of normal subjects were correlated with comparable anatomic sections obtained with a cryomicrotome whole-organ sectioning technique. The anterior epidural venous plexus is a prominent structure in the cervical spinal canal and was consistently identified both with cryomicrotomy and with MR in sagittal and axial planes. Epidural veins can be displaced and distorted in patients with cervical disk disease. Nerve roots including dorsal and ventral rootlets were consistently identified on axial images coursing through the subarachnoid space. Oblique-plane imaging showed nerve roots "en face" in their respective foramina; this may be a useful imaging technique in the diagnosis of nerve root impingement.

This study was undertaken to define normal anatomic structures within the cervical spinal canal using MR, with particular attention to the cervical epidural veins and the cervical nerve roots. Abnormal anatomy can only be detected in comparison to normal anatomy. High-resolution MR images obtained in sagittal, axial, and oblique planes were correlated with corresponding anatomic sections obtained with a cryomicrotome whole-organ sectioning technique.

The anterior epidural cervical venous plexus is a prominent structure previously well-identified with bolus intravenous contrast CT studies. It was consistently identified on parasagittal images and also on axial images in the anterolateral recesses of the spinal canal on T1-weighted MR images. Its normal appearance should be appreciated, since distortion of this extensive venous network can occur in patients with cervical disk disease.

Axial imaging allows identification of both the ventral and dorsal nerve roots individually as they course through the subarachnoid space. Significant neural foraminal disease may be difficult to identify in the axial and sagittal plane, making MR somewhat controversial as an imaging technique in the patient with an isolated radiculopathy. Electronically activated oblique-plane imaging was used to show the nerve roots in their respective neural foramina. This may be a useful method for evaluating patients with radiculopathy.

Materials and Methods

Cervical spine examinations were performed on 30 volunteers using a flexible neck coil and a 0.3 T permanent magnet imaging system (Fonar B-3000, Melville, NY). The vertical orientation of the axis of the main magnetic field allowed the use of a solenoidal (circumferential) neck coil. Multislice imaging was performed in the axial, sagittal, and oblique planes using a spin-echo, multislice pulse sequence. Electronically activated oblique-plane imaging was performed by using an axial scout image and placing line cursors perpendicular to one neural foramen and parallel to the opposite foramen (see Fig. 6A). This enabled us to obtain images of the nerve roots on one side "en face" comparable to a 45° oblique plain radiograph,

This article appears in the January/February 1987 issue of *AJNR* and the April 1987 issue of *AJR*.

Received December 19, 1985; accepted after revision July 10, 1986.

[1] Department of Radiological Sciences, UCLA Medical Center, Los Angeles, CA 90024. Address reprint requests to B. D. Flannigan.

[2] Present address: Valley Presbyterian Hospital, 15107 Vanowen St., Van Nuys, CA 91405.

[3] Department of Neurosurgery, UCLA Medical Center, Los Angeles, CA 90024.

[4] Department of Orthopedics, University Hospital, Uppsala, Sweden.

[5] NMR Imaging of the Laboratory, Huntington Medical Research Institutes, Pasadena, CA 91109.

