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Tears of the Anulus Fibrosus:
Assessment with Gd-DTPA–Enhanced MR Imaging

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T2-weighted images have been shown to be capable of defining anular tears in vitro as increased signal intensity within the normal low-signal-intensity anulus fibrosus. Since growth of granulation tissue into anular tears has been described as part of the healing process, it seemed likely that gadolinium-DTPA should enhance anular tears as it does scar tissue in other parts of the spine. We retrospectively reviewed spinal MR images from 30 previously unoperated patients and correlated areas of increased signal intensity within the anulus on T2-weighted images with areas of enhancement on T1-weighted images, and to a limited extent, with surgical findings. Eighteen separate areas of anular enhancement were found in 12 patients (six cervical, 12 lumbar). Only five of these enhancing areas showed increased signal intensity on T2-weighted images, four of a type II tear pattern and one of a type III tear pattern. Contrast enhancement within the anulus was in a pattern of type II tear in 14 and type III in four. Histology from an enhancing type II anulus demonstrated vascularized granulation tissue within the avascular anulus, without focal herniation.

Anular tears may be imaged in vivo not only with T2-weighted images but also with gadolinium-DTPA–enhanced T1-weighted images by virtue of their vascularized granulation tissue.

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It is well known that severe back pain can be present without the appearance of definable morphologic alterations such as disk herniation or canal stenosis on conventional radiologic studies (CT or myelography). A controversial entity, diskogenic pain, has been proposed as a possible mechanism for some of these cases [1, 2]. Diskogenic pain is defined as chronic back pain thought to be due to leakage of the nucleus pulposus into the outer anulus or epidural canal without frank herniation [2, 3]. This proposed etiology, while by no means proved, has spawned a resurgence in diskography in selected cases as a diagnostic tool to define the proposed causal factor, the internal disk disruption or anular tear. Recently, Yu et al. [4] suggested that T2-weighted MR can also define anular disruption without herniation in vitro by the identification of high-signal-intensity material within the anulus.

Park et al. [1] stated that "true tears occur with considerable frequency in elderly subjects, often accompanied by invading fibrovascular tissue which provides evidence of antecedent disruption and repair." On the basis of previous work with gadolinium-DTPA (Gd-DTPA) in both the operated and nonoperated spine, it seemed likely that enhanced MR should be able to identify these regions of disruption via enhancement of granulation tissue [5–7]. To define whether or not Gd-DTPA would enhance anular tears, we reviewed retrospectively the MR images from 30 previously unoperated patients and correlated areas of increased signal intensity within the anulus on T2-weighted images with the appearance on T1-weighted images following contrast and, to a limited extent, with surgical findings. It was not the purpose of this article to address the clinical relevance, if any, of anular disruption.

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Materials and Methods

The subjects of this retrospective study were 30 previously unoperated patients with symptoms suggestive of disk disruption or herniation who were entered into a pilot study evaluating Gd-DTPA in the diagnosis of extradural disease, the results of which have been reported [7]. The 15 men and 15 women had a mean age of 49.2 years.

Examinations were performed on 1.0- or 1.5-T superconducting units.* Images were obtained by using a 12-cm-diameter planar circular surface coil in the receive mode, with the 50-cm body coil serving as the transmitter. Sequences included sagittal and axial T1-weighted spin-echo (SE) images, 400–500/17 (TR/TE), before and after administration of contrast material (0.1 mmol/kg Gd-DTPA†). A 4-mm slice thickness, 50% interslice gap, 256 × 256 matrix and four excitations were used. Sagittal T2-weighted images, SE 2000/90, were obtained before enhancement; a 4-mm slice thickness, 50% interslice gap, 256 × 256 matrix, and one excitation were used.

Images were interpreted independently by two neuroradiologists with specific attention directed to defining areas of enhancement within the anulus on postcontrast T1-weighted images and increased signal intensity within the anulus on T2-weighted images. Anular enhancement was defined as linear or globular increased signal intensity within the confines of the outer margin of the intervertebral disk (anulus fibrosus) after injection of contrast material.

T2-weighted images were evaluated for patterns of increased signal intensity as described by Yu et al. [4]: type II tears show increased signal within the anulus extending from the surface to the nucleus; type III tears show increased signal in the region in the torn Sharpey's fibers.

Surgical confirmation was available in one patient in whom an anular tear was seen on T2-weighted images and anular enhancement was seen in the same region.

