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MR imaging of infectious spondylitis.

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AJNR Am J Neuroradiol 1990, 11 (6) 1171-1180

<http://www.ajnr.org/content/11/6/1171>

This information is current as
of May 15, 2025.

MR Imaging of Infectious Spondylitis

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MR images of 14 patients with pyogenic and three patients with tuberculous infectious spondylitis were studied to develop criteria for diagnosis. T1-weighted scans, 800/20 (TR/TE), were obtained in 17 patients and T2-weighted scans, >2000/30,80, were obtained in 14. In seven patients, T2*-weighted scans (gradient-recalled acquisition into steady state, 25/15/5-7° [TR/TE/flip angle]) and short-T1 inversion-recovery scans (STIR), 1400/150/40 (TR/TI/TE), as well as fat and water images (using a suppression technique), were obtained. Unenhanced and gadopentetate-dimeglumine-enhanced scans were obtained in four patients. In all but two patients with pyogenic infectious spondylitis, the T1-weighted sagittal scan showed characteristic findings: narrowed disk space, low signal intensity in the marrow of at least two adjacent vertebrae, subligamentous or epidural soft-tissue masses, and erosion of cortical bone. In one patient the T1-weighted scan was normal and abnormalities could be detected only on the T2-weighted scan. The remaining patient had abnormal marrow signal on the T1-weighted scan but only in one vertebral body. On T2-weighted images the major findings were a narrowed disk space with variable signal changes, abnormal high signal in marrow of at least two adjacent vertebrae, high-signal subligamentous or epidural masses, and cortical bone erosion. The findings in the three patients with tuberculous spondylitis included areas of increased and decreased signal intensity in vertebrae on T1-weighted images. Disk spaces were relatively spared given the extent of disease. Extrasosseous soft-tissue components could be large. Bone erosion was best seen on the first echo of a T2-weighted sequence and on a water image; the latter was most reliable since it had no chemical-shift artifact. The use of gadopentetate dimeglumine could obscure or clarify MR findings, depending on the situation.

T1- and T2-weighted MR images should be obtained for assessment of infectious spondylitis. STIR scans are particularly helpful. Fat images can be useful in subtle presentations, since they are very sensitive to marrow replacement, and gadopentetate dimeglumine may be helpful for epidural delineation of disease.

AJNR 11:1171-1180, November/December 1990

MR imaging has proved to be a sensitive technique for investigating spinal diseases. It often replaces myelography and CT for the detection of herniated disks, metastatic disease, and spinal cord tumors. Owing to its high sensitivity in detecting subtle changes in the water and fat content of medullary bone, MR was expected to be sensitive to the disk and marrow changes seen in infectious spondylitis. Modic et al. [1] studied 23 patients with the microbiologic and histologic diagnosis of spinal osteomyelitis and found that MR had a sensitivity of 96%, a specificity of 92%, and an accuracy of 94%. Bertino et al. [2] described the spin-echo and short-T1 inversion-recovery (STIR) signal characteristics in a patient with spinal osteomyelitis and an epidural abscess. Smith et al. [3] studied four patients with tuberculous spondylitis. We undertook a retrospective and prospective analysis of MR scans of 17 patients with infectious spondylitis to develop diagnostic criteria for T1- and T2-weighted scans and other types of images: water and fat (using suppression techniques), variable-flip angle gradient-recalled acquisition in the steady state (GRASS), and STIR.

Received August 31, 1989; revision requested October 30, 1989; final revision received May 25, 1990; accepted May 30, 1990.

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0195-6108/90/1106-1171
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Subjects and Methods

Seventeen patients were imaged on a 1.5-T system with T1-weighted, 800/20 (TR/TE), and T2-weighted peripherally gated, >2000/30,80 sequences. Other scanning parameters were 3- and 5-

mm-thick sagittal and axial scans, 24- to 32-cm field of view, 256 × 256 matrix, and two excitations. T1-weighted scans were obtained in all patients (17 sagittal, one axial); T2-weighted scans in 14 (nine sagittal, 10 axial); GRASS scans, 40/16/5°/8 (TR/TE/flip angle/excitations), in seven (six sagittal, one axial); sagittal fat and water images

TABLE 1: MR Characteristics of Pyogenic Infectious Spondylitis

Case No.	Age (years)	Sex	Organism	Loss of Cortex	Marrow		Disk		No. of Vertebrae
					T1	T2	T1	T2	
1	27	M	Not cultured	Yes	—	+	I	+	2
2	30	F	Not cultured	Yes	—	+	I	—	2
3	45	F	<i>Streptococcus</i>	Yes	—	+	I	—	2
4	77	M	<i>Streptococcus</i>	Yes	—	+	I	+	3
5	40	F	<i>Salmonella</i>	Yes	—	+	I	NP	2
6	15	F	Not cultured	Yes	—	+	— ^a	— ^a	2
7	69	M	<i>Staphylococcus aureus</i>	Yes	—	+	— ^b	— ^b	2
8	70	M	<i>Streptococcus</i>	Yes	—	+	I	+	2
9	73	M	<i>Klebsiella</i>	Yes	—	+	I	+	4
10	64	M	<i>Staphylococcus aureus</i>	Yes	—	+	I	+	3
11	68	F	Not cultured	Yes	—	+	I	—	2
12	55	M	<i>Aspergillus</i>	Yes	—	+	I	+	2
13	66	M	<i>Torulopsis</i>	Yes	—	+	I	—	2
14	27	M	Not cultured	Yes	—	+	I	I	1

Note. — = hypointense signal; + = hyperintense signal; I = isointense signal; NP = not performed.

^a Fused disks.

^b Obliterated disk.