AJNR 8:27-32, January/February 1987
0195-6108/87/0801-0027

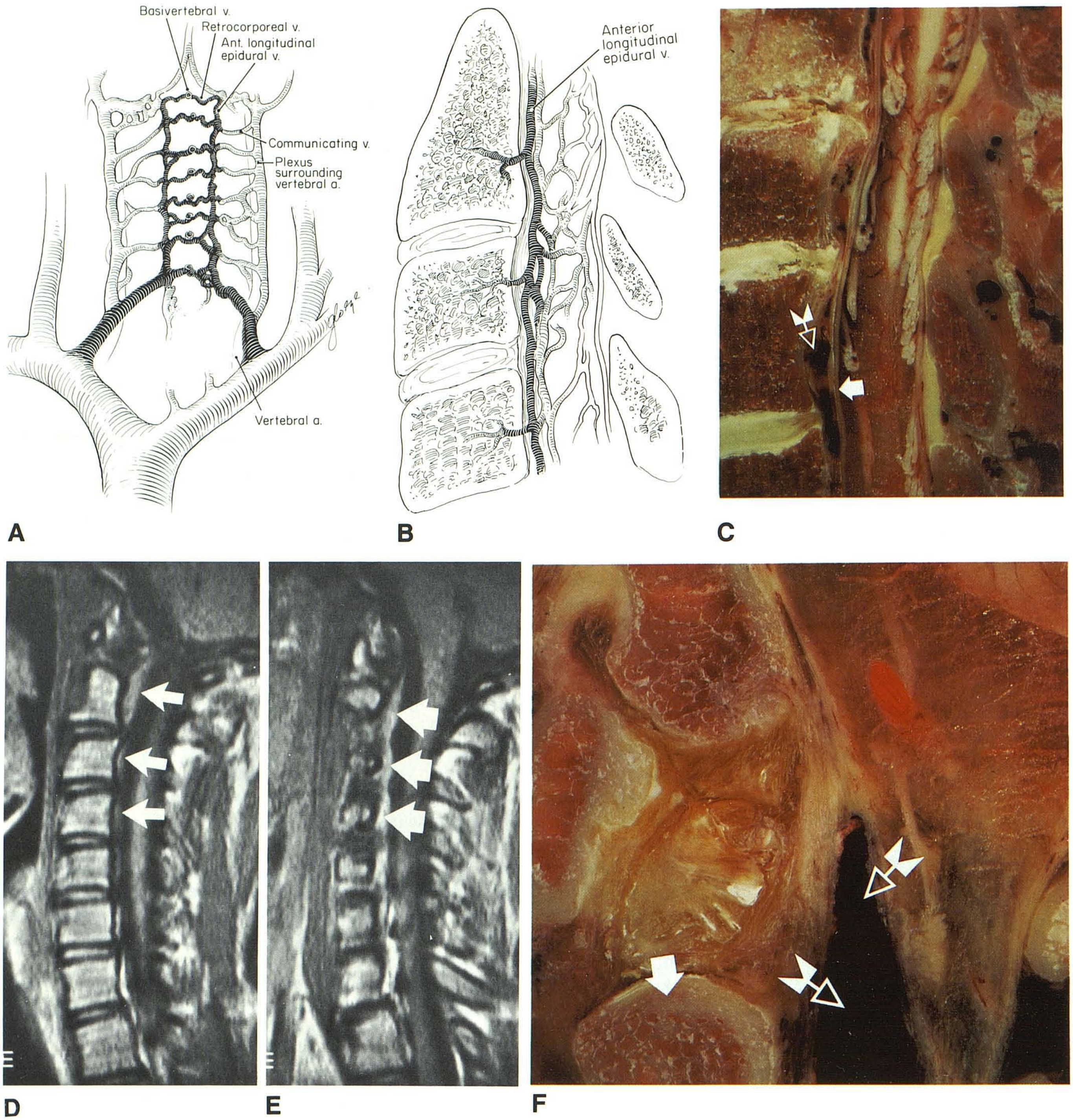


Fig. 1.—*A*, Anatomic drawing of epidural venous plexus in anteroposterior projection.

B, Anatomic drawing of epidural venous plexus in sagittal plane.

C, Corresponding parasagittal cryosection shows anterior epidural veins (*open arrow*) and dura mater (*closed arrow*).

D, *E*, Parasagittal MR (SE 500/28) shows segmented longitudinal band of increased signal intensity (*arrows*) behind vertebral bodies, particularly prominent behind dens and extending caudally.

F, Parasagittal cryosection at level of dens shows huge venous sinus posterior to dens (*open arrows*) and lateral aspect of body of C2 (*closed arrow*).

and on the opposite side in a plane parallel to the root itself in an oblique coronal plane.

T1-weighted image parameters were used for the purpose of anatomic demonstration (SE 500/28). Four averages were used with a matrix of 256 × 256. A "zoom" mode with a field of view of 19.2 cm decreased the pixel size to 0.75 mm^2. Slice thickness varied from 3–5 mm, with a 2-mm interslice gap. Imaging time for each T1-weighted sequence was 8 min.