Bulging disks were measured from sagittal images by using the computer console and graphic display device. Measurements were obtained from the outer margin of the anulus to a point along the line connecting the adjacent endplate margins.

Results

Results are shown in Table 1. There were 18 separate areas of anular enhancement at 18 disk levels in 12 patients (six cervical, 12 lumbar) (Figs. 1 and 2). Only five of these enhancing areas showed increased signal intensity on T2-weighted images. The pattern of increased signal intensity on the T2-weighted images was consistent with type II tears in four, being centrally placed within the outer anulus, and type III tear in one, being along the endplate margin of the anulus [4].

Contrast enhancement was either globular or linear within the central portion of the anulus in 14, in a pattern similar to the signal-intensity changes seen in type II tears. The enhancement pattern was linear, along the endplate margin in the region of Sharpey's fibers, in four; this pattern was similar to the signal-intensity changes described for type III tears [4].

One patient with a type II tear pattern of enhancement at the L3–L4 level had surgery principally for a lateral herniation at the level below (Fig. 2). However, a specimen from the enhancing region was obtained at L3–L4. Surgery and histology showed vascularized granulation tissue within the anulus fibrosus, without focal herniation.

Fifteen of 18 disk levels were abnormal, showing bulging anuli that varied in size from 2 to 5 mm (average, 2.4 mm).

Discussion

Diskogenic pain is described as chronic back pain thought to be due to leakage of the nucleus pulposus into the outer anulus or epidural canal without focal protrusion or extrusion [3, 8]. A similar phenomenon, gradual disk prolapse, has been described by Adams and Hutton [9]. In cadaveric spines subjected to fatigue loading, Adams and Hutton found the initial injury was anular distortion that progressed to radial fissures with eventual extrusion of nuclear pulp. These are not trivial definitions, since the treatment proposed by some for this condition is total excision of the nucleus or interbody fusion via the anterior or posterior approach, respectively [10, 11]. Previously, the only method available to evaluate anular tears was diskography, a diagnostic technique that has come under increasing scrutiny [8, 12–17]. MR has entered into this controversial arena by the recent demonstration of its ability to noninvasively image anular tears in vitro as areas of increased signal intensity on T2-weighted images [4].

Gd-DTPA has shown its ability to image a variety of diseases associated with degenerative disk disease. Gd-DTPA causes enhancement of scar or granulation tissue, either surrounding disk herniations or within endplates or intervertebral disks, associated with the body's reparative process [5–7]. Since growth of granulation tissue, nerves, and blood vessels into anular tears as part of the healing process has been implicated as a source of diskogenic pain [18], it is a logical extension of the use of Gd-DTPA to enable evaluation of anular tears, provided that vascularized granulation tissue is present, and in sufficient amount.

TABLE 1: Gd-DTPA Enhancement of Anular Tears on T1-Weighted Images vs Increased Signal on T2-Weighted Images

Case No.	T1-Weighted Images: Region of Enhancement	T2-Weighted Images: Increased Signal	Size of Anular Bulge (mm)
1	L5, posterior	L5, posterior	0
2	L3, L lateral	L3, L lateral	4
	L3, R lateral	L3, R lateral	2
	L4, R lateral	L4, R lateral	3
3	L4, R lateral	–	5
4	L4, R lateral	–	3
5	L5, anterior	–	4
	L4, anterior	–	4
6	L5, anterior	–	2
7	L4, anterior	–	0
	L4, posterior	–	2
	L2, anterior	–	0
8	C5, posterior	–	2
9	C5, posterior	–	3
10	C6, posterior	C6, posterior	3
11	C5, posterior	–	3
	C7, posterior	–	2
12	C6, posterior	–	2