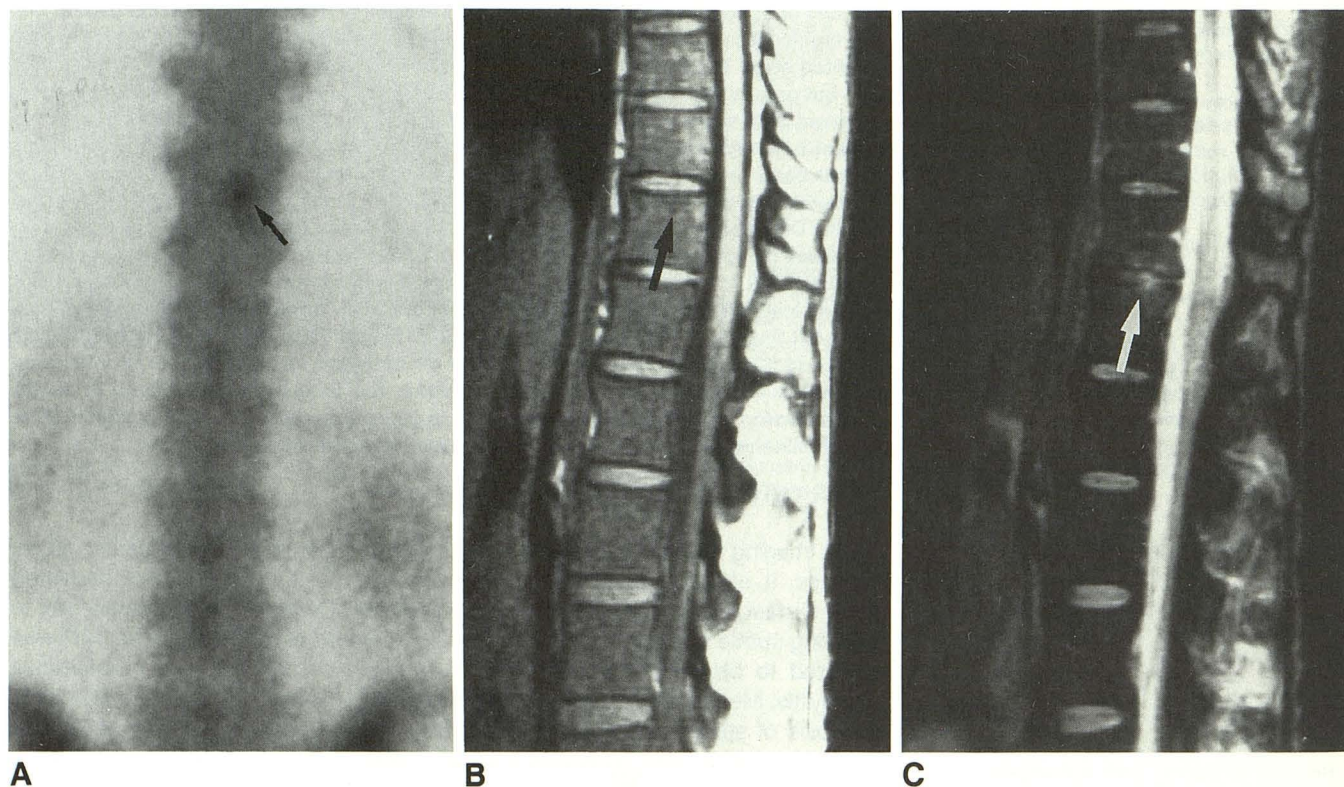


Fig. 1.—Case 3: Streptococcal infectious spondylitis.

A, Bone scan shows small area of abnormal uptake at T11–T12 disk space (arrow).

B, Sagittal T1-weighted scan (800/20) shows no significant abnormality in terms of abnormal vertebral marrow signal intensity and abnormal soft-tissue masses. There is subtle disk-space narrowing and partial loss of superior endplate of T12 (arrow).

C, Sagittal T2-weighted scan (gated 1900/80) shows subtle but definite abnormalities at T11–T12 disk space, which is narrowed and of lower signal intensity than other disk spaces. In addition, abnormal high signal is noted in adjacent vertebral bodies (arrow). In this patient a T2-weighted scan was necessary to definitively detect abnormalities characteristic of infectious spondylitis.

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in seven; and STIR scans, 1500/150/30/1 (TR/TI/TE/excitations), in seven. The fat and water scans were used to help analyze signal abnormalities on T1- and T2-weighted scans. The prospective segment of this series comprised the seven patients who had fat, water, and STIR scans. Gadopentetate dimeglumine was used in four patients. CT and nuclear bone scans were available for correlation in four patients.

Sites of involvement were the lumbar (11), thoracic (four), and cervical (three) spines. One patient had two sites of infection involving the cervical spine and a lumbar facet joint. Biopsies of the involved vertebral body were obtained in three patients. No organism could be cultured from the biopsies of two patients who had been on intermittent antibiotic therapy; the biopsy in the third patient revealed *Salmonella*. Pathologic organisms were cultured in 12 patients: *Staphylococcus aureus*, three; *Streptococcus*, three; *Aspergillus*, one; *Salmonella*, one; *Torulopsis* one; and tuberculous, three. In three patients, no specific organism could not be identified. Pathologic correlation was not obtained in two patients. The most frequent presenting symptom was pain, acute or chronic. Four patients presented with acute onset of pain and fever. One of these patients had *S. aureus* sepsis, two patients had subacute bacterial endocarditis, and the fourth patient was an IV drug abuser.

Results

Pyogenic Infectious Spondylitis

T1-Weighted Images (14 Patients).—In all but two patients the T1-weighted sagittal scans (Figs. 1–6) demonstrated characteristic findings (Table 1) of pyogenic infectious spondylitis: (1) loss of signal intensity in the marrow of two or more adjacent vertebral bodies (12 patients), (2) disk-space narrowing (nine), (3) subligamentous or epidural soft tissue or both (11), and (4) erosion of cortical bone (14).

The low-signal abnormality in the marrow was adjacent to the involved disk space. This low marrow signal was seen in two or more adjacent vertebrae with only two exceptions. In one patient T1-weighted images were normal and only T2-weighted images showed the abnormality to involve two adjacent vertebral bodies (Fig. 1). In another patient only one vertebral body had abnormal signal on T1- and T2-weighted images, but this was associated with prevertebral soft-tissue swelling (Fig. 2). The diagnosis of infectious spondylitis was presumptive in this case. Although the blood cultures were