The MR images were compared with whole-organ section photographs obtained at comparable levels from two cadavers using the

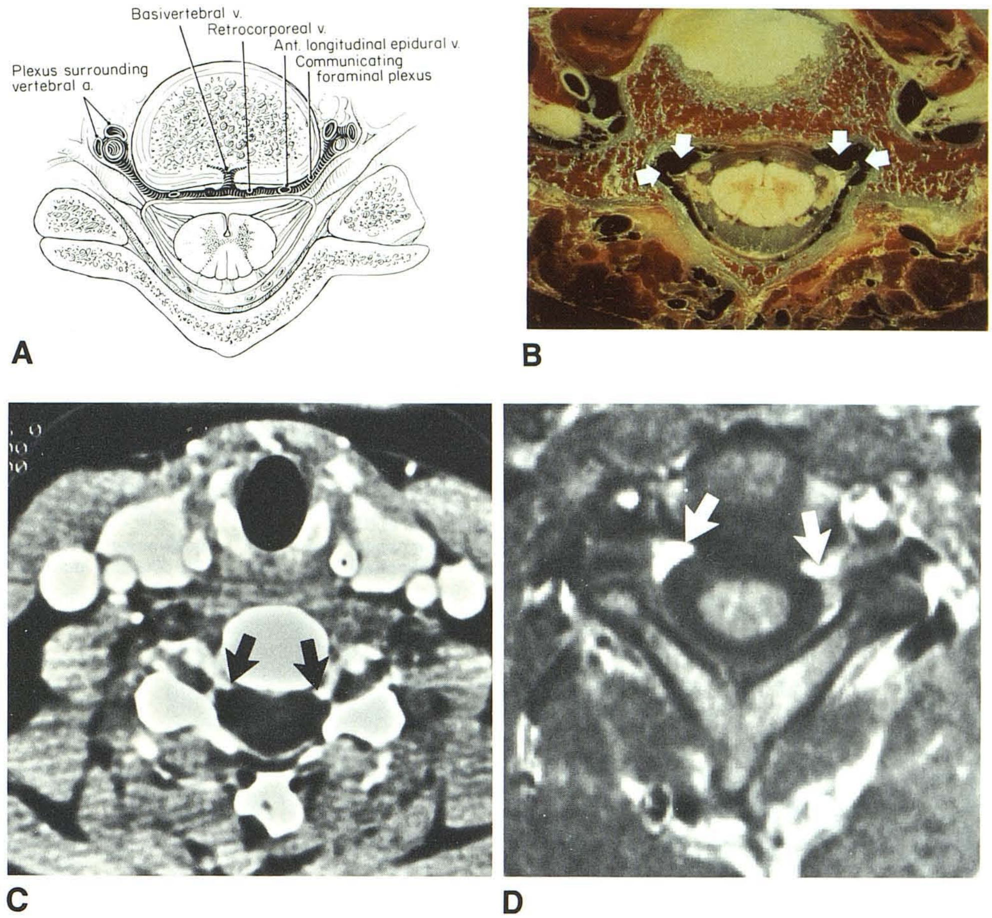


Fig. 2.—*A*, Anatomic transverse depiction of venous anatomy.

***B*, Axial cryosection through pedicles of C5 shows prominent venous sinusoids (*arrows*) in anterolateral recesses of spinal canal and surrounding the dural sac.**

***C*, Axial CT through C5–C6 with intravenous bolus IV infusion shows venous sinusoids (*arrows*).**

***D*, Axial MR (TR = 500, TE = 28). Increased intensity (*arrows*) corresponds to venous structures.**

cryomicrotome whole-organ sectioning technique [1] in the axial, sagittal, and oblique planes.

MR images of 10 patients with a diagnosis of acute cervical disk herniation were retrospectively reviewed for signs of anatomic distortion. Surgical follow-up was obtained in each case. Eight of these patients had had additional studies before surgery that confirmed disk herniation, including X-ray CT, X-ray CT with intravenous contrast, and myelography and postmyelography CT.

