AJNR

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AJNR Am J Neuroradiol 1989, 10 (6) 1243-1249
http://www.ajnr.org/content/10/6/1243

Assissment of Extradural Degenerative Disease with Gd-DTPA–Enhanced MR Imaging: Correlation with Surgical and Pathologic Findings

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To test whether gadolinium-DTPA–enhanced MR would increase the conspicuity of extradural degenerative disease in the previously unoperated patient, we prospectively studied a group of 30 patients with symptoms suggestive of disk disease. Surgical findings and pathologic correlations were used as an objective measure of accuracy. Gadolinium-DTPA increased the confidence of diagnosis at one of eight operated cervical levels (six patients) and changed the diagnosis from extradural degenerative disease to tumor in one patient. The mechanism of enhancement of the epidural space and peridiskal region appears to be related to accumulation of contrast material within the epidural venous plexus, as well as to epidural fibrosis associated with disk disruption and herniation.

While the immediate clinical utility of gadolinium-DTPA for morphologic analysis seems limited to difficult cervical spine cases, the presence of enhancement as a marker of epidural fibrosis and attempted healing may prove to be of great importance in studying the natural history and basic pathophysiology of degenerative disk disease.

***AJNR* 10:1243–1249, November/December 1989; *AJR* 154: January 1990**

Despite the rapid advances in MR imaging of the spine, evaluation of degenerative disk disease and extradural disease remains imperfect. Gadolinium-DTPA (Gd-DTPA) has recently shown its utility in the MR evaluation of the spine in postoperative patients by enhancing epidural fibrosis [1]. Epidural fibrosis has long been known to be associated with disk herniations in the previously unoperated patient [2]. The epidural venous plexus has also shown consistent enhancement in the operated spine, a finding that has been used to advantage in the unoperated cervical spine by using contrast material with CT to increase the conspicuity of extradural disease [3]. Our hypothesis was that enhancement of the epidural plexus and/or peridiskal fibrosis with Gd-DTPA would increase the conspicuity of extradural disease on T1-weighted images when compared with nonenhanced images in the unoperated patient. To test this hypothesis, we prospectively studied a group of 30 unoperated patients with symptoms suggestive of disk disease using subsequent surgical findings and careful pathologic correlation as an objective measure of accuracy.

Subjects and Methods

Thirty patients were entered into this pilot study group. Entry criteria included major clinical symptoms and signs of herniated disk disease including radicular pain ($n = 27$), myelopathy ($n = 3$), paresthesias ($n = 6$), muscle weakness ($n = 8$), and low back or neck pain ($n = 3$); in addition, a high likelihood that surgery would be performed was a predisposing condition. The patients had to be at least 18 years old and without a prior history of spine surgery. The 15 men and 15 women were 29–73 years old (mean, 49.2 years).

All patients underwent a baseline and 24-hr postcontrast physical examination. Baseline and 24-hr postcontrast hematologic and blood chemistry studies were also performed. A recent pregnancy test (within 72 hr) was mandatory for all women of childbearing age before

Received December 30, 1988; revision requested February 22, 1989; revision received March 28, 1989; accepted April 11, 1989.

This work was supported in part by a grant from Berlex Laboratories, Inc.

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they were given Gd-DTPA. Informed consent was obtained in all cases.

Examinations were performed on a 1.0- or 1.5-T superconducting magnet* using a 12-cm-diameter planar circular surface coil operating in the receive mode. A 50-cm body coil served as the transmitter. All patients were studied with the following imaging sequences before and after administration of 0.1 mmol/kg of Gd-DTPA/dimeglumine†: (1) sagittal T1-weighted spin-echo (SE) 400/17 (TR/TE), (2) axial T1-weighted SE 500/17, (3) axial T2-weighted SE 2000/30, 90, and (4) axial fast low-angle shot (FLASH) gradient-echo 200/13 with a 90° flip angle. In addition, T1-weighted axial delayed images were obtained with the same imaging variables 30–45 min after injection. The imaging matrix was 256 × 256, with a section thickness of 4 mm and an intersection gap of 2 mm. Sagittal images were obtained from neural foramen to neural foramen. Initial postcontrast sagittal and axial T1-weighted images were obtained immediately after administration of contrast material and completed within 15 min.