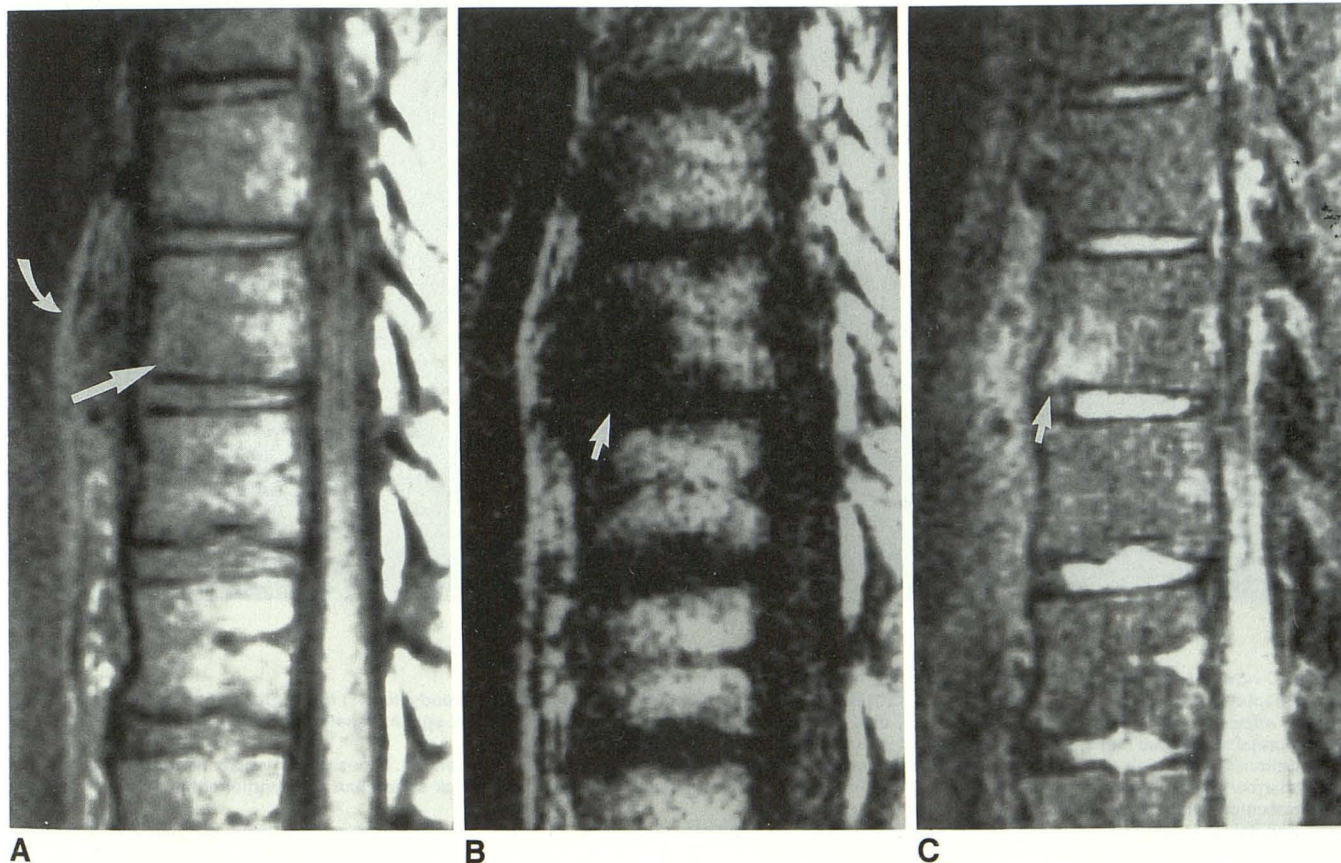


Fig. 2.—Case 1: Infectious spondylitis. This 27-year-old man had a history of drug abuse, but no specific organism could be cultured. Only one vertebral body was involved.

A, Sagittal T1-weighted scan shows slightly abnormal low signal intensity in anterior inferior portion of T9 (straight arrow) but disk space is within normal limits. Soft tissue anterior to this vertebral body and adjacent vertebral bodies, however, is abnormally prominent (curved arrow).

B, Fat image shows loss of vertebral marrow fat in anterior inferior portion of T9 (arrow). In addition, anterior displacement of prevertebral fat plane is well seen.

C, Sagittal water image shows abnormal high signal intensity in anterior inferior portion of T9 (arrow) and in adjacent prevertebral soft tissues. Soft-tissue changes are more evident and appear more extensive on water scan than on conventional T1-weighted scan.

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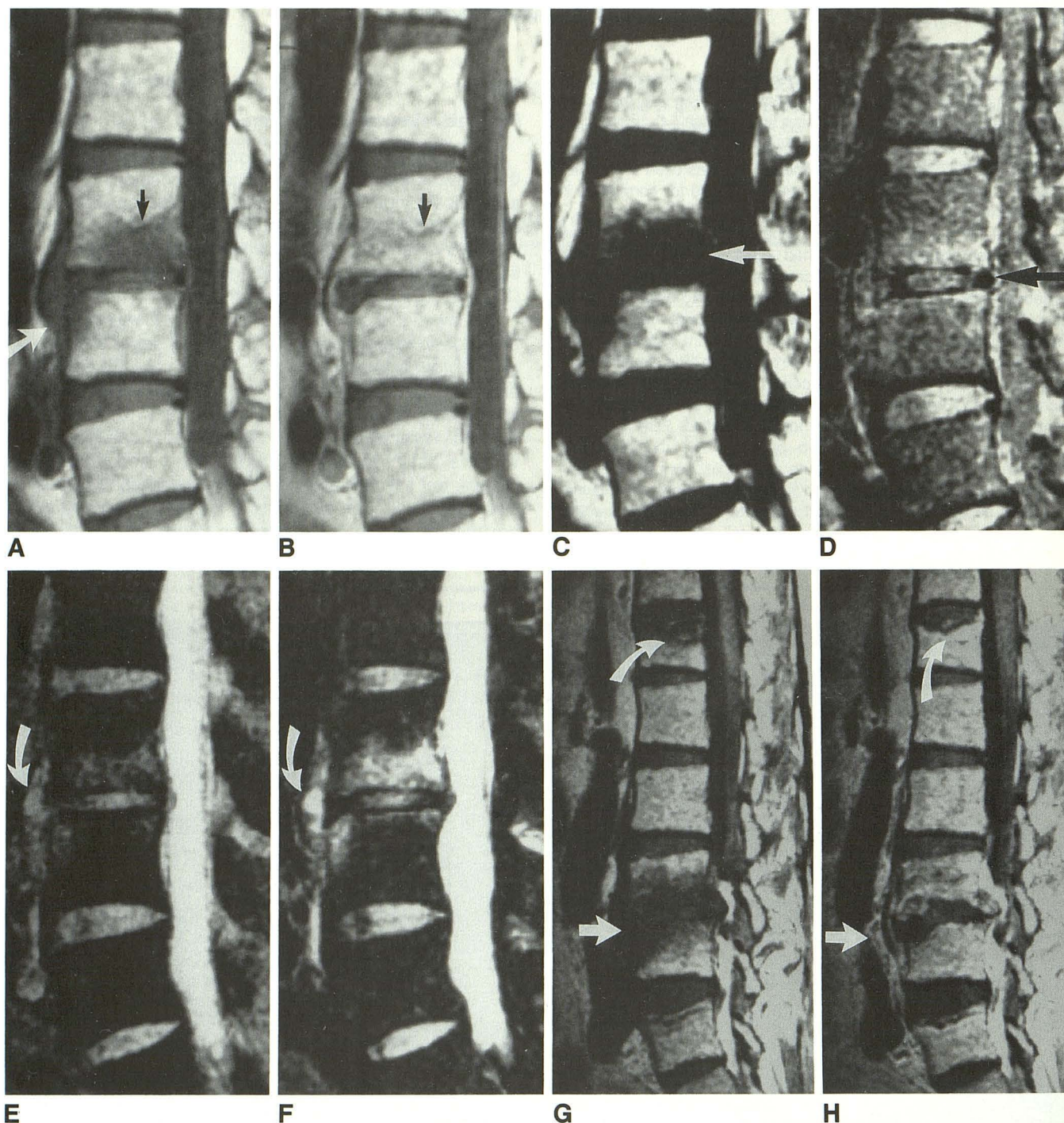


Fig. 3.—Case 12: *Aspergillus* infectious spondylitis.

A, Unenhanced sagittal T1-weighted scan (800/20) shows characteristic findings of infectious spondylitis: (1) low signal intensity of vertebral body marrow adjacent to a disk space (black arrow); (2) disk-space narrowing; (3) minimal change of disk-space signal intensity on T1-weighted image; and (4) abnormal soft-tissue mass, which in this patient is in anterior subligamentous space (white arrow).

B, Enhanced T1-weighted scan shows some of the same characteristic findings as unenhanced scan (A). Low-signal-intensity abnormality in vertebral body marrow, however, is less evident (arrow). There is no definite contrast enhancement within disk space and only partial enhancement of anterior subligamentous soft-tissue mass.