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

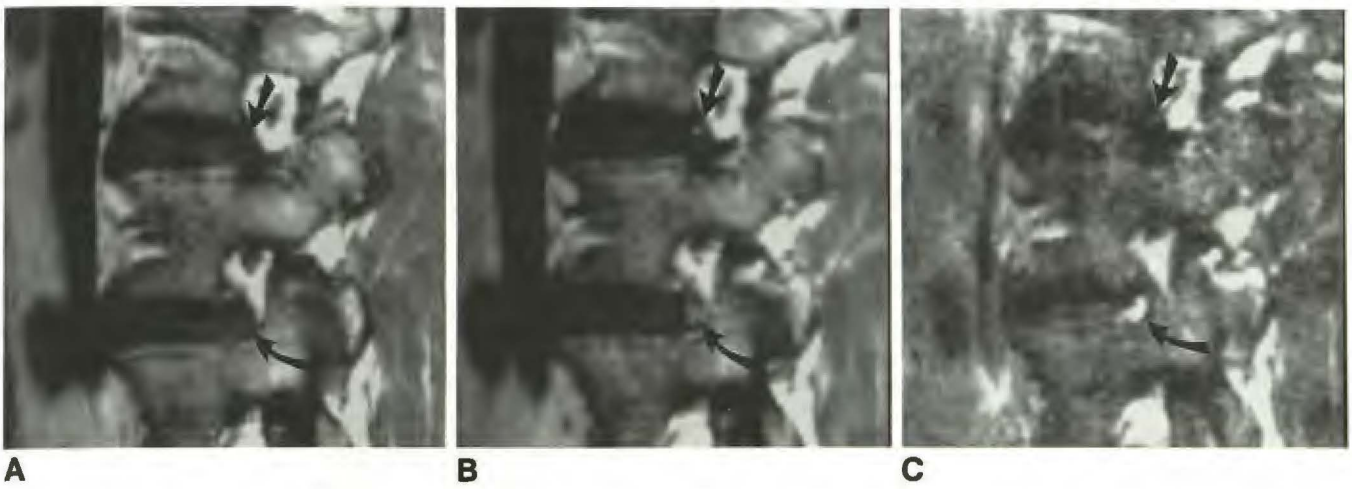

Fig. 1.—*A–C*, Types II and III anular tears on T1-weighted parasagittal images before (*A*) and after (*B*) contrast and on T2-weighted image (*C*). Type III tear (*straight arrows*) is seen at L3–L4 level as small linear area of enhancement adjacent to inferior L3 endplate on T1-weighted images (*A* and *B*) and as small linear area of increased signal on T2-weighted image (*C*). Type II tear (*curved arrows*) is seen at L4–L5 level as a more globular area of enhancement within central portion of peripheral anulus on T1-weighted images (*A* and *B*) and as increased signal on T2-weighted image (*C*).

