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The Postoperative Lumbar Spine: Enhanced MR Evaluation of the Intervertebral Disk

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PURPOSE: To document the pattern of enhancement and morphologic changes on MR images that occur in the intervertebral disk and adjacent vertebral bodies after diskectomy and to correlate the presence of intervertebral disk enhancement with the preoperative and postoperative clinical findings. **METHODS:** Preoperatively, and at 3 months and 6 months after surgery, 94 adults who had first-time surgery for a herniated lumbar intervertebral disk that was associated with radiculopathy, expressed as leg symptoms or signs (with or without lower back pain), were asked to respond to a questionnaire regarding pain, were given serial physical examinations, and were examined with contrast-enhanced MR imaging. The measures of clinical outcome that were evaluated included the straight leg raise sign, radicular pain, and lower back pain. Type of disk herniation, intervertebral disk enhancement, disk space height, and degenerative end-plate changes were also assessed. **RESULTS:** Of the 94 patients evaluated, 19 (20%) had postoperative intervertebral disk enhancement that was not present on the preoperative study. The pattern of enhancement was remarkably consistent, with 18 of the cases showing linear enhancement within the intervertebral disk, manifested as two thin bands paralleling the end plates. End-plate enhancement was present in 7 (37%) of the 19 patients with disk enhancement. There were no significant associations between disk enhancement and specific clinical symptoms before or after surgery. **CONCLUSION:** Our group of asymptomatic postoperative patients had anular enhancement (curette site), disk enhancement, and vertebral end-plate enhancement on MR images without evidence of disk space infection. This finding points out the need to understand asymptomatic postoperative changes that are sequelae of surgery and not necessarily indicators of infection.

Index terms: Spine, intervertebral disks; Spine, magnetic resonance; Spine, surgery; Magnetic resonance, postoperative

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The postoperative lumbar spine has been studied extensively with magnetic resonance (MR) imaging mainly in regard to such changes within the epidural space as residual and recurrent herniation and epidural fibrosis (1–3). More recently, Boden et al (4) suggested that in the postoperative spine the triad of intervertebral disk space enhancement, anular enhancement, and vertebral body enhancement lead to the diagnosis of disk space infection, when present with the appropriate laboratory findings, such as an elevated sedimentation rate. The natural changes in signal intensity and enhancement of the vertebral end plates and intervertebral disk proper that occur after diskectomy are poorly understood, yet knowledge of such changes is fundamental to understanding such overt pathologic processes as disk space infection.

For instance, the postoperative diagnosis of disk space infection may be complicated by the presence of preoperative asymptomatic degenerative end-plate changes. These degenerative end-plate changes may also show low signal on T1-weighted MR images, and they may show enhancement, as does infection (5, 6). We have also anecdotally noted that intervertebral disk space enhancement and degenerative end-plate changes (type I) can occur in the postoperative state presumably as a consequence of

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TABLE 1: Inclusion and exclusion criteria

Inclusion Criteria	
1.	Clinical signs and symptoms consistent with a single-level unilateral extruded or sequestered lumbar disk.
2.	Radiologic evidence consistent with compression of a nerve root and/or confirming the existence of a single-level unilateral extruded or sequestered disk fragment.
3.	Men and women of nonchildbearing potential. Women of childbearing potential were eligible if they had a negative pregnancy test at the enrollment visit and were using oral contraceptives or an intrauterine device during study participation.
4.	18 to 60 years of age.
5.	Good general health with no significant systemic abnormalities on baseline examination. All results from usual, routine laboratory tests must have been within normal limits.
6.	Patients entering the study must have undergone a period of at least 2 weeks of nonsurgical treatment without resolution of the problem, unless the surgeon decided the patient was experiencing intractable pain or there was substantial presence or progression of loss of neurologic function.
7.	Informed consent signed by the patient or the patient's legally authorized representative before surgery.
Exclusion Criteria	
1.	Previous lumbar surgery.
2.	Presence of symptoms consistent with either multilevel and/or bilateral herniated disk.
3.	Presence of severe scoliosis or any other severe spinal condition(s) that may affect the patient's clinical outcome.
4.	Previous far lateral herniated disk with extraspinal removal.
5.	Presence of any immunodeficiency disease, diabetes, hypertension, or any systemic condition that, in the surgeon's opinion, may influence the outcome of the proposed surgery.
6.	Incision of the dura during surgery.
7.	Treatment with any peridural steroids within 4 weeks before surgery.
8.	Treatment with oral steroids or nonsteroidal antiinflammatory drugs within 24 hours before surgery.
9.	Treatment with anticoagulant therapy within 7 days before surgery.
10.	Previous percutaneous nucleotomy or chemonucleolysis.
11.	Presence of thrombocytopenia or other bleeding disorders.
12.	Treatment with platelet-inhibiting medications, such as aspirin within 24 hours before surgery.
13.	Myelogram or lumbar puncture for any reason within 24 hours before surgery.
14.	Prisoner, pregnant woman, or minor (under 18 years of age).