C, Sagittal fat image (800/20) using water-suppression technique confirms replacement of fatty marrow by inflammatory tissue (arrow). This is the major reason for low signal intensity on conventional T1-weighted image.

D, Sagittal water scan (800/20) using fat-suppression technique shows increased water content in vertebrae adjacent to involved disk space, as evidenced by increased signal (arrow).

E, Sagittal T2*-weighted scan (GRASS 25/16/5°) confirms findings on water scan (D), showing increased signal intensity in vertebral bodies adjacent to affected disk space. Soft-tissue abnormality in anterior subligamentous space is also of increased signal intensity (arrow).

F, Sagittal STIR scan (1400/150/40) shows abnormal high signal within vertebral bodies more clearly than either the T2*-weighted image or water image. This pulse sequence yielded highest contrast of abnormalities within vertebral body and in adjacent soft tissues. Abnormal anterior subligamentous soft-tissue mass also has high signal intensity (arrow). T2-weighted types of images (e.g., T2, water, and STIR images) show decreased signal intensity of disk space compared with other normal disk spaces in this patient. This differs from T1-weighted images, where disk intensity is generally within normal limits.

G and H, Unenhanced (G) and enhanced (H) T1-weighted scans (800/20) 6 weeks after initial study (A and B). Destructive changes at L3-L4 disk space have increased (straight arrows). There is further bone erosion and greater involvement of L3 and L4 vertebral bodies. New site of infection is present at T12 (curved arrows). Contrast enhancement continues to obscure marrow abnormalities (H).

(Fig. 3 is continued on the opposite page.)

Fig. 3.—(Continued).

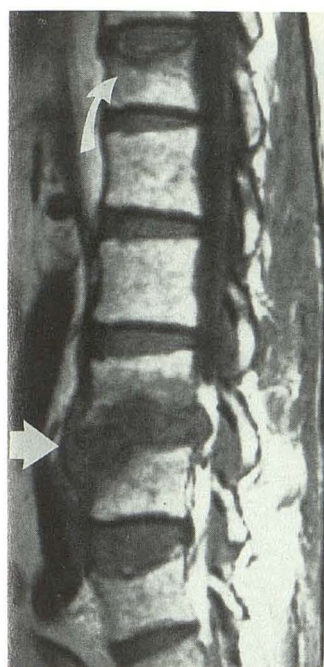
I, Sagittal STIR scan (1400/150/40) shows progression of lesions at L3–L4 level with increased abnormal high signal within vertebral bodies and disk space compared with F. In addition, new sites of infection also are seen better. T12 vertebral body shows marked high signal intensity (*black arrow*), while adjacent disk space and T11 vertebral body appear within normal limits. In addition, a subtle area of increased signal intensity has also appeared in superior portion of L5 (*white arrow*). This latter area of new involvement is difficult to appreciate on either pre- or postenhancement T1-weighted scan (G and H).

J, Unenhanced T1-weighted scan (800/20) 10 weeks after initial study. There has been some interval restoration of normal signal within L3–L4 vertebral bodies (*straight arrow*). L5 vertebral body shows barely detectable abnormality at its superior endplate. T12 vertebral body (*curved arrow*) shows interval loss of height but it has regained some fat signal within marrow.

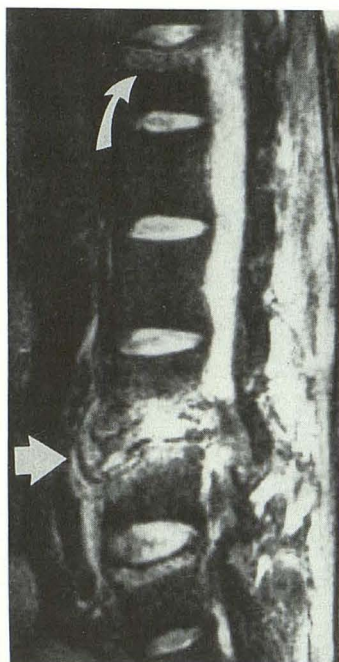
K, Sagittal STIR scan (1440/150/40) shows regression of abnormal high signal within all involved vertebral bodies: T12 (*curved arrow*), L3–L4 (*straight arrow*), and L5. STIR scan shows continued abnormal signal at L5, which looks relatively normal on T1-weighted scan (J).

L and M, Sagittal T2-weighted sequence (2200/30,80). Second-echo image (M) has more information than first (L), showing findings analogous to those on STIR scan (K).

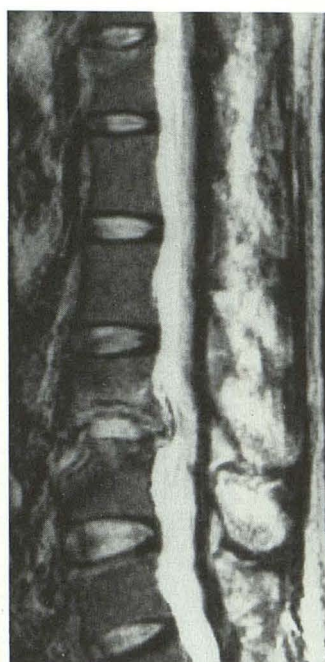
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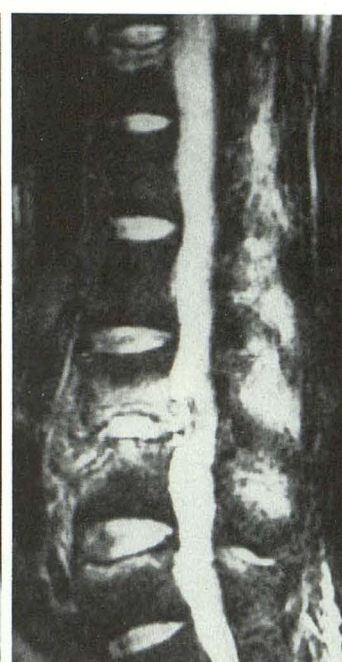
J



K



L



M

negative, the age of the patient (27-year-old IV drug abuser) and the rapid decrease in the size of the paraspinal mass on a follow-up scan were consistent with an infectious etiology.

The disk space was narrowed in nine patients and obliterated in two. Disk spaces were normal in three patients. Serial scans in four patients showed progression of disk space abnormalities (Fig. 3) and the beginning of bony fusion late in the disease course in one (Fig. 4).

The paraspinal (11) and epidural (seven) soft-tissue masses had a signal isointense relative to the adjacent disk.

The paraspinal masses were usually subligamentous and anterior to the involved disk space. When present, epidural soft-tissue masses were isointense and centered anterior to the thecal sac at the level of the involved disk and extended both rostrally and caudally when large (Figs. 2–4). In two patients the epidural mass compressed the spinal cord. Erosion of cortical bone was best seen on sagittal images.