The MR images were interpreted by two of the authors without clinical data or results of previous imaging studies. Precontrast MR images were evaluated for the presence or absence of abnormal epidural soft tissue, which, if present, was characterized by signal intensity, location, level, mass effect, and contiguity with the intervertebral disk. The pre- and postcontrast images were then evaluated together for the presence and type of enhancement as well as the previously described factors. On the precontrast studies a diagnosis of normal, bulging, or herniated disk was made independent of the postcontrast images. A diagnosis of bulging disk was made when a smooth, concentric bulge of the disk outline was noted beyond the margins of the vertebral bodies. The diagnosis of a herniated disk entailed the identification of a focal protrusion, extrusion, or free fragment, as has been described previously [4]. On the postcontrast images, similar diagnoses were made, and, in addition, notation was made of any associated enhancement of either the herniated disk itself, the parent disk, or adjacent vertebral bodies. On the basis of previous experience with the operated spine, a diagnosis of associated epidural fibrosis was made when enhancement was noted on the early postcontrast study, either in the epidural space surrounding a herniated disk or within the outer margins of the anulus and posterior longitudinal ligament complex [1]. Abnormal epidural soft tissue that did not enhance on the early postcontrast scan was classified as disk material. A central nonenhancing mass surrounded by peripheral irregular enhancement was classified as a disk wrapped with epidural fibrosis. A nodular nonenhancing mass intermixed with and surrounded by enhancement was classified as a disk wrapped and/or incorporated in epidural fibrosis. Linear enhancement surrounding irregularities of the peripheral parent disk margin was interpreted as anular scar (anular tear). Smooth linear or crescentic enhancement immediately posterior to the vertebral body, or "tented" over an extradural defect, was defined as venous plexus. This was seen parasagittally and extending out into the neural foramen in the cervical spine, or more centrally placed in the thoracic and lumbar areas.

A degree of confidence in the diagnosis was assigned to the pre- and postcontrast scans on the basis of a 0–3 scale: 0 = normal, 1 = indeterminate, 2 = probably abnormal, and 3 = definitely abnormal. After analysis, the data were stored according to hospital number for subsequent comparison with surgical and histologic results.

Intraoperative correlation of aberrant soft tissue was made at the time of surgery by matching the anatomic locations with the MR findings. Surgeons had the benefit of the MR diagnosis from a neuroradiologist who was not involved in the blind evaluation. Numerous operative specimens of aberrant epidural soft tissue were obtained and given directly to a neuroradiologist in attendance after a final review of location. In this manner, extreme care was taken to ensure accurate localization and correct identification of surgically obtained tissue specimens. These specimens were kept separate and labeled numerically. Multiple representative sections from each numbered specimen were subsequently reviewed by an experienced musculoskeletal pathologist without knowledge of the specimen location, surgical findings, or MR impression. Histologic diagnosis of herniated disk, epidural fibrosis, or herniated disk and epidural fibrosis was then made. Only after this last step were the pre- and postcontrast MR interpretations, surgical findings, and histologic diagnosis compared.

Surgical approaches were posterolateral for cases of thoracic disk herniation, anterior for cases of cervical disk herniation, and posterior for cases of lumbar disk disease. It is acknowledged that the exact surgical and MR correlation was best with the posterior approach in the lumbar region; it was intermediate for thoracic and lowest for cervical procedures.

Results

Surgical/Gd-DTPA MR Findings

Table 1 lists the operated patient levels and summarizes the results.

Cervical spine.—Fifteen patients in this group were imaged. Six patients underwent surgery at eight operative levels. The final histologic diagnoses were disk herniation ($n = 6$), scar and herniation ($n = 1$), and herniation and osteophyte ($n = 1$). Gd-DTPA did not change the diagnosis of extradural disease in any patient imaged for cervical spine extradural disease. Gd-DTPA did increase the confidence of diagnosis at one of eight operated levels (Figs. 1 and 2). This was a change from a score of 2 (probably abnormal) to 3 (definitely abnormal). In one patient MR both with and without contrast material identified only a disk herniation (confidence level 3), but disk herniation and osteophyte were present at surgery.

Thoracic spine.—Two patients in this group were imaged and four abnormal levels identified. One patient underwent surgery at one operative level at which three disk herniations were seen on MR. Final histologic diagnosis was disk herniation, as predicted from both the contrast-enhanced and noncontrast MR images (Fig. 3). Gd-DTPA did not change the diagnosis, or increase the confidence of diagnosis at the operated level.

Lumbar spine.—Thirteen patients in this group were imaged. Four patients underwent surgery at nine operative

TABLE 1: Effect of Gd-DTPA–Enhanced MR Imaging in the Diagnosis of Patients Who Underwent Surgery for Disk Disease

Effect of Gd-DTPA by Level	No. of Levels		
	Cervical ($n = 6$)	Thoracic ($n = 1$)	Lumbar ($n = 4$)
Changed diagnosis	0	0	0[a]
Increased confidence of diagnosis	1	0	0
No change	7	1	9
Total	8	1	9

[a] In a fifth patient not included in this tabulation, a diagnosis changed on the basis of Gd-DTPA findings was confirmed by CSF cytology.

* Magnetom, Siemens Medical Systems, Iselin, NJ.
† Berlex Laboratories, Inc., Cedar Knolls, NJ.