the diskectomy and the degenerative process, without evidence of disk space infection.

The purpose of this study was to document the pattern of enhancement and morphologic changes on MR images that occur in the intervertebral disk and adjacent vertebral bodies after diskectomy and to correlate the presence of intervertebral disk enhancement with the preoperative and postoperative clinical symptomatology. This knowledge is necessary to put into proper perspective the pathologic changes, such as disk space infection, whose imaging characteristics may overlap those of degenerative changes.

Materials and Methods

The study population was formed from a portion of a randomized, multicenter clinical trial designed to evaluate postoperative peridural fibrosis and related symptoms after single-level unilateral laminectomy/diskectomy for lumbar disk herniations. Patients eligible for this study were adults who were scheduled to undergo first-time surgery for diagnosed acute or subacute herniation of lumbar intervertebral disk material associated with radiculopathy, expressed as leg symptoms or signs, with or without lower back pain, and who met the criteria shown in Table 1. The exclusion criteria were formulated principally to obtain a pristine patient population who had not had prior spine surgery and who had well-defined radicular symptoms and to minimize any potential problems related to wound healing, since the investigational device inhibited fibroblast migration.

To eliminate any potential treatment bias, analysis was restricted to the control group of patients, who had no investigational device inserted into the laminectomy site at the time of surgery. All 94 patients in the control group underwent a presurgical eligibility evaluation, which included physical examination by a surgeon and MR imaging performed with and without intravenous contrast material. Patients also completed a questionnaire concerning their signs and symptoms.

All surgeries were performed via a midline approach with open visualization of the affected interspace achieved by surgical loupes or a microscope. Surgeons were free to perform whatever degree of laminectomy was necessary to assure adequate visualization and ultimate decompression of the affected nerve root.

Follow-up evaluations were performed at 3 months and 6 months after surgery and included 1) examination of the wound site for quality of healing and presence of irritation

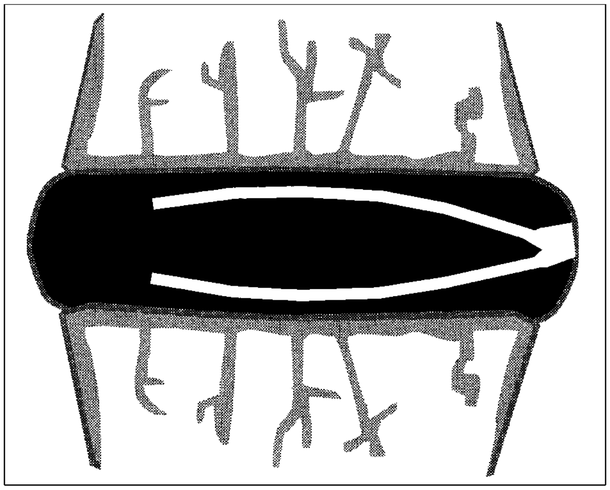


Fig 1. Schematic of typical postoperative enhancement pattern, with linear horizonal bands of enhancement paralleling the end plates, which converge upon the surgical site in the posterior anulus fibrosus.

by physical examination; 2) MR imaging with and without contrast material; 3) completion of a questionnaire; and 4) clinical evaluation. An investigator blinded to the preoperative data conducted each of the postoperative clinical evaluations.