T2-Weighted Images (14 patients).—The major findings (Table 1) on T2-weighted scans were (1) abnormal high signal in the marrow of two or more adjacent vertebrae (13), (2) disk-space narrowing (nine), (3) abnormal disk signal (10), (4)

abnormal high signal in paraspinous and/or epidural soft-tissue masses (11), and (5) erosion of cortical bone (14).

On all T2-weighted scans, the marrow signal adjacent to the involved disk was higher than the T2-weighted signal from nonadjacent vertebrae. This high signal was always seen in adjacent vertebrae. Disk-space narrowing was seen on the sagittal T2-weighted scans. The disk itself was of variable signal intensities. High signal was seen in six patients, decreased signal in four patients, and normal signal in one patient. Two disk spaces were obliterated and a sagittal T2-weighted scan was not obtained in one patient. Paraspinous (11) and epidural (seven) soft-tissue masses had high signal. Cortical bone erosion was best visualized on the first echo of a T2-weighted scan. Bone erosion was seen in all 14 patients.

Tuberculous Spondylitis

Findings on T1-weighted images in the three patients with tuberculous spondylitis differed and showed heterogeneous

bone-marrow abnormalities in adjacent vertebral bodies with areas of high and low signal intensity (Fig. 7). On T2-weighted images the marrow showed a heterogeneous increase in signal. Both the high- and low-signal areas on T1-weighted scans were high-signal abnormalities on T2-weighted images. Another atypical finding was relative preservation of the disk space, even in the face of advanced disease of two or more adjacent vertebrae and collapse of a vertebral body (two cases). Two patients had pedicle involvement, a finding not seen in the pyogenic cases. All three patients with tuberculous spondylitis had focal areas of cortical bone erosion. They also had subligamentous spread of disease, as manifested by anterior and lateral paraspinous soft-tissue masses. Two patients had anterior epidural masses. The signal from the paraspinous and epidural masses was similar to the signal seen in the pyogenic patients; that is, isointense on T1-weighted images and increased signal on T2-weighted images. Disk signal of involved vertebrae remained isointense relative to noninvolved disks.

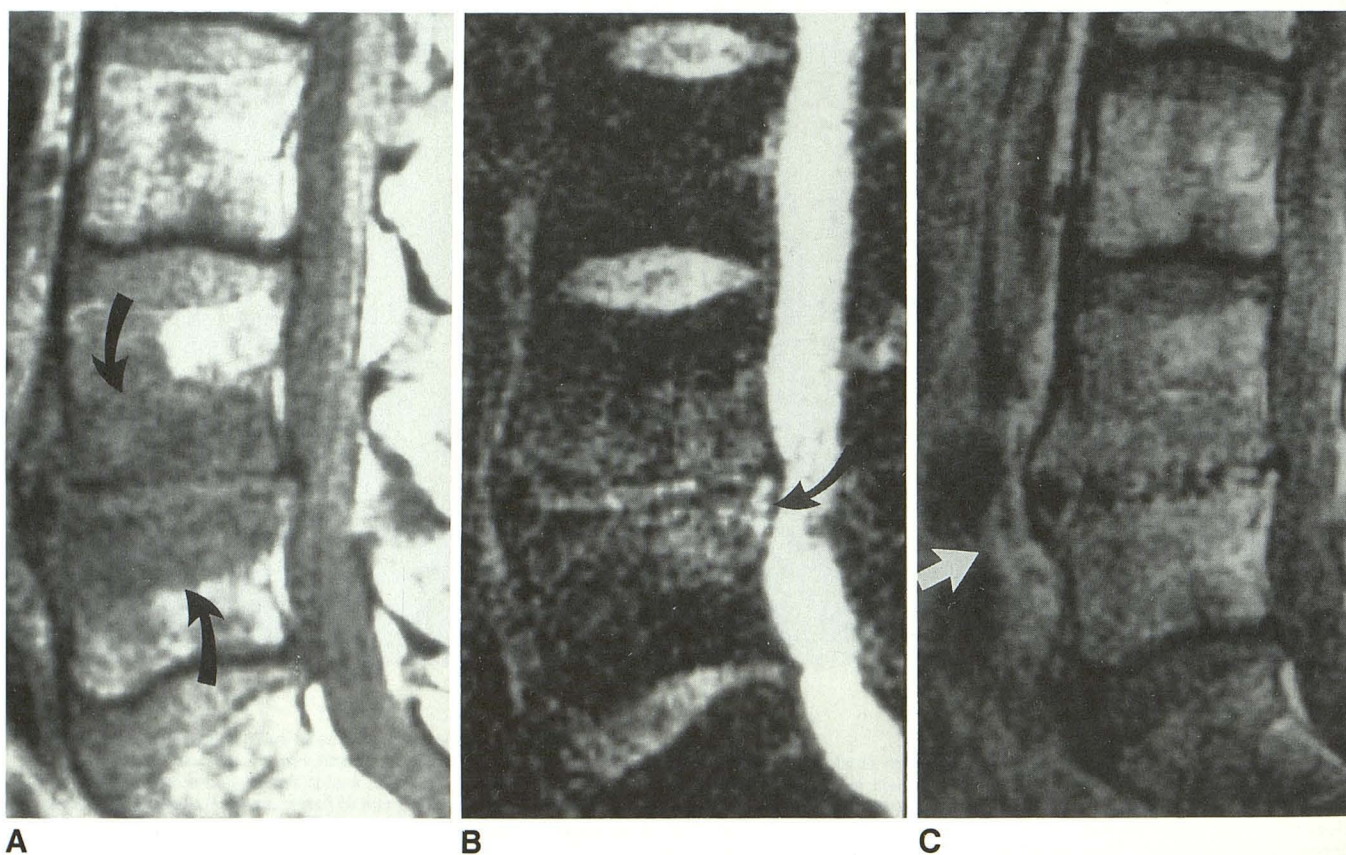


Fig. 4.—Case 13: *Torulopsis* infectious spondylitis.

A, Initial T1-weighted scan (800/20) shows typical findings of infectious spondylitis with low signal of vertebral body marrow adjacent to narrowed disk space (arrows). Small abnormal soft-tissue masses are noted in anterior subligamentous space and in epidural location in spinal canal at L4–L5 disk space.

B, Initial STIR scan (1400/150/40) shows abnormal high signal in same regions as low signal intensity on T1-weighted scan. Disk space is narrowed and of decreased signal intensity compared with L3–L4. Epidural mass at L4–L5 disk space is of high signal intensity (arrow). Both T1-weighted and STIR scans show characteristic findings of infectious spondylitis.