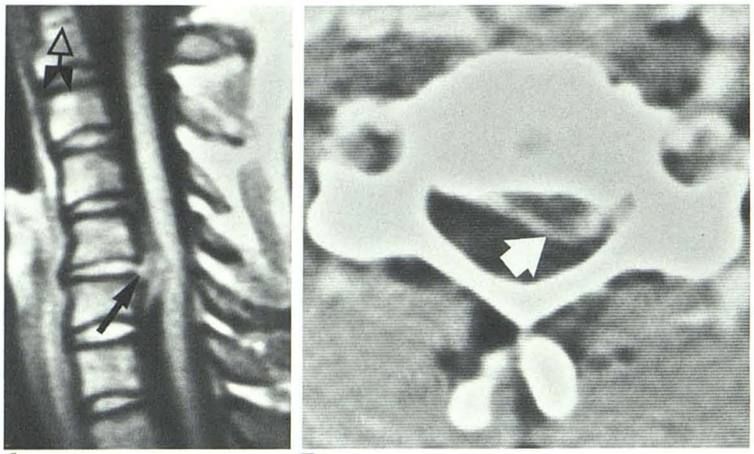
Results

Cervical Epidural Venous Plexus

Examination of sagittal and parasagittal anatomic sections revealed a prominent venous sinusoidal plexus in the anterior epidural space. This plexus is particularly prominent at the level of C2. The epidural venous system consists of medial and lateral longitudinal channels located in the anterolateral portion of the epidural space. These two channels are connected behind each vertebral body by retrocorporeal veins (like rungs on a ladder) that communicate with the basivertebral venous system. The longitudinal channels communicate with a foraminal venous plexus that extends anteriorly to surround the vertebral artery on each side. This system is an intricate latticelike network composed of slowly flowing blood (Fig. 1A–C). It corresponds to the segmented, longitudinal band of increased intensity frequently identified on parasagittal T1-weighted MR images (Fig. 1D, E). This band is particularly prominent behind the body of C2 seen on cryosection and MR (Fig. 1E, F). The increased intensity is representative of slow-to-stagnant venous flow (microscopic flow within the venous sinusoidal channels). Venous anatomy is also recognized on axial MR images (Fig. 2). This anatomy has previously been described with contrast-enhanced CT scanning [2]. The high intensity located in the anterolateral aspect of the spinal canal represents slowly flowing or stagnant venous blood within the longitudinal venous channels. Anatomic sections revealed little or no fat in this region.

All 10 patients with the proven acute cervical disk herniations demonstrated high-intensity protruding disk material and posterior displacement of a high-intensity band (the epidural veins) on the sagittal MR images. This vertically oriented band was lifted posteriorly by high-intensity disk material (Figs. 3A, 4A).

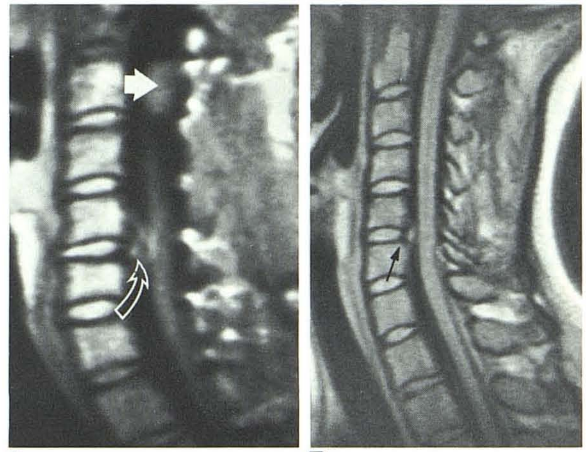
Ligamentous structures of the cervical spine include the posterior longitudinal ligament that extends cephalad to merge into the tectorial membrane and dura mater. Anterior to this, just behind the dens, are the inferior and superior cruciate ligaments that merge to form the transverse ligament. These ligaments, owing to their fibrous nature, theoretically should show decreased MR signal and thus are not routinely



A B

Fig. 3.—*A*, Sagittal MR (SE 500/28) shows acutely herniated disk at C5–C6 as high-intensity material (*solid arrow*) lifting a vertical band from posterior aspect of vertebral bodies above and below disk level and effacing cord. Subdental synchondrosis (*open arrow*).