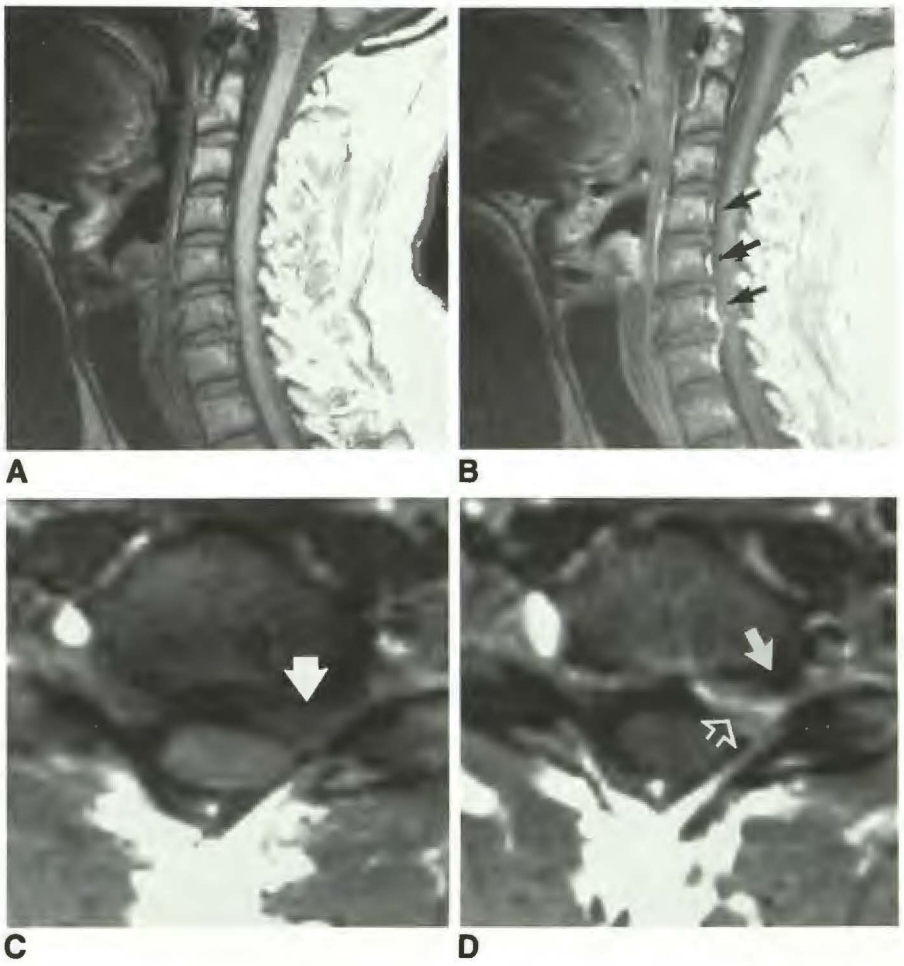


Fig. 1.—*A* and *B*, Sagittal unenhanced (*A*) and enhanced (*B*) T1-weighted SE 400/17 images of cervical spine. Unenhanced study shows disk herniations at C5–C6 and C6–C7 (C6–C7 surgically proved). Enhanced study shows linear areas of increased signal posterior to vertebral bodies representing enhancing venous plexus (*arrows*). Small disk protrusion at C4–C5 is better defined after contrast.

C, Axial unenhanced SE 500/17 image at C6–C7 level shows large extradural soft-tissue mass (*arrow*).

D, Axial enhanced SE 500/17 study shows nonenhancing disk herniation centrally within mass (*solid arrow*) surrounded by enhanced scar and/or plexus (*open arrow*). Disk herniation is considerably smaller than would be expected from unenhanced image.