Clinical Evaluation

The clinical outcome measures that were evaluated included the straight leg raise sign, radicular pain, and lower back pain.

Straight leg raise sign.—This test was done on both legs of each patient, and the approximate angle at which the patient experienced pain was recorded. The rating for each leg was converted to a score on a scale of 0 to 3 as follows: 0 = leg raised 90°, 1 = leg raised more than 75° but less than 90°, 2 = leg raised more than 45° but less than 75°, 3 = leg raised less than 45°. The leg that was scored highest (smallest angle) was used for analysis.

Radicular (leg/buttock) pain.—For radicular pain, the patient was asked to evaluate leg and buttock pain only. The score was based on the leg and/or buttock with the most severe pain. The patient rated the most severe pain he or she had experienced on a standard visual analog scale, on which 0 represented no pain and 10 represented the most excruciating pain imaginable (7). The patient drew a line through the scale on the form at the position that most accurately described the level of pain he or she was trying to relate. The full scale was 10 cm long, and the patient's mark was converted to a score according to the following key: 0) 0 cm = none; 1) 1–3 cm = mild; 2) 4–6 cm = moderate; 3) 7–10 cm = severe.

Lower back pain.—For lower back pain, the patient was asked to evaluate back pain (as distinguished from leg and/or buttock pain) using the same procedure described above for radicular pain.

MR Evaluation

All MR imaging was performed on superconducting units (0.5 T to 1.5 T) using an 8-inch elliptical spine surface coil or equivalent.

Protocol.—Two-dimensional axial T1-weighted spin-echo and sagittal T1-weighted and T2-weighted spin-echo images were obtained before administration of contrast material. Gadopentetate dimeglumine or equivalent was administered at a dosage of 0.1 mmol/kg, slow intravenous push. Axial and sagittal two-dimensional T1-weighted spin-echo images were obtained after administration of contrast material and completed within the first 20 minutes after injection.

Axial images were obtained in a gap-and-fill fashion to allow complete coverage of the surgical site and were continuous (ie, not only disk space levels). Axial images covered at least one level above the surgical site to one level below the site (except for L-5 to S-1, where the most caudal section was to the middle S-1 body).