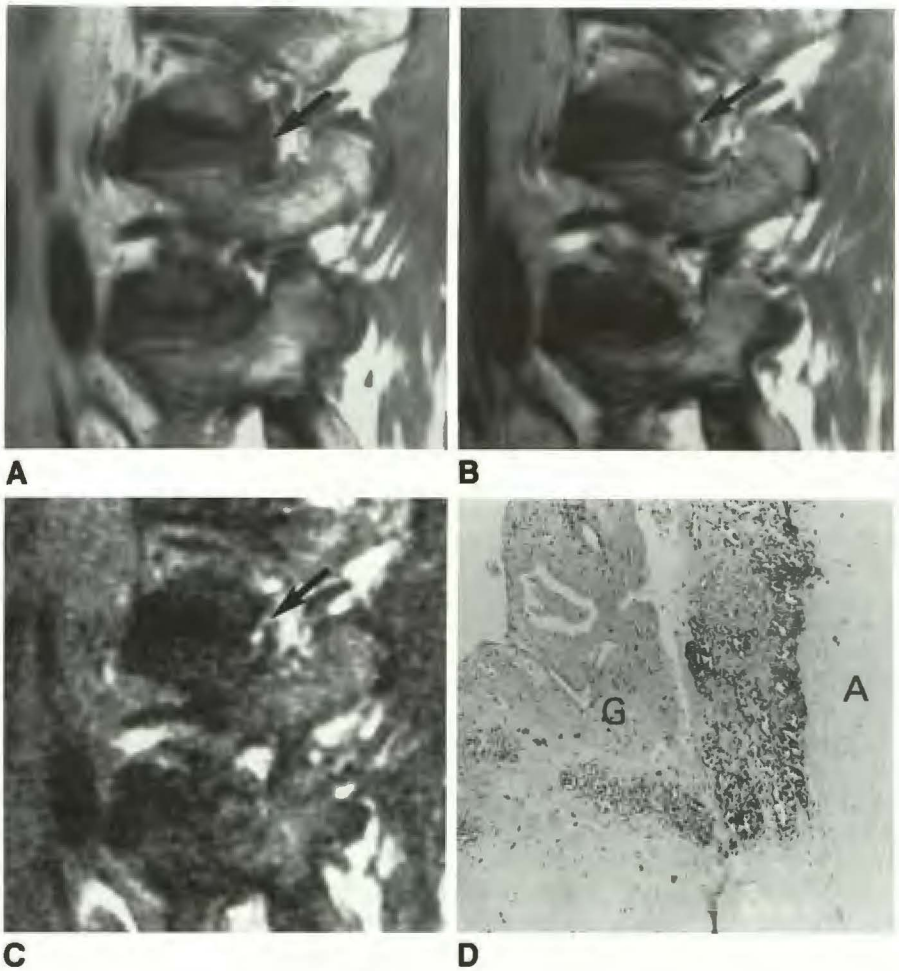

Fig. 2.—*A–C*, Anular tear on T1-weighted images before (*A*) and after (*B*) contrast and on T2-weighted image (*C*). Type II tear pattern (*arrows*) is seen as globular increased signal intensity within lateral L3–L4 anulus on T1-weighted images (*A* and *B*). Tear is seen as high signal intensity within low-signal-intensity anulus on T2-weighted image (*C*). At surgery, granulation tissue was present within anulus, without focal herniation.

D, Histologic specimen from L3–L4 anulus. Vascularized granulation tissue (G) is present, alongside avascular anulus fibrosus (A). (H and E, original magnification ×50)

Although the configuration of enhancement is similar to the areas of increased signal on T2-weighted images described by Yu et al. [4], our only objective correlation was in the single patient in whom there was linear enhancement of the anulus, increased signal from within the anulus on T2-weighted images, and surgical confirmation of granulation tissue within the anulus. Thus, preliminary experience indicates that anular tears may be imaged in vivo not only with T2-weighted

images, but also with Gd-DTPA–enhanced T1-weighted images by virtue of their vascularized granulation tissue.

Firooznia et al. [19] have described anular enhancement on CT in the postoperative patient. They saw anular enhancement in 25% of normal disks and 54% of bulging disks, which they postulated as secondary to normal vascularity of the disk margin, as well as to "regrowth of vascularity through the cartilagenous endplate into the disk concomitant with aging and degenerative changes" [19–22].

The possibility that the enhancing regions we saw within the anuli represent normal outer anular vascularity is unlikely for several reasons: (1) the observed enhancement was quite focal and did not correspond to the diffuse peripheral anular vascularity described by Hassler [23] or the diffuse anular enhancement described by Firooznia et al. [19]; (2) the enhancement appeared to extend deeper within the substance of the anulus and was not just along the periphery (as normal vascularity has been defined) [23]; (3) areas of anular enhancement may show increased signal on T2-weighted images in a pattern similar to that of pathologically demonstrated anular tears [4]; and (4) pathologic proof in one case in our series showed granulation tissue within the anulus at the site of enhancement.

The abnormality of the bulging anulus has been documented by Yu et al. [4], who saw radial tears within 84% of disks bulging more than 2.5 mm [24]. Of the 16 disk levels in which we observed this enhancement, only two did not have bulging disks. The majority of the disks bulged 3 mm or more.

Many more areas of enhancement within the anulus were visualized on T1-weighted enhanced images than on T2-weighted images in our limited series. It is tempting to speculate that enhanced MR is more sensitive to tears than T2-weighted images are, perhaps because of improved contrast and signal-to-noise. Our T2-weighted images were not heavily T2-weighted, and this may have contributed to the apparently poor sensitivity of this sequence in our series. Another possible explanation for the apparently poor sensitivity of the T2-weighted images is partial-volume averaging of high-signal-intensity anular tears with adjacent low-signal-intensity intact anuli on the 4-mm-thick slices, or small tears that were quite vascular but had a relatively small interstitial space with little free water. Yu et al. [4] did not mention how often the anular tears seen in vitro in their cadaver study were successfully imaged with MR, nor did they specify the number of excitations used for the T2-weighted images. Further studies are needed to define which technique is superior.

No attempt was made to undertake a clinical study correlating pain with MR findings. Rather, these findings are presented as an anatomic study regarding the utility of Gd-DTPA–enhanced T1-weighted images for imaging the healing response of the intervertebral disk in vivo. This study is necessarily incomplete. Correlation of diskographic findings, MR, and pathology is possible in vitro. However, the in vivo MR characteristics are much more difficult to define: Few surgical specimens from anular tears without frank herniation are available at our institution owing to the reluctance of surgeons to operate without grossly identifiable morphologic alterations (i.e., herniation), and the use of diskography is highly variable.