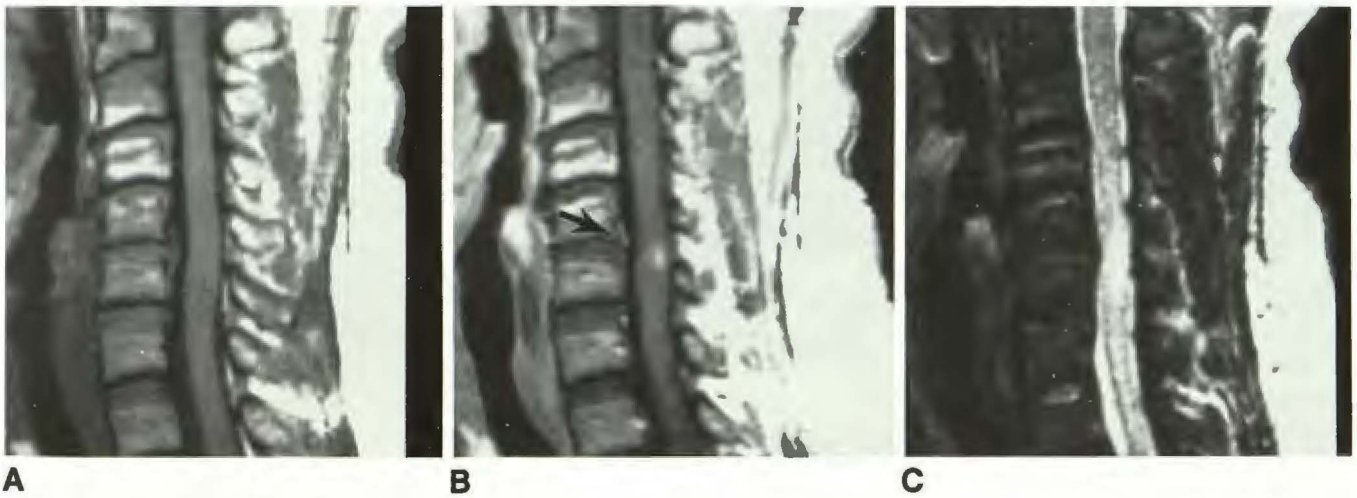


Fig. 2.—C5–C6 disk herniation with cord contusion (surgically proved).

A, Sagittal SE 400/17 image shows large disk herniation at C5–C6, with mild mass effect on cord. Type II marrow change is also noted at C3–C5.

B, Sagittal SE 400/17 postcontrast image shows focal area of increased signal within cord consistent with contusion. A small amount of enhancement is present at C5–C6 in region of posterior longitudinal ligament/outer anulus (*arrow*), and at C6–C7 within posterior anulus.

C, Sagittal SE 2000/90 image shows increased signal within cord in region of contrast enhancement.

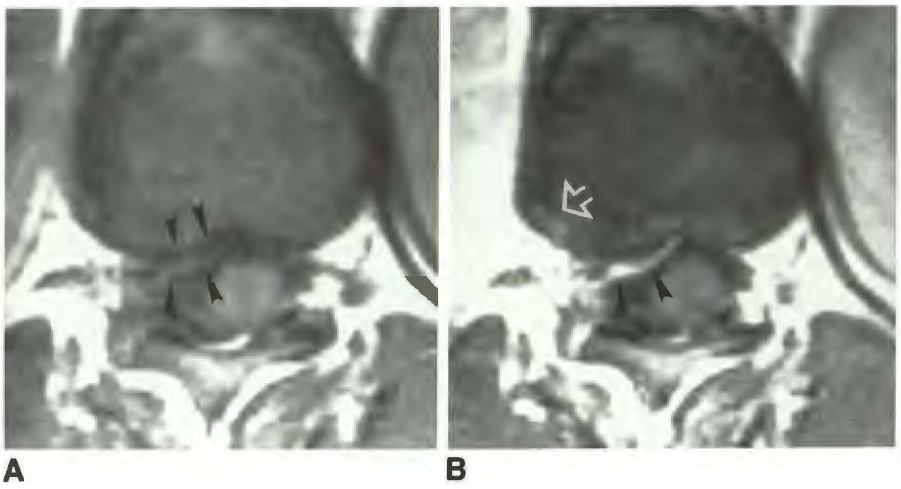


Fig. 3.—Thoracic disk herniation (surgically proved).

A, Axial unenhanced SE 500/17 image shows right-sided herniation (*arrowheads*).

B, Axial enhanced SE 500/17 image shows marked peripheral enhancement (*arrowheads*) representing plexus and/or scar. Central disk herniation does not enhance. Note also peripheral intervertebral disk enhancement (*arrow*).