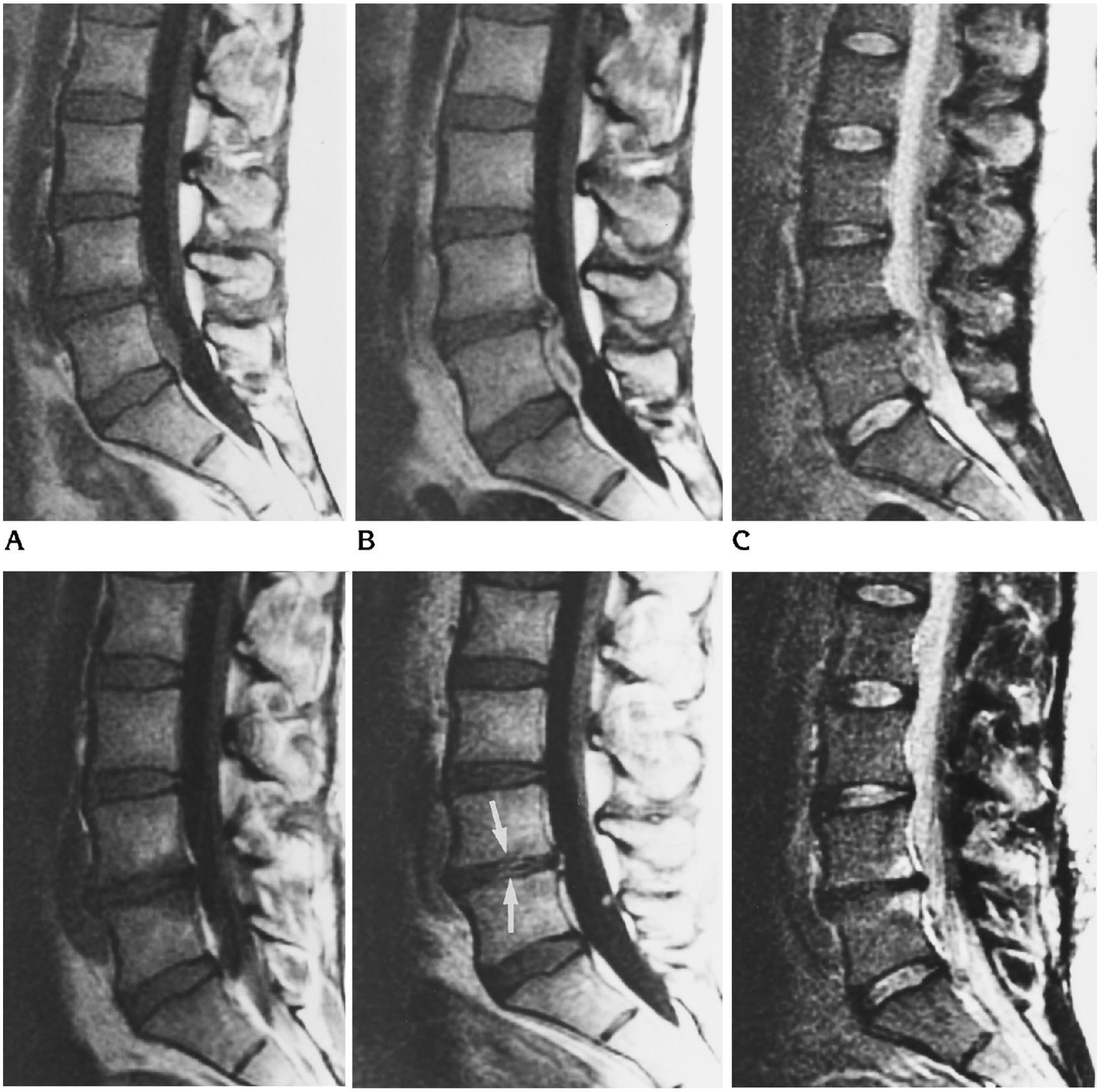
Postoperative images.—Evaluation of all MR images was initially done by one reader who was blinded to the clinical findings. After initial identification of the subset of patients in the study group who had intervertebral disk space enhancement, these MR images were reevaluated by two neuroradiologists for more specific analysis of the disk spaces and adjacent vertebral bodies.

Classification of disk abnormalities was as follows: normal = no disk extension beyond the interspace; bulge = circumferential symmetric extension of the disk beyond the interspace; protrusion = focal or symmetric extension of the disk beyond the interspace, with the base against the disk of origin broader than any other dimension of the protrusion; and extrusion = more extreme extension of the disk beyond the interspace, with the base against the disk of origin narrower than the diameter of the extruding material itself. A sequestered disk was defined as herniation that is no longer attached to the remaining parent disk. The imaging finding is an extension of the disk beyond the interspace with superior or inferior migration of the disk material away from the parent interspace. The size of each of the different herniation types was qualitatively rated on a scale of 0 to 4, with 0 = none; 1 = small; 2 = medium; 3 = large, and 4 = very large. With these definitions of bulge, protrusion, and extrusion, interobserver agreement of 80% has been previously found in a group of 125 subjects (κ = .59) (8).

Disk space enhancement morphology was graded as diffuse, linear, mottled, or mixed. Any loss of disk space height was noted, as were end-plate degenerative changes (types I and II), signal intensity of the disk on the T2-weighted spin-echo images relative to the preoperative study, and presence of end-plate enhancement.

Statistics

Fisher's Exact Test was used to determine whether there was an association between disk enhancement and



A B C D E F

Fig 2 *A–C,* Preoperative sagittal T1-weighted images before (*A*) and after (*B*) administration of contrast material show a large free fragment extending from the L4–5 intervertebral disk with inferior migration behind the L-5 body. There is a moderate amount of surrounding enhancement. The T2-weighted image (*C*) shows decreased signal from the L4–5 disk space, and heterogeneous signal from the disk fragment.