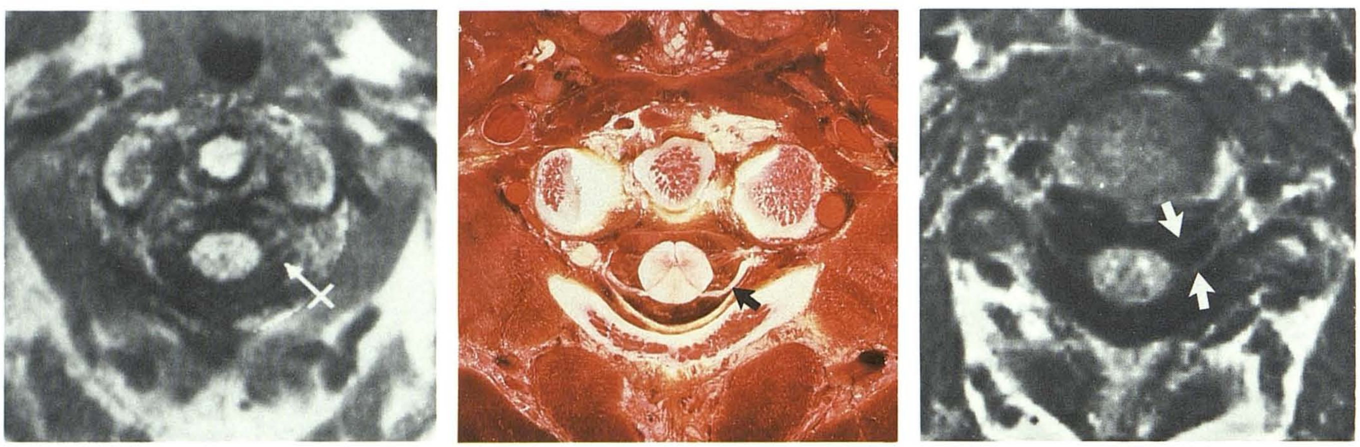
B, Corresponding bolus-infusion CT scan shows displaced epidural venous structures (*arrow*).



A B

Fig. 4.—*A*, In another patient, a central herniated disk with displacement of epidural vein is identified at C5–C6 (*open arrow*) (SE 500/28). Incidentally noted is a neurofibroma at C3 (*solid arrow*).

B, Central disk herniation is present at C5–C6 (*arrow*) (SE 500/28).



A B C

Fig. 5.—*A*, Axial MR (SE 500/28) shows ventral and dorsal nerve roots in subarachnoid space (*arrow*, left dorsal root).

B, Corresponding cryosection (*arrow*, left dorsal root).

C, Axial MR (SE 500/28) at C5–C6 level shows left ventral and dorsal nerve roots (*arrows*).

visualized. Over 90% of patients demonstrated a synchondrosis at the base of the dens (subdental synchondrosis) (Fig. 3A). This is an important normal structure to appreciate, especially in cases of trauma.

Cervical Nerve Roots

Ventral and dorsal nerve roots were frequently (75%) identified on axial images (Fig. 5). With thinner slices, nerve roots were more often identified coursing through the subarachnoid space. The dorsal root ganglia were not consistently identified with axial imaging (3-mm and 5-mm slices). Nerve roots within their foramina are sometimes seen with sagittal imaging; however, oblique-plane imaging allows optimal visualization of the nerve roots "en face" and also in a coronal oblique plane (Fig. 6). Higher intensity fat and foraminal venous sinusoids surround the lower-intensity nerve root sheaths that are in the inferior portion of their respective foramina on cryomicrotome sections [3]. With MR, each foramen is outlined by a dark line corresponding to the compact cortical bone of the inferior pedicle cortex superiorly, the superior pedicle cortex inferiorly, the posterior cortical bone of the vertebral bodies anteriorly, and the cortical bone of the posterior elements posteriorly.