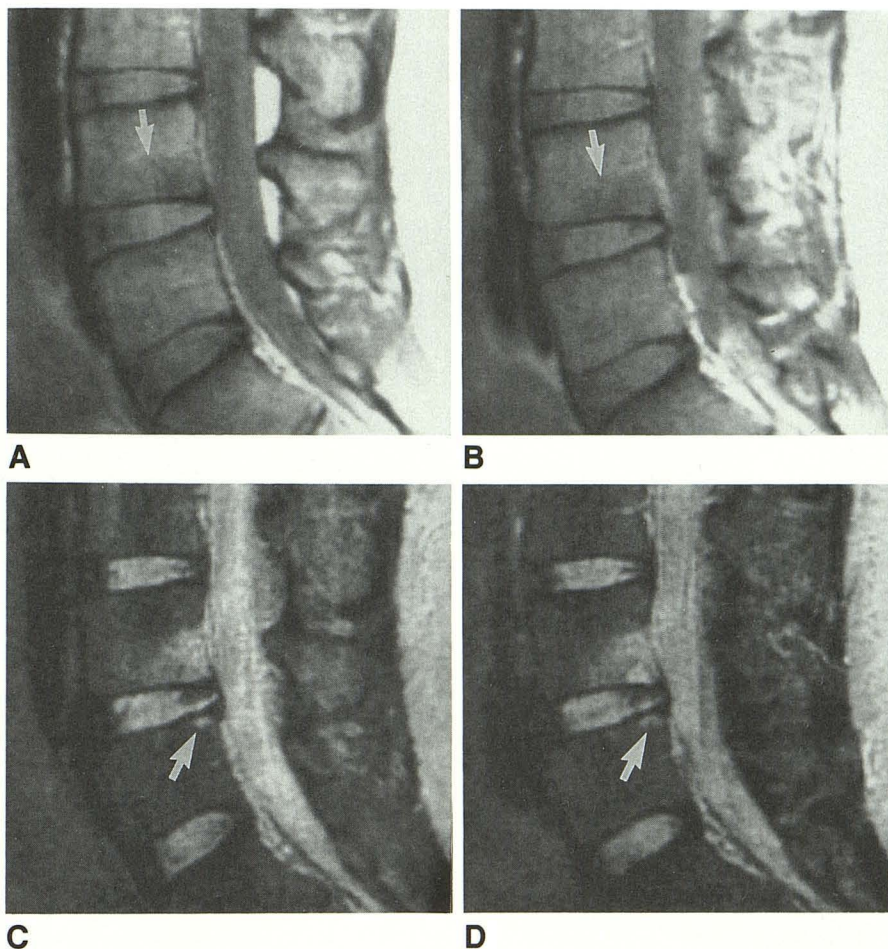
C, Follow-up scan 2 months later shows resolution of some MR findings. T1-weighted sagittal scan (800/20) shows decrease in abnormal low signal intensity of vertebral body marrow. Disk space is now narrowed further and beginning to show changes of bony fusion. Anterior subligamentous mass is still present (arrow).

Fig. 5.—Case 2: Infectious spondylitis after diskography.

A and B, Sagittal T1-weighted scans (800/20) show subtle abnormalities with only low signal intensity noted in posteroinferior portion of L4 vertebral body (arrows). No definite abnormalities were noted in disk space or in upper portion of L5 vertebral body. No soft-tissue mass was detected.

C and D, Corresponding sagittal T2-weighted scans (gated 1800/80) show more definitely abnormal high signal intensity in L4 vertebral body and also show subtle area of increased signal intensity in posterior, upper region of L5 vertebral body (arrows). Minimal low signal intensity is noted in posterior portion of the L4–L5 disk space. A T2-weighted scan was required to detect abnormal marrow signal intensity adjacent to disk space in L5, characteristic finding in infectious spondylitis.

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Other MR Sequences

Fat and water scans were obtained to analyze signal intensities seen on conventional T1- and T2-weighted scans. Fat sequences (i.e., water signal suppressed) correlated closely with T1-weighted scans in all patients. The site of low-signal marrow on T1-weighted scans correlated with the loss of normal marrow fat as seen on the fat images (Figs. 2–4). With healing, some fat signal reappeared (Figs. 3 and 4). The water sequences correlated closely with the T2-weighted, T2*-weighted, and STIR scans, showing an increase in marrow signal in all patients. The variable-flip-angle (GRASS) scans showed an increase in signal intensity in the marrow in six patients, being comparable to but having less contrast than the T2-weighted, water, and STIR images. In this series of 17 patients, STIR images showed the highest contrast between abnormal tissue and adjacent normal marrow.

The gadopentetate dimeglumine scans did not increase the conspicuity of marrow lesions; in fact, it decreased them. The abnormal low signal in the marrow was well visualized on the unenhanced T1-weighted images, but it was obscured on enhanced scans in all three patients with pyogenic infections. In one patient the use of gadopentetate dimeglumine helped delineate the extent of epidural involvement (Fig. 6). Unenhanced and enhanced scans were obtained in one patient

with tuberculous spondylitis, showing a ring-enhancing lesion that corresponded to an area of high marrow signal on the T1-weighted images. The ring enhancement extended beyond the cortical margins (Fig. 7).

Other Studies

The CT findings in three patients correlated closely with the MR scans. In one patient, CT 1 week before MR identified large paraspinous and epidural masses. Subsequent MR imaging showed the paraspinous and epidural masses, abnormal marrow signal in two adjacent vertebral bodies, and loss of cortical bone. In the second patient, who had increasing back pain, CT and MR were performed on the same day. CT demonstrated cortical erosion of the L2 vertebral body and a small paraspinous mass. MR demonstrated extensive involvement of the vertebral bodies of L2 and L3, a small epidural mass, cortical bone erosion, and the small paraspinous mass seen on CT. A radionuclide bone scan in a patient with subacute bacterial endocarditis demonstrated a small focus of increased uptake near the left pedicle of T11 (Fig. 1). The T2-weighted MR image demonstrated changes in the marrow of T11 and T12.