D–F, Sagittal T1-weighted image 3 months after surgery at L4–5 (*D*) shows slightly decreased disk space height and low signal from the adjacent end-plate marrow and complete removal of the disk fragment. After administration of contrast material (*E*), there are parallel bands of enhancement within the disk (*arrows*) and slight posterior anular enhancement. Note the incidental small intradural enhancing lesion (presumed neurinoma), which was stable in appearance over the course of the study. The T2-weighted image obtained postoperatively (*F*) shows the high signal from the end plates typical for type I degenerative change.

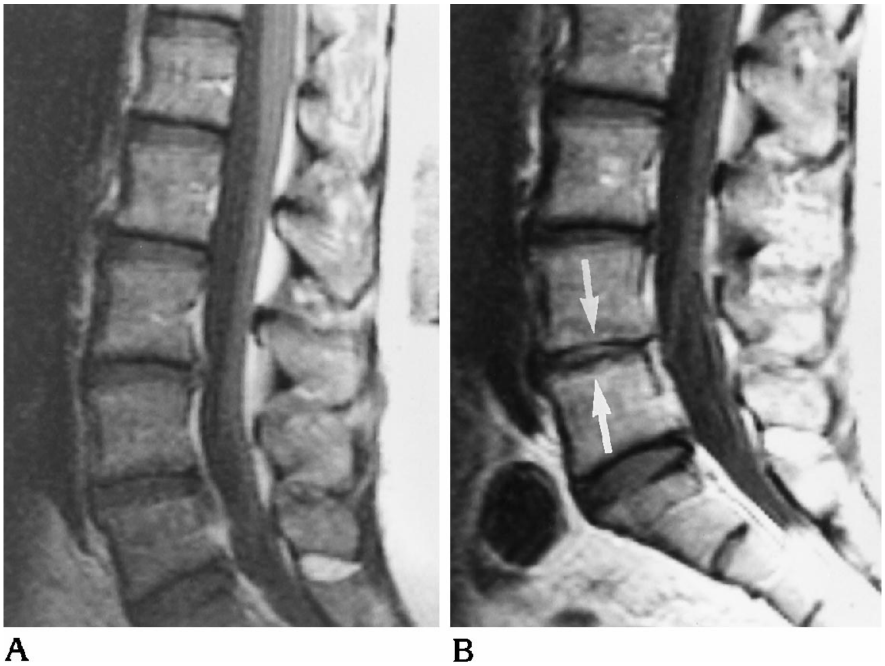


Fig 3. Lost disk space height.

A, Preoperative T1-weighted sagittal image after administration of contrast material shows a small free fragment extending inferiorly from the L4–5 disk space behind the L-5 body. The L4–5 disk space is mildly decreased in height.

B, After surgery, the sagittal contrast-enhanced T1-weighted image shows complete removal of the fragment, with pronounced loss of disk space height. There is linear enhancement of the L4–5 disk space (arrows).

specific physical findings. A significance level of $P = .05$ (two-tailed) was applied. Additionally, logistic regression analysis was used to assess the significance of motor weakness or sensory deficit at any site 1 month after surgery and of sensory deficit 6 months after surgery. Owing to the fact that fewer than 10 patients had motor weakness at 6 months, no modeling was performed.

Results

Of the 94 patients evaluated, 19 (20%) had postoperative intervertebral disk enhancement that was not present on the preoperative study. The pattern of enhancement was remarkably consistent; 18 of the patients had linear enhancement within the intervertebral disk, seen as two thin bands paralleling the end plates (Figs 1–4). In all 94 patients, anular enhancement was seen postoperatively within the posterior aspect of the intervertebral disk at the site of surgical curette. One patient had a mixed pattern of mottled and linear enhancement.

Degenerative end-plate changes, disk space height, and intervertebral disk signal changes on the T2-weighted images are described in Table 2. All the patients who had a change in end-plate signal to type I (decreased signal on T1-weighted images and increased signal on T2-weighed images) had end-plate enhancement (7[38%] of 19).