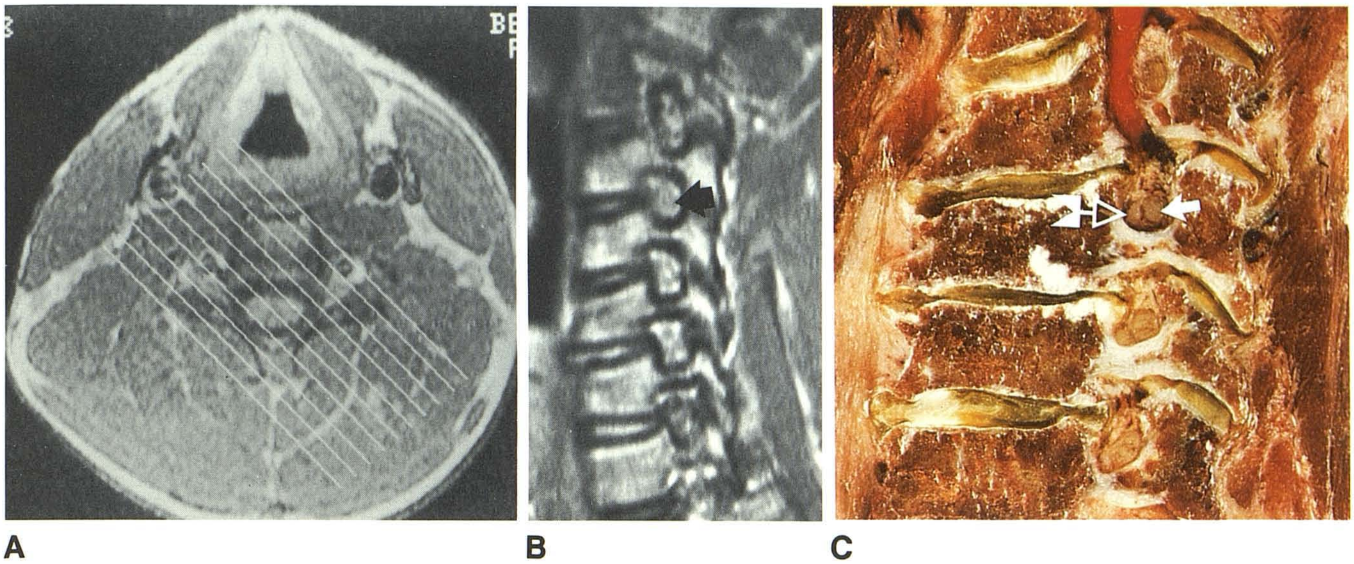


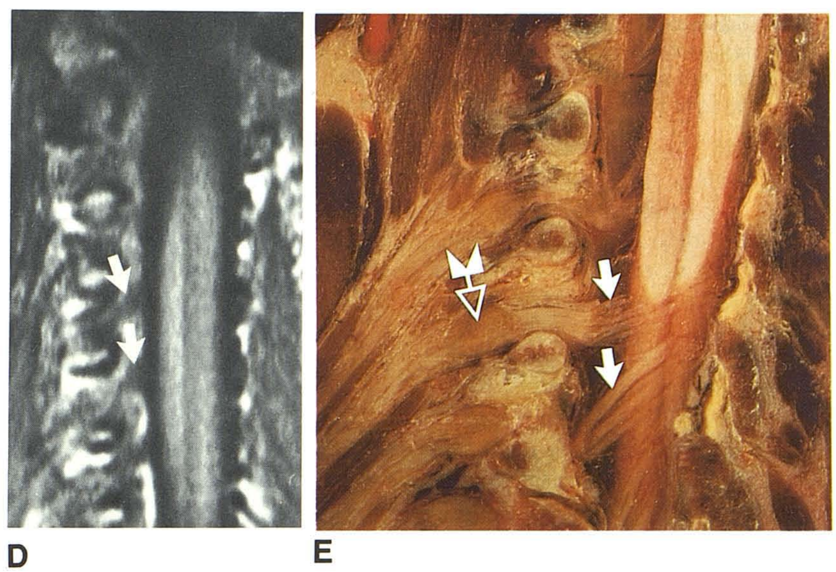
Fig. 6.—*A*, Axial scout view for oblique plane imaging with cursor line placement perpendicular to left neural foramen.