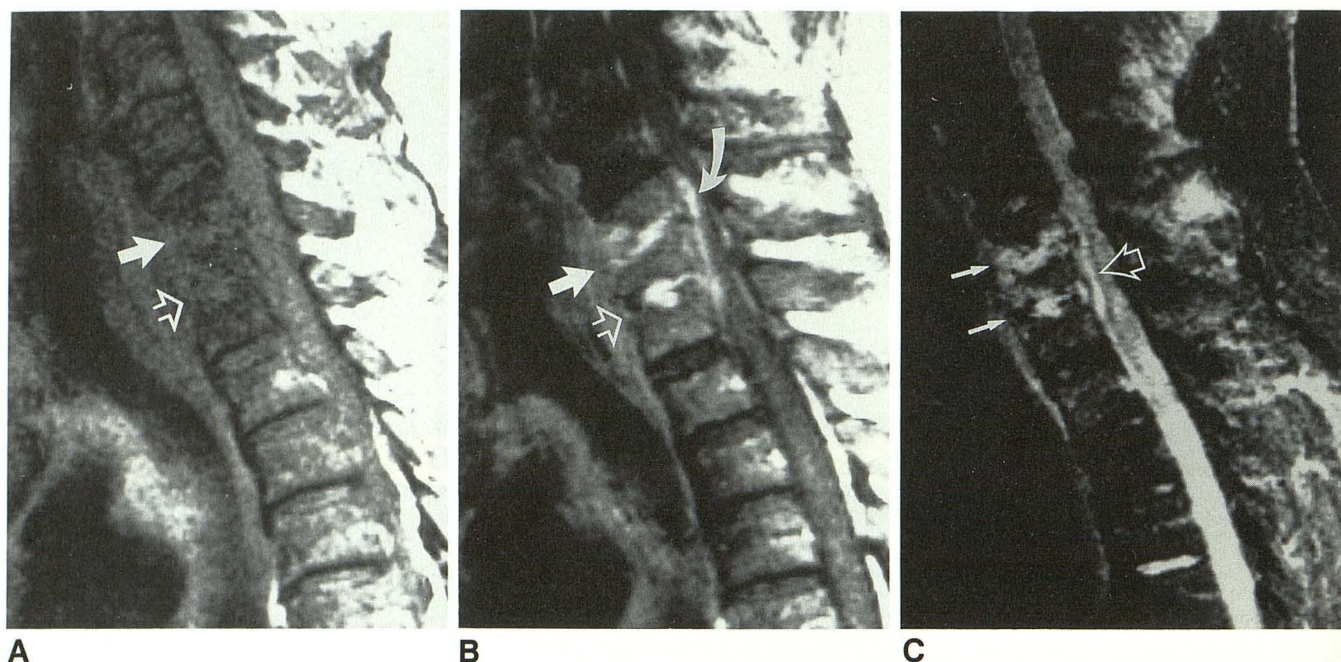


Fig. 6.—Case 9: Infectious spondylitis in a patient with *Klebsiella* infection of the urinary tract. This case illustrates the use of gadopentetate dimeglumine to delineate extraosseous (epidural) extension of infection.

A and B, Unenhanced (A) and enhanced (B) T1-weighted scans (800/20) show bone and disk destruction from C6 to T1 (straight arrows) with increased soft tissue within spinal canal obscuring cord margins. Although cord compression can be suspected on unenhanced scan, severity is difficult to evaluate because of loss of normal anatomic landmarks. Enhanced scan shows not only enhancement of disk spaces and vertebral bodies but also of soft tissue in anterior subligamentous disk space and in epidural space (curved arrow). Degree of cord compression is better visualized on enhanced scan.

C, Sagittal STIR scan (1400/150/40) shows findings quite similar to enhanced T1-weighted scan (B). Marked increase in signal intensity is noted within disk spaces (C6–C7, C7–T1) that exhibited contrast enhancement (solid arrows). Epidural component (open arrow) shows high signal intensity in configuration similar to that delineated by contrast enhancement (B). On sagittal image, therefore, STIR scan shows findings similar to those on enhanced scan in delineating extent of extraosseous (epidural) disease.

Discussion

Infectious spondylitis is uncommon, accounting for approximately 5% of all cases of pyogenic osteomyelitis [4]. Pyogenic and nonpyogenic infections of the spine usually involve both the vertebral body and disk. Pathogenic organisms reach the spine by hematogenous spread or by direct inoculation from penetrating wounds, diagnostic procedures, or surgery [5]. Despite these different routes, the MR findings in nontuberculous spondylitis appear quite similar to those in pyogenic spondylitis.

Staphylococcus aureus is the most common pyogenic organism, but *Streptococcus*, Gram-negative organisms, and *Mycobacterium* are frequent offenders. IV drug abusers are particularly prone to Gram-negative infections. *Aspergillus* has also been reported in infectious spondylitis and was seen in our series [6].

Symptoms vary widely. Pain, acute and chronic, is a common but nonspecific complaint. The patient may be febrile or afebrile with an abnormal or slightly elevated WBC count and erythrocyte sedimentation rate. Clinical signs and symptoms frequently precede bone changes on conventional radiographs [7]. Bone radiographs typically are negative at 8–10 days after the onset of symptoms [8]. Plain film abnormalities often are subtle and may not be detected until late in the disease process. This is particularly true of infections that

originate in the disk or those caused by tuberculosis or fungi [9, 10]. Plain films eventually show the characteristic findings of disk-space narrowing and endplate erosions several weeks after clinical onset [3].

Radionuclide bone scans are sensitive early, but the findings are often nonspecific for infection, trauma, tumor, or degenerative changes. They may be negative in early aggressive disease [11, 12]. They do not have the spatial resolution to define cortical bone loss, disk-space narrowing, and involvement of adjacent vertebral bodies, nor can the bone scan define small areas of paraspinal or epidural disease. All of these findings are critical in differentiating infection from tumor. CT can detect paraspinal masses but may not detect epidural involvement without administration of intrathecal contrast material. Sagittal reformatted CT scans show disk-space narrowing but only after moderately severe changes have occurred.

Because MR is becoming the initial imaging test for suspected spinal disease, diagnostic criteria for infectious spondylitis are important. On the basis of this limited experience, MR is likely to show diagnostic findings earlier than other imaging techniques. A constellation of four major MR findings indicates pyogenic infectious spondylitis and differentiates it from other diseases. These findings are (1) replacement of the normal marrow by abnormal tissue adjacent to the disk, usually in two adjacent vertebrae; (2) narrowing of the disk