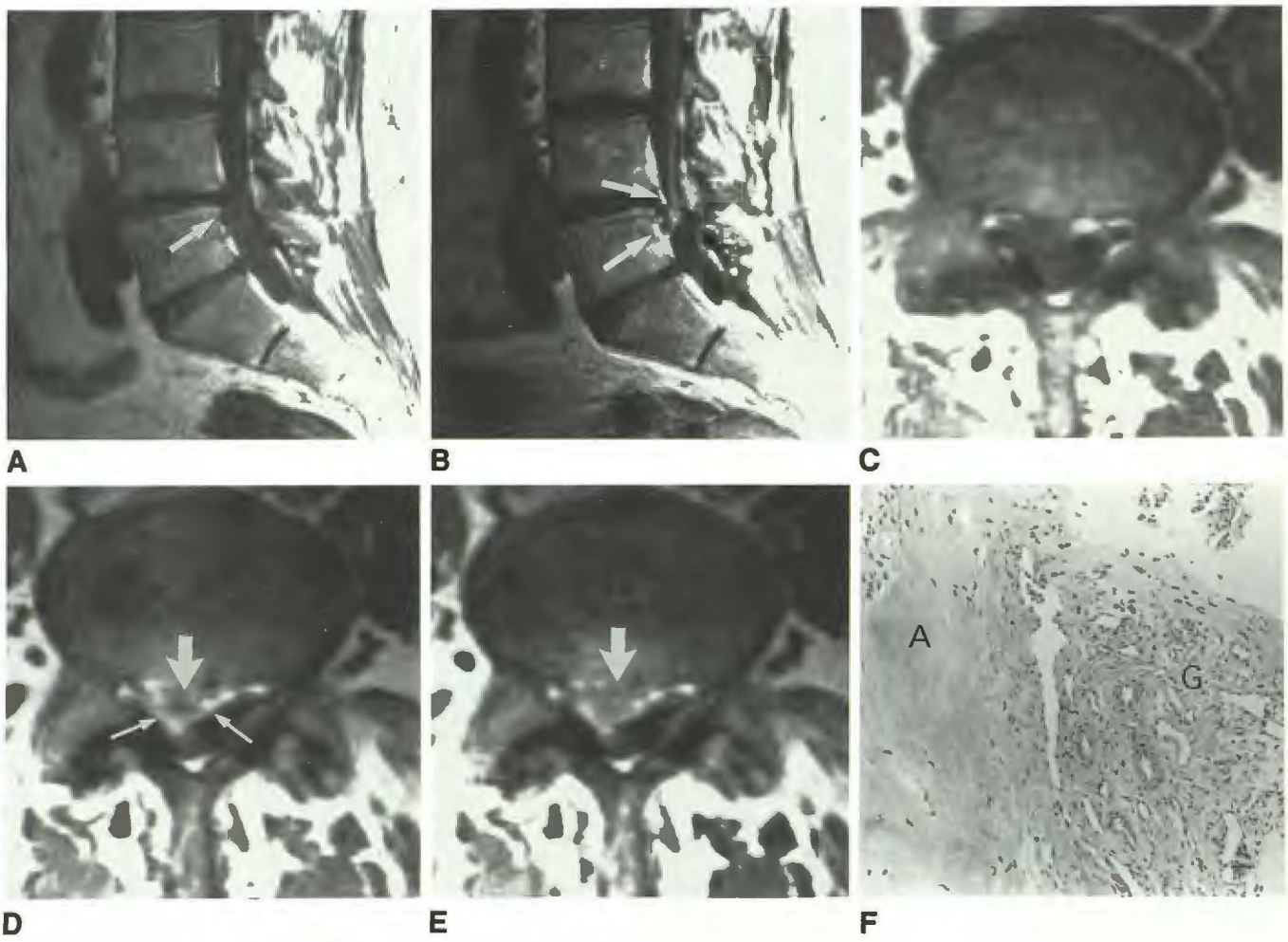


Fig. 4.—Disk herniation with peripheral scar (surgically proved).

A, Sagittal SE 400/17 image shows poorly defined extradural defect at L4–L5 (*arrow*).

B, Sagittal postcontrast image shows central nonenhancing disk herniation with peripheral enhancement (*arrows*).

C–E, Axial SE 500/17 images before (*C*), immediately after (*D*), and 45 min after (*E*) contrast material. Large disk herniation in *C* shows intense peripheral enhancement after contrast (*D*, *small arrows*) with herniation showing no appreciable enhancement centrally (*large arrow*). Delayed scan (*E*) shows enhancement centrally within disk herniation (*arrow*).

F, Low-power light micrograph of surgical specimen shows disk material (A = anulus) in contiguity with granulation tissue (G) with many vessels. (H and E)

Delayed enhancement of disk herniation is presumably related to diffusion of contrast material from adjacent vascularized scar tissue over time.