Findings at 3-Month Follow-up

Fifteen patients had intervertebral disk enhancement at the first postoperative follow-up study who did not have enhancement preoperatively. These 15 patients were operated on by 9 different surgeons at 3 different clinical centers. There was no clinical evidence of abscess or wound infection during the study period. Types of herniations among these 15 patients included protrusion (n = 3), extrusion (n = 4), and sequestered (n = 8); they occurred at the L3–4 level (n = 1), the L4–5 level (n = 5), and the L5-S1 level (n = 9).

Findings at 6-Month Follow-up

Four patients had intervertebral disk enhancement at the 6-month postoperative study but not at the 3-month postoperative examination. These four patients were operated on by three different surgeons at two different clinical centers. There was no clinical evidence of abscess or wound infection during the study period. Types of herniations among these four patients included protrusion (n = 1) and extrusion (n = 3); they occurred at the L4–5 level (n = 1) and the L5-S1 level (n = 3).

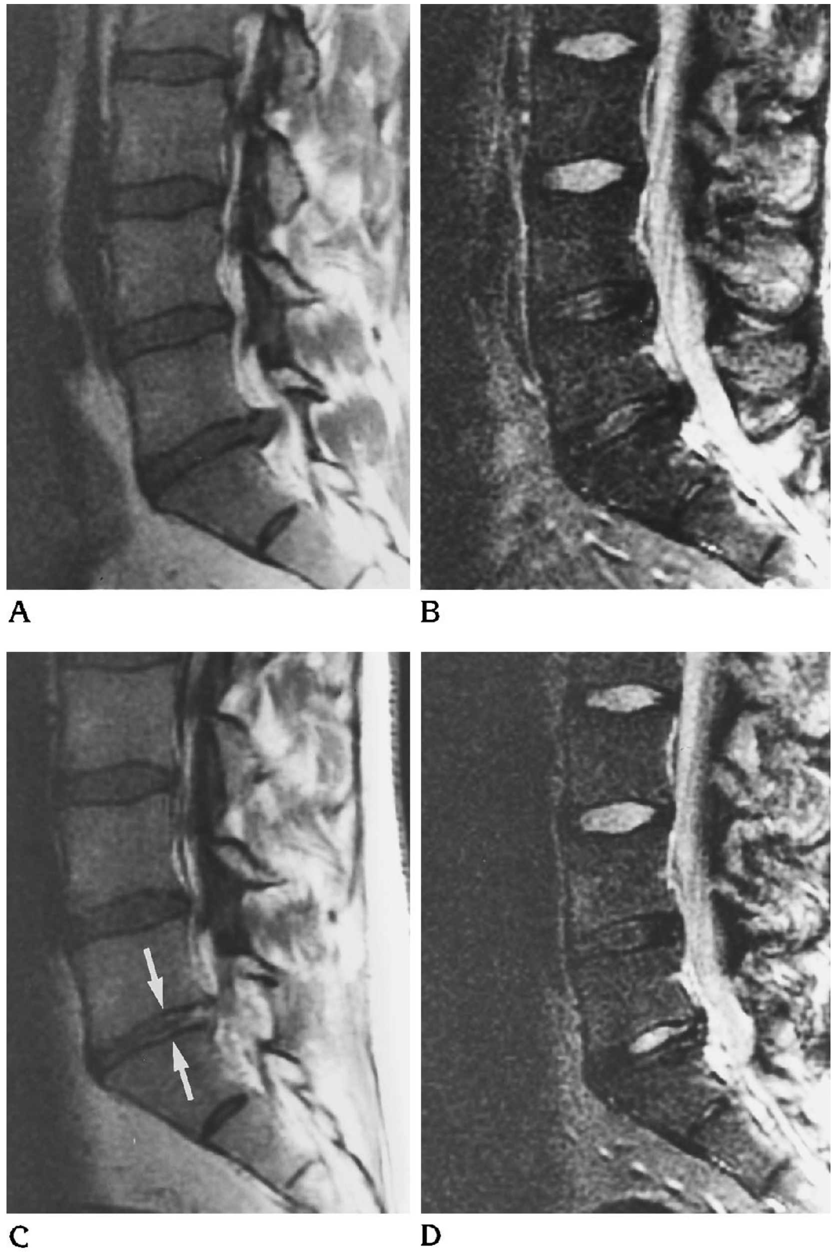


Fig 4. *A and B,* Contrast-enhanced sagittal T1-weighted (*A*) and T2-weighted (*B*) images before surgery show an extrusion of the L5-S1 intervertebral disk.