In conclusion, preliminary evidence indicates that enhanced T1-weighted images are able to image anular tears in vivo, secondary to ingrowth of vascularized granulation tissue. Future research needs to address (1) how diskography and enhanced MR correlate with clinical symptoms and outcome after surgery and (2) the relationship of anular enhancement to diskogenic pain [25].

REFERENCES

1. Park WM, McCall IW, O'Brien JP, Webb JK. Fissuring of the posterior anulus fibrosus in the lumbar spine. *Br J Radiol* **1979**;52:382–387
2. Milette PC, Melanson D. Lumbar diskography (letter). *Radiology* **1987**;163:828–829
3. McCarron RF, Wimpee MW, Hudkins PG, Laros GS. The inflammatory effect of nucleus pulposus, a possible element in the pathogenesis of low back pain. *Spine* **1987**;12:760–764
4. Yu S, Sether LA, Ho PSP, Wagner M, Haughton VM. Tears of the anulus fibrosus: correlation between MR and pathologic findings in cadavers. *AJNR* **1988**;9:367–370
5. Hueftle MG, Modic MT, Ross JS, et al. Lumbar spine: postoperative MR imaging with Gd-DTPA. *Radiology* **1988**;167:817–824
6. Modic MT, Steinberg PM, Ross JS, Masaryk TJ, Carter JR. Degenerative disk disease: assessment of changes in vertebral body marrow with MR imaging. *Radiology* **1988**;166:193–199
7. Ross JS, Modic MT, Masaryk TJ, Carter J, Marcus RE, Bohlman H. Assessment of extradural degenerative disease with Gd-DTPA–enhanced MR imaging: correlation with surgical and pathologic findings. *AJNR* **1989**;6:1243–1249
8. Laros GS, Leo J-S. Role of diskography after negative postmyelography CT scans (letter). *AJNR* **1988**;9:1244
9. Adams MA, Hutton WC. Gradual disc prolapse. *Spine* **1985**;10:524–531
10. Fernstrom V. A discographic study of ruptured lumbar intervertebral discs. *Acta Chir Scand [Suppl]* **1960**;258:11–60
11. Cloward RB. Discography: technique, indications and evaluation of normal and abnormal intervertebral disc. *AJR* **1952**;68:552–564
12. Shapiro R. Current status of lumbar diskography (letter). *Radiology* **1987**;159:815
13. Abdelwahab IF, Gould ES. The role of diskography after negative postmyelography CT scans: retrospective review. *AJNR* **1988**;9:187–190
14. Milette PC, Melanson D. A reappraisal of lumbar diskography. *J Can Assoc Radiol* **1982**;33:176–182
15. Grubb SA, Lipscomb HJ, Guilford WB. The relative value of lumbar roentgenograms, metrizamide myelography, and discography in the assessment of patients with chronic low-back syndrome. *Spine* **1987**;12:282–286
16. Scullin DR. Lumbar diskography (letter). *Radiology* **1987**;162:284
17. Errico TJ. The role of diskography in the 1980's (letter). *Radiology* **1987**;162:285–286
18. Hirsch C, Schajowicz F. Studies on structural changes in the lumbar anulus fibrosus. *Acta Orthop Scand* **1952**;22:184–223
19. Firooznia H, Kricheff II, Rafii M, Golimbu C. Lumbar spine after surgery: examination with intravenous contrast-enhanced CT. *Radiology* **1987**;163:221–226
20. Coventry MB, Ghormley RK, Kernochan JW. The intervertebral disc: its microscopic anatomy and pathology. I. Anatomy, development, and physiology. *J Bone Joint Surg [Am]* **1945**;27-A:105–112
21. Coventry MB, Ghormley RK, Kernohan JW. The intervertebral disc: its microscopic anatomy and pathology. II. Changes in the intervertebral disc concomitant with age. *J Bone Joint Surg [Am]* **1945**;27-A:233–247
22. Coventry MB, Ghormley RK, Kernohan JW. Intervertebral disc: its microscopic anatomy and pathology. III. Pathologic changes in the vertebral disc. *J Bone Joint Surg [Am]* **1945**;27-A:460–474
23. Hassler O. The human intervertebral disc: a microangiographical study on its vascular supply at various ages. *Acta Orthop Scand* **1970**;40:765–772
24. Yu S, Haughton VM, Sether LA, Wagner M. Anulus fibrosus in bulging intervertebral disks. *Radiology* **1988**;169:761–763
25. Mooney V. Where is the pain coming from? Presidential address, International Society for the Study of Lumbar Spine. *Spine* **1987**;12:754–759