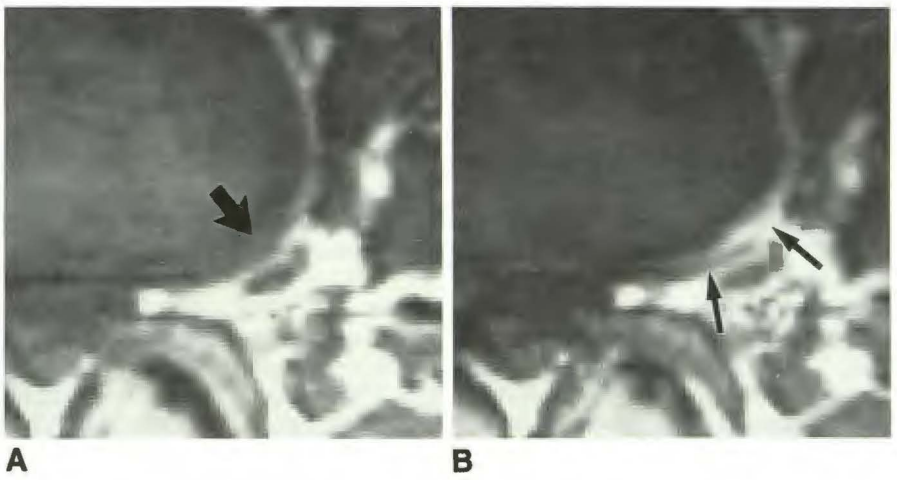


Fig. 5.—Lateral disk bulge with scar (anular tear, surgically proved).
***A*, Axial unenhanced SE 500/17 scan shows moderate-sized lateral bulge (*arrow*).**
***B*, Axial postcontrast image shows peripheral disk enhancement (*arrows*).**

levels; in one other patient, a diagnostic lumbar puncture was performed. The final histologic diagnosis in the operated levels were herniation only ($n = 1$), herniation and scar ($n = 6$), bulge ($n = 1$), and scar only ($n = 1$). Gd-DTPA changed the diagnosis from normal to intrathecal tumor seeding in one patient when roots were seen to enhance diffusely after contrast material. This was subsequently confirmed by CSF cytology as CSF spread of lymphoma. No change in the level of confidence was provided by Gd-DTPA in the operated group (Figs. 4 and 5). MR findings agreed with operative findings at six of nine levels. At one level a lateral herniation with peripheral scar was diagnosed on MR, but only a "swollen" nerve root and scar were found at surgery. In one patient a bulging anulus was diagnosed, but a disk herniation was seen at surgery. In one additional level, a disk herniation was diagnosed, but a bulging anulus was found at surgery.

Pre- vs postcontrast MR.—The postcontrast T2-weighted studies did not contribute additional information to the precontrast studies, except for a case of high signal in the cervical cord adjacent to a herniated disk, which was visualized on the T2-weighted image, but not on the precontrast T1-weighted SE image. Although the enhanced T1-weighted study showed the cord contusion, the T2-weighted findings before enhancement precluded a score of increased confidence after enhancement (Fig. 2).

Comparison of MR sequences.—For lumbar disease, the T1-weighted SE studies provided the most information after enhancement. The FLASH sequence failed to define lateral disk herniations in two cases. As in the cervical spine, the T2-weighted sequence did not add any additional information.

Miscellaneous Findings

Miscellaneous findings are summarized in Table 2. In the cervical and lumbar spines there was consistent enhancement of the foraminal and epidural plexus after contrast administration. This was less obvious in the thoracic spine. Plexus enhancement was evident on sagittal images as a linear band of increased signal intensity that often was "tented" over the extradural defect. The dorsal root ganglia were seen to enhance consistently.

Enhancement of herniated disks.—At seven cervical levels (one operated), in addition to the linear enhancement of the epidural plexus, there was more focal peripheral enhancement surrounding the herniation. In the operated case, scar was identified in the epidural space at the site of disk herniation that showed this focal peridiskal enhancement.

TABLE 2: Summary of Miscellaneous Findings on Gd-DTPA–Enhanced MR Imaging in Patients with Symptoms of Herniated Disk

Finding	Cervical	Thoracic	Lumbar
Peripheral enhancement of herniated disks (no. of levels)	7/27	0/4	12/15
Spinal cord or root enhancement (no. of patients)	1/15	0/2	1/13
Type I endplate (no. of levels)	5/27	0/4	0/15
Parent disk enhancement (no. of levels)			
Central	7/27	0/4	2/15
Peripheral (anular)	6/27	0/4	12/15

In the thoracic spine, linear peripheral plexuslike enhancement also outlined the disk herniation. Linear enhancement was seen as a fine line posterior to the vertebral bodies. Definite scar tissue was not identified in the small surgical specimens obtained via the costotransversectomy used for disk removal.

In the lumbar spine group, there were nine operated levels (four patients). Focal peridiskal enhancement was present on MR at seven levels. At two levels there was no enhancement. In one of these two cases a bulging anulus was diagnosed on MR, but a disk herniation was seen at surgery and showed no associated scar at pathology. The other case was called a disk herniation on MR, but a bulging anulus was found at surgery and a specimen was not obtained. Specimens were obtained at surgery from the periphery of the extradural defects at six of the seven levels; these showed vascularized scar tissue surrounding, and contiguous with, the more central disk material (Figs. 4 and 5). The peridiskal enhancement was qualitatively similar to the amount of scar tissue seen in the surgical specimens; that is, a large amount of enhancement correlated with a large amount of scar tissue present within the histologic specimens. One lumbar spine case was an exception in that the amount of scar tissue seen histolog-

ically was much less than would have been predicted by MR. Enhancement was intense and confined to the periphery of the extradural defect on early enhancement images (less than 15 min). On the delayed axial T1-weighted images, enhancement was present more centrally within the extradural mass (Fig. 4E). In one unoperated patient there was inhomogeneous enhancement of a posterior lateral extradural defect that was diagnosed presumptively as a synovial cyst. Peripheral enhancement was seen surrounding nonenhancing disks in four unoperated patients at four levels.