C and D, After surgery, the enhanced sagittal T1-weighted image (*C*) shows typical parallel bands of enhancement within the central aspect of the disk (*arrows*) merging with the posterior anular enhancement. The end plates are well defined and normal in appearance. The sagittal T2-weighted sequence after surgery (*D*) shows reduction in the herniation, but increased signal within the disk proper compared with the preoperative state.

Clinical Correlations

No significant associations were found between disk enhancement and specific clinical symptoms (including leg and back pain) on preoperative or postoperative studies. Tables 3 through 5 summarize the findings.

Motor weakness and sensory deficit at 3 months.—Twenty-one patients had motor weakness and 66 patients had no motor weakness at the 3-month follow-up study. Preoperative disk enhancement was not a univariate predictor of motor weakness ($P = .598$) or sensory deficit ($P = .964$).

Sensory deficit at 6 months.—Twenty patients had sensory deficit at the 6-month follow-up and 42 patients did not. Disk enhancement was not a significant predictor of sensory deficit at 6 months ($P = .663$).

Discussion

In this study, close to 20% of the patients showed intervertebral disk enhancement at the surgical level 3 months after surgery. There was no correlation of this enhancement with motor or sensory deficits. The type of enhancement

TABLE 2: Comparison of preoperative and postoperative end-plate patterns and disk morphology

Preoperative End-plate Pattern	Postoperative End-plate Pattern	Number (n = 19)	Decreased Disk Space Height	Postoperative Disk Signal on T2-Weighted MR Images
Pattern Change				
0	Type I	4	1	1-decreased
Type II	Type I + II	2	2	. . .
Type II	Type I	1	. . .	. . .
0	Type II	1	. . .	1-increased
Pattern Stable				
Type II	Type II	3	2	2-increased
0	0	8	1	3-increased

Note.—Type I = decreased signal on T1-weighted images, increased on T2-weighted images, and enhancing on postcontrast images; Type II = increased signal on T1-weighted images.

TABLE 3: Number (percentage) of patients with enhancement and motor weakness, sensory deficit, or straight leg raise of less than 60°

Clinical Findings	Two-Tailed *P*	Preoperative Enhancement Present	Postoperative Enhancement Present		
Preoperative					
Motor weakness					
Thigh	0.697	3 (15)	8 (11)		
Foot	0.795	6 (30)	25 (34)		
Big Toe	1.0	6 (30)	23 (31)		
Sensory deficit					
Thigh	0.546	5 (25)	14 (19)		
Calf	0.322	12 (60)	34 (47)		
Foot	0.612	13 (65)	42 (57)		
Straight leg raise <60*	0.131	9 (45)	45 (67)		
3-Month Follow-up					
Motor weakness					
Thigh	0.316	2 (11)	3 (5)		
Foot	1.0	2 (11)	8 (12)		
Big Toe	1.0	2 (11)	9 (14)		
Sensory deficit					
Thigh	0.570	0 (0)	4 (6)		
Calf	0.520	5 (26)	15 (18)		
Foot	0.795	8 (42)	25 (38)		
Straight leg raise <60*	1.0	3 (16)	12 (19)		
6-Month Follow-up		Preoperative Only	Postoperative Only	Both Preoperative and Postoperative	No Enhancement
Motor weakness					
Thigh	1.0	0 (0)	0 (0)	0 (0)	0 (0)
Foot	1.0	0 (0)	0 (0)	0 (0)	0 (0)
Big Toe	1.0	0 (0)	1 (6)	0 (0)	0 (0)
Sensory deficit					
Thigh	0.827	0 (0)	0 (0)	0 (0)	0 (0)
Calf	0.184	0 (0)	1 (5)	2 (33)	3 (14)
Foot	1.0	0 (0)	5 (33)	2 (33)	8 (38)
SLR <60*	0.582	0 (0)	1 (5)	1 (17)	1 (5)