B, Oblique plane imaging shows combined dorsal and ventral nerve roots "en face" in respective neural foramen (*arrow*) (SE 500/28). Foramen is well outlined by a black line representing cortical bone of pedicles posterior elements and posterior aspect of vertebral bodies.

C, Corresponding oblique plane cryosection shows dorsal nerve root (*solid arrow*) and smaller ventral nerve root (*open arrow*) in inferior portion of foramen.

D, Oblique coronal MR (SE 500/28) shows exiting right nerve roots coursing into their respective formina (*arrows*).

E, Corresponding oblique coronal cryosection shows right nerve roots coursing into their respective formina (*solid arrows*) and dorsal root ganglion (*open arrow*).



Discussion

Cervical spinal nerves (including differentiation of ventral and dorsal roots) are now identified with high-resolution thin-slice MR imaging. Oblique-plane imaging best displays nerve roots "en face" within their respective foramina. This may be a useful scanning technique for patients with a radiculopathy. With thinner slice capabilities, bony foraminal disease may be diagnosed with MR. Identification of individual nerve roots in the axial plane and of nerve roots "en face" is indicative of the great potential high-resolution MR has for diagnosing foraminal disease in the patient with radiculopathy [1].

The anatomy of the anterior epidural venous plexus has been previously well defined with infusion CT scanning, and displacement of these veins is often seen on X-ray CT with cervical disk herniations. Our experience suggests similar findings with MR, as seen in the 10 cases of acute cervical disk herniation ("lifted band appearance"). The high intensity of the venous plexus on T1-weighted images is related to the slow sinusoidal flow (less than 1 cm/sec). The anatomic information available from MR imaging correlated 100% with CT myelography (metrizamide or infusion) in eight patients with acute disk herniations. This suggests a potential for obviating metrizamide studies in the future.

With advanced technology and increased spatial resolution [4–10], increasingly detailed morphologic structure will be revealed with MR. Appreciation of this will be useful in detecting and diagnosing disease.

REFERENCES

1. Rauschning W, Bergstrom K, Pech P. Correlative craniospinal anatomy studies by computed tomography and cryomicrotomy. *J Comput Assist Tomogr* **1983**;7:9–13
2. Russell EJ, D'Angelo CM, Zimmerman RD, Czervionke LF, Huckman MS. Cervical disk herniation: CT demonstration after contrast enhancement. *Radiology* **1984**;152:703–712

3. Pech P, Daniels DL, Williams AL, Haughton VM. The cervical neural foramina: correlation of microtomy and CT anatomy. *Radiology* **1985**;155(1):143–146
4. Lee BC, Deck MD, Kneeland JB, Cahill PT. MR imaging of the craniocervical junction. *AJNR* **1985**;6(2):209–213
5. Hyman RA, Edwards JH, Vacirca SJ, Stein HL. 0.6 T MR imaging of the cervical spine: multislice and multiecho techniques. *AJNR* **1985**;6(2):229–236
6. Hawkes RC, Holland GN, Moore WS, Corston R, Kean DM, Worthington BS. Craniovertebral junction pathology: assessment by NMR. *AJNR* **1983**;4(3):232–233
7. Modic MT, Weinstein MA, Pavlicek W, Boumphrey F, Starnes D, Duchesneau PM. Magnetic resonance imaging of the cervical spine: technical and clinical observations. *AJR* **1983**; 141(6):1129–1136, *AJNR* **1984**;5:15–22
8. Han JS, Kaufman B, El Yousef BJ, et al. NMR imaging of the spine. *AJR* **1983**;141(6):1137–1145, *AJNR* **1983**;4:1151–1159
9. Norman D, Mills CM, Brant-Zawadzki M, Yeates A, Crooks LE, Kaufman L. Magnetic resonance imaging of the spinal cord and canal: potentials and limitations. *AJR* **1983**;141:1147–1152, *AJNR* **1984**;5:9–14
10. Han JS, Benson JE, Yoon YS. Magnetic resonance imaging in the spinal column and craniovertebral junction. *Radiol Clin North Am* **1984**;22(4):805–827