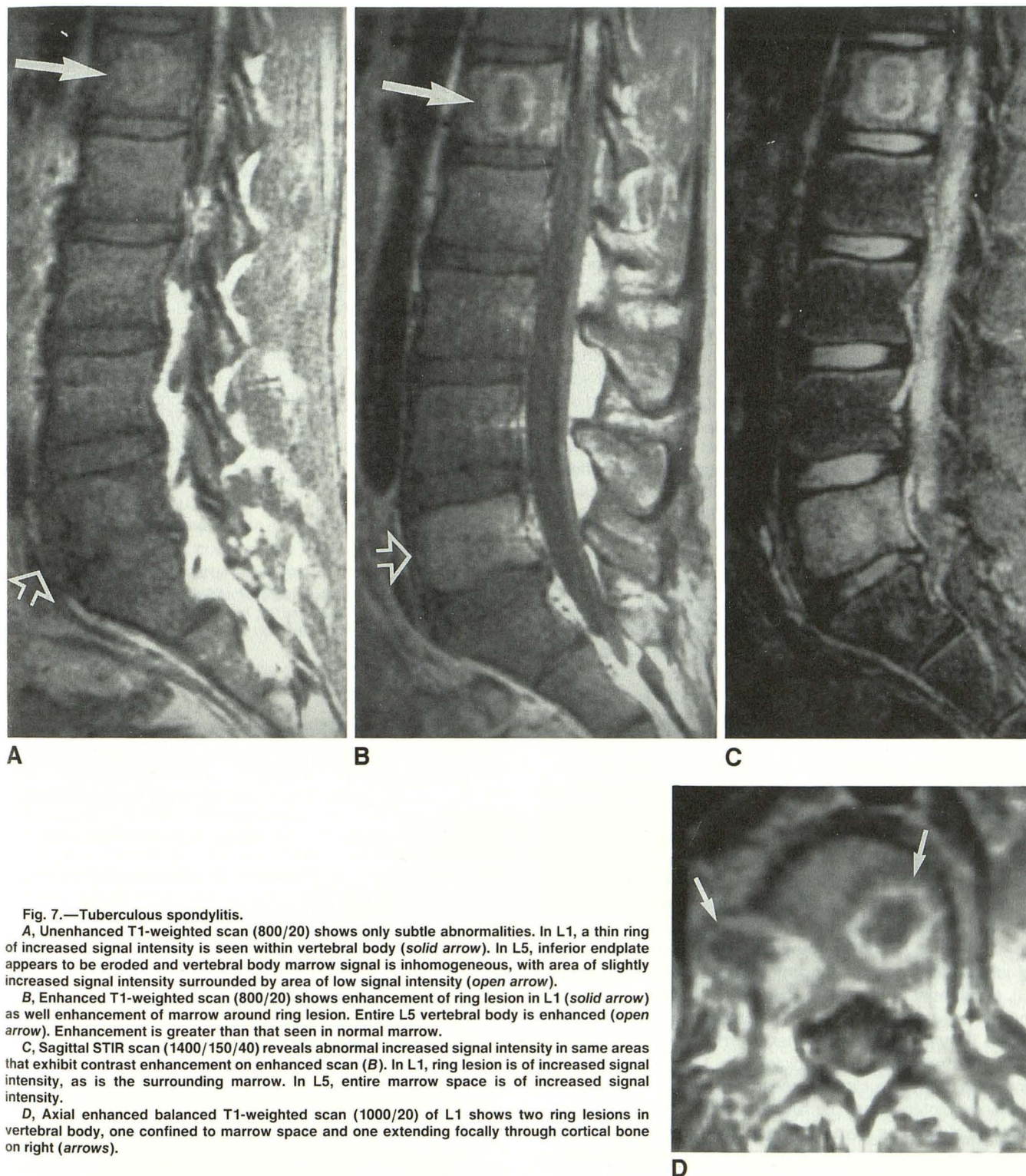


Fig. 7.—Tuberculous spondylitis.

A, Unenhanced T1-weighted scan (800/20) shows only subtle abnormalities. In L1, a thin ring of increased signal intensity is seen within vertebral body (*solid arrow*). In L5, inferior endplate appears to be eroded and vertebral body marrow signal is inhomogeneous, with area of slightly increased signal intensity surrounded by area of low signal intensity (*open arrow*).

B, Enhanced T1-weighted scan (800/20) shows enhancement of ring lesion in L1 (*solid arrow*) as well enhancement of marrow around ring lesion. Entire L5 vertebral body is enhanced (*open arrow*). Enhancement is greater than that seen in normal marrow.

C, Sagittal STIR scan (1400/150/40) reveals abnormal increased signal intensity in same areas that exhibit contrast enhancement on enhanced scan (**B**). In L1, ring lesion is of increased signal intensity, as is the surrounding marrow. In L5, entire marrow space is of increased signal intensity.

D, Axial enhanced balanced T1-weighted scan (1000/20) of L1 shows two ring lesions in vertebral body, one confined to marrow space and one extending focally through cortical bone on right (*arrows*).

space; (3) abnormal paraspinous soft tissue; and (4) cortical bone erosion. All these findings are manifest on T1- and T2-weighted images. Inflammatory tissue in marrow typically has lower signal than normal marrow on T1-weighted images, primarily because it replaces normal fatty marrow. This is well demonstrated on fat images, which show marked loss of

marrow fat signal. At times, the loss of fat signal and increased water signal can offset each other, making the T1-weighted scan appear normal (Fig. 4). The granulomatous inflammatory tissue of tuberculous spondylitis can be of higher signal than adjacent marrow. Inflammatory tissue has high signal on T2-weighted images and its analogues, water images, T2*-

weighted, and STIR scans (Figs. 1–6). Of these, the STIR scans showed the highest contrast and the T2*-weighted the lowest (Fig. 3). It may require a T2-weighted type of image to demonstrate the key finding of abnormal marrow signal on both sides of the disk space. Early in the disease a T1-weighted image may not show this important finding. In this series, there was abnormal signal in at least two adjacent vertebral bodies with T2-weighted sequences in all but one patient. In only one patient was just one vertebral body involved, but this in conjunction with paraspinal soft-tissue swelling was still indicative of early infection (Fig. 2).

Disk-space narrowing is seen well on sagittal images but may not be present early in the disease. In three of our patients the height of the disk space was preserved, although the signal intensity arising from the two adjacent vertebral bodies was already abnormal. Disk signal intensity remained isointense relative to normal marrow on T1-weighted scans. Modic et al. [1] reported a decrease in signal of involved disks on T1-weighted scans in their MR study of vertebral osteomyelitis. A 0.6-T magnet was used in that study, and perhaps the lower magnetic field strength accounts for this different finding. The signal from the disk on T2-weighted scans is variable, being either high or low [1]. Modic et al. reported increased disk signal on T2-weighted scans in 86% of patients.

Identification of paraspinal and epidural soft-tissue masses is important for diagnosis. These soft-tissue masses were isointense on T1-weighted scans and usually centered on the involved disk space. They were of high signal on T2-weighted, T2*-weighted, water, and STIR scans. STIR scans showed the highest contrast of abnormal soft-tissue masses (Fig. 3). All showed contrast enhancement. In one patient, this contrast enhancement better delineated the extent of epidural involvement and the degree of cord compression.

Erosion of cortical bone, especially the endplates, was identified in 14 patients. It was seen best on the first echo of a T2-weighted sequence and on water images, the latter because of the lack of chemical-shift artifact. On suggestive scans, in order to better evaluate the endplate, the frequency axis can be oriented perpendicular to the spine to eliminate a chemical-shift artifact at the endplate.

Tuberculous spondylitis may present with findings atypical of infectious spondylitis and may mimic metastatic disease [3]. Smith et al. [3] reported four cases of tuberculous spondylitis, two of which were initially misdiagnosed as metastases. They reported involvement of the entire body, anterior body, posterior body, or pedicles. On T1-weighted images, one case showed a slight increase in the marrow signal, one showed isointense marrow, and two showed decreased marrow signal [3]. Our own experience with tuberculous spondylitis demonstrated similar findings, but clues to the correct

diagnosis are (1) Heterogeneous marrow pattern with increased signal on T1-weighted images representing the abnormal inflammatory tissue. This can be confirmed on the T2-weighted images or with gadopentetate dimeglumine. (2) Relative sparing of the disk space but definite involvement at the periphery of the body in the setting of extensive vertebral body disease. (3) Focal cortical bone erosion associated with high-signal mass. (4) Extensive paraspinal involvement.

Our experience with gadopentetate dimeglumine and this disease process is limited and generalizations are not yet warranted, but the reported experience of obscuration of vertebral metastases with gadopentetate dimeglumine and the findings in three patients in this series with infectious spondylitis suggest caution [13, 14]. Because findings may already be subtle on T1-weighted scans early in the disease course, the use of an enhanced scan alone is not recommended. For epidural delineation of disease, gadopentetate dimeglumine may be helpful. The basic protocol for infectious spondylitis should include T1- and T2-weighted sequences. A STIR sequence is highly recommended. A fat scan could be useful in subtle presentations, since it is very sensitive to marrow replacement.

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