TABLE 4: Number (percentage) of patients with intervertebral disk enhancement versus herniation type

	Protrusion	Extrusion	Sequestered
Disk enhancement			
Preoperative only	1 (9)	0 (0)	1 (6)
Postoperative only	2 (18)	9 (60)	8 (50)
Both preoperative and postoperative	2 (18)	2 (13)	2 (13)
No enhancement	6 (55)	4 (27)	5 (31)

was very consistent, with all but one case showing linear bands of enhancement in the superior and inferior aspects of the intervertebral disk that paralleled the end-plate margins. Although we do not have pathologic proof of the enhancing tissue, it most likely reflects granulation or scar tissue related to accelerated disk degeneration postoperatively. Granulation or scar tissue may be seen in association with herniations both before and after surgery, as well as within anular tears (9, 10).

Seven (7%) of the 94 patients had intervertebral disk enhancement and type I end-plate changes that enhanced postoperatively at the surgical level. Several patterns of end-plate changes from before to after surgery were noted; however, two general patterns emerged: 1) postoperatively stable with no identifiable marrow changes relative to the preoperative state, and 2) change toward type I enhancing end plates, which is a conversion of normal marrow to fibrovascular marrow. Type II end-plate changes (which represent conversion to fatty marrow) were also seen to change to type I or to a mixed type I and II pattern. Similar end-plate changes are seen in patients after injection of chymopapain, which can be viewed as a model of accelerated disk degeneration (11). A similar course of events could be postulated after diskectomy, with curettage of the posterior disk with subsequent accelerated degenerative change. End-plate changes after surgery have been described previously in studies with fewer patients. Ross et al (3) described type I changes postoperatively in the lumbar spine in 3 of 13 patients, and Boden et al (12) reported end-plate changes in 1 of 17 postoperative patients.

We emphasize that there are asymptomatic postoperative patients who have anular enhancement (curette site), disk enhancement, and vertebral end-plate enhancement without evidence of disk space infection. This further points to the necessity of understanding asymptomatic postoperative changes that are sequelae of surgery and not necessarily indicators of infection. Furthermore, although asymptomatic postoperative disk enhancement coupled with degenerative end-plate changes is very similar to disk space infection (enhancement of anulus, disk, and end plates) from a gross descriptive standpoint, these conditions may be distinguished by the presence of the typical smooth linear bands of enhancement seen with the benign postoperative changes.

Concerning changes in signal intensity on T2-weighted sequences, Balagura and Neumann (13) reported increased signal from the disk space in all 10 of their patients on the second day after surgery that decreased in eight of the patients by 3 months. In that study, disk space height also decreased in 7 of the 10 patients by 3 months. In the present study, we saw increased signal from the intervertebral disk space 3 months

TABLE 5: Number (percentage) of patients with disk enhancement pattern by clinical symptoms

Clinical Symptoms	Two-tailed P	Preoperative Enhancement	No Preoperative Enhancement		
Preoperative					
Back pain >4	1.0	14 (70)	51 (72)		
Leg pain >4	0.573	20 (100)	68 (94)		
3-month follow-up					
Back pain >4	1.0	3 (25)	13 (27)		
Leg pain >4	0.489	5 (42)	14 (29)		
		Preoperative Only	Postoperative Only	Both Preoperative and Postoperative	No Enhancement
6-month follow-up					
Back pain >4	0.593	0 (0)	4 (33)	3 (60)	0 (0)
Leg pain >4	1.0	0 (0)	3 (27)	2 (40)	0 (0)

after surgery in 7 of 19 patients who had enhancement; in 6 of 19 patients, there was a decrease in disk space height. The differences in numbers between the two studies most likely reflect different surgical techniques andvarious amounts of curettage of the disk space proper.

In conclusion, we have defined a pattern of asymptomatic changes in the intervertebral disk and end plates related to single-level diskectomy in 20% of subjects that appears to reflect accelerated disk degeneration. This is typically manifested as two bands of enhancement of the intervertebral disk that parallel the end plates at the surgical level and that may be associated with type I end-plate changes, which also enhance. This pattern should be distinguished from the amorphous enhancement seen with disk space infection.

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