Enhancement of parent disks.—Enhancement of central parent intervertebral disks occurred in six patients (five cervical, one lumbar) in either clumped (one level), linear (six levels), or homogeneous (two levels) patterns. This was always associated with evidence of degenerative disk disease, which was manifested as either decreased signal intensity on T2-weighted images within the intervertebral disk or evidence of bulging or herniation. Peripheral intervertebral disk enhancement in the region of the anulus fibrosus occurred in 12 patients at 18 levels (six cervical, 12 lumbar) (Figs. 3B and 6). This was usually seen as a small crescentic rim of enhancement within the region of the anulus/longitudinal ligament that could be anterior, lateral, or posterior and was associated with small disk protrusions. This is discussed more fully in our companion article [5].

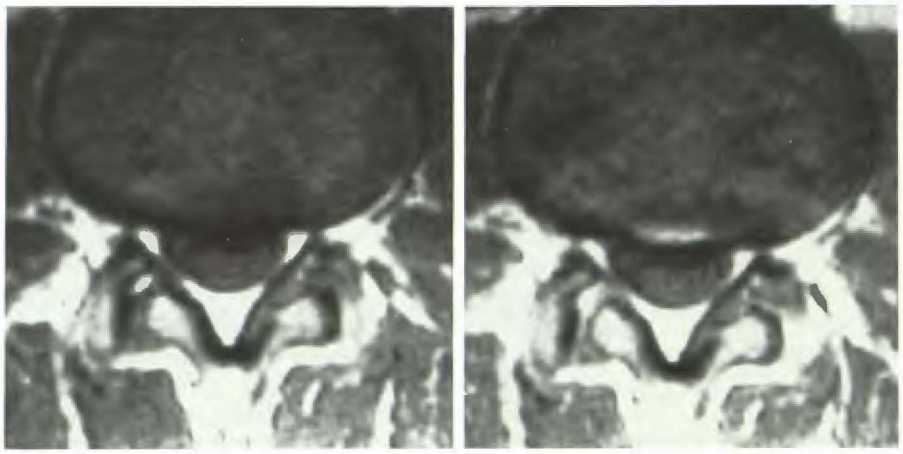
Enhancement of vertebral bodies.—Signal-intensity changes of vertebral bodies associated with degenerative disk disease were seen in eight patients [6]. In the cervical spine group, decreased signal intensity was seen on T1-weighted images (type I) in three patients (five levels). All these cases showed enhancement after contrast administration. In five patients in the lumbar spine group (six levels) and in three patients in the cervical spine group (five levels), increased signal intensity was seen on T1-weighted images (type II). In these cases, enhancement was not seen after administration of contrast material.

Discussion

Considering the small number of patients in the operated group, the value of Gd-DTPA in facilitating the diagnosis of extradural degenerative disease seems limited, with Gd-DTPA increasing the diagnostic confidence in only one of 11 patients and changing the diagnosis in one of 11 patients. However, there was an intrinsic bias that must be considered in the operated group, in that all the patients tended to have had gross disease that was well characterized without contrast material with the use of two orthogonal planes and a 4-mm slice thickness. A larger population needs to be studied to determine the usefulness of Gd-DTPA in more subtle disease. Nevertheless, these preliminary data indicate that Gd-DTPA may still have a role in defining extradural degenerative disease in the cervical region in selected patients because of (1) the consistent and impressive enhancement of the foramina and anterior epidural space due to the foraminal and epidural venous plexus and (2) the enhancement of the epidural fibrosis associated with disk disruption and/or herniation.

While the enhancement pattern seen with Gd-DTPA may play only a limited role in increasing the conspicuity of extradural defects, the observations regarding the enhancement of epidural fibrosis associated with unoperated degenerative disk disease may have greater implications. Enhancement is a marker of epidural fibrosis and attempted healing, which is not necessarily critical for identification of herniations per se but may provide important information about the body's attempt to deal with this disruption. For instance, in the lumbar spine, where our pathologic information is the most precise, there was dramatic enhancement surrounding disk herniations, distinct from plexus enhancement. On histologic study, this proved to be due to peridiskal scar tissue within the anterior epidural space. In several cases, we were frankly surprised at the large amount of enhancing scar relative to the small amount of central nonenhancing disk. While not quantitative, the amount of peridiskal scar was at least equivalent to the amount of disk material in the majority of cases. This scar was identical histologically to the epidural scar seen in postoperative patients, containing a mixture of fibrocytes, collagen, and many small vessels [1]. The combination of vascularized tissue with a large extracellular space containing collagen to sequester the contrast material allows for the intense enhancement [7].

Furthermore, linear enhancement of the peripheral portion of the intervertebral disk (outer anulus/posterior longitudinal ligament complex) was an additional common finding. This



A B

Fig. 6.—Anular enhancement.
***A* and *B*, Axial 500/17 images before (*A*) and after (*B*) contrast administration show intense linear enhancement of outer anulus fibrosus.**

type of enhancement was invariably associated with evidence of degenerative disk disease and anular bulging. While histologically proved in only one case (Fig. 5) [5], this too proved to be a region of scar tissue.

It is well known in the pathologic literature that scar is associated with disk herniations in the previously unoperated patient, and may be looked on as a sign of repair and restitution [2]. However, this has not been studied previously with in vivo imaging and has received scant attention in the imaging literature. Scar is capable of "digesting" or absorbing disk material, and is most intense in the region of the prolapsed portion of the disk [2]. Lindblom et al. [2] hypothesized that this absorption accounted for the disappearance of symptoms with time. Edge neovascularization of the disk material is considered by some pathologists to be the only reliable histologic clue that intervertebral disk prolapse has occurred [8].

Enhancement of the central portion of nonoperated intervertebral disks was seen in the cervical and lumbar spine; to our knowledge, this has not been reported previously. In this small series, cervical disk enhancement was not unusual, and was much more common than lumbar enhancement. Parent intervertebral disk enhancement was always associated with evidence of disk degeneration, either herniation, loss of disk space height, or loss of signal on T2-weighted images. Although we do not have pathologic correlation in this group, the association of disk degeneration suggests the growth of vascularized granulation tissue into the substance of the disk. We have seen similar granulation tissue along the endplate in histologically proved cases of type I marrow change, which consistently enhances after administration of contrast material [6]. Similar changes have been seen in the postoperative spine [1].

The mechanism of enhancement of the epidural space and peridiskal region may have several different etiologies. Another potentially important mechanism, besides scar and plexus described above, is the role that venous stasis has in the development of peri- and intraneural fibrosis [9]. Hoyland et al. [9] found that osteophytic outgrowths into the foramina can cause compression, congestion, and dilatation of the foraminal veins, with resultant peri- and intraneural fibrosis. This fibrosis and venous endothelial injury can occur at a site remote from the compressive force, and was infrequently associated with direct nerve compression. Lindblom et al. [2] also noted that disk herniations lead to fibrosis in the "neighborhood of the disks, the longitudinal ligament, the dura, the roots, the ganglion and the nerves."

Thus, the use of Gd-DTPA in the evaluation of degenerative disease of the spine may have potential for delineating several different distinct mechanisms. In the cervical spine, where Gd-DTPA shows some potential, albeit small, for improving morphologic diagnosis, its major role may be in the enhancement of the epidural plexus outlining the extradural structures. Owing to the anatomy of the cervical plexus, the anterolateral epidural space and foramina show the most enhancement [10]. A second mechanism, much better defined for the lumbar spine, is the presence of scar tissue surrounding disk disruption and herniation. Disk scar tissue contains many small vessels and would account for more focal peridiskal enhancement [1, 7]. Although enhancement of the plexus certainly contributes to the identification of an extradural defect (especially when a large herniation may obstruct venous flow and dilate the plexus above and below the lesion), it is rarely needed for morphologic diagnosis. The enhancement of the peridiskal scar, however, may prove to be of greater value in terms of identifying more subtle disruption and even the various components of the extradural mass produced by herniation.

The immediate clinical utility of Gd-DTPA seems quite limited in the evaluation of extradural disease. It may be helpful in difficult cervical spine cases for morphologic analysis owing to enhancement of the venous plexus. This limited study shows no use for Gd-DTPA in lumbar disk herniations in the unoperated patient. The future use of MR contrast material in a research application for studying the natural history and basic pathophysiology of degenerative disk disease seems brighter. Enhancement of the parent central intervertebral disk and surrounding disk herniations would seem to represent a spectrum of the normal reparative process involving fibrous or granulation tissue. Linear enhancement of the outer anulus/posterior longitudinal ligament in cases of more subtle disruption may represent scar tissue within an anular or radial tear [11]. In addition, the ability to discern the difference between actual disk material and peridiskal scar within an extradural mass may have important prognostic and treatment implications. What is unknown at present is whether or not this scar tissue regresses or progresses and how it relates to the patient's symptomatology and response to various forms of treatment, in particular conservative management with, for example, rest and steroids, as compared with surgery.

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