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ORIGINAL RESEARCH

Unusual Manifestations of Vertebral Osteomyelitis: Intraosseous Lesions Mimicking Metastases

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BACKGROUND AND PURPOSE: Vertebral osteomyelitis can have different imaging manifestations. The purpose of this study was to demonstrate the unusual MR imaging patterns of vertebral osteomyelitis with intraosseous lesions mimicking metastases.

MATERIALS AND METHODS: From September 2000 to August 2007, 7 patients were selected from our data base of 214 patients with confirmed vertebral osteomyelitis and MR images. All of those having misinterpreted MR imaging reports and unusual imaging patterns were analyzed. The presence of a peripheral curvilinear area of low signal intensity in an osseous lesion (the rim sign) and a peripheral rim of high signal intensity on T2-weighted images around an osseous lesion (the halo sign) was evaluated. Follow-up MR imaging studies were performed in all patients.

RESULTS: The patients were 5 men and 2 women, with an age range of 42–80 years. MR imaging findings of those with vertebral osteomyelitis showed a solitary lesion in 2 and multiple lesions in 5 patients. The intraosseous lesions revealed low signal intensity on T1-weighted images, mixed or high signal intensity on T2-weighted images, high signal intensity on short τ inversion recovery images, and global or marginal enhancement. The rim sign was found in 6 (86%) patients; halo sign, in 7 (100%); preserved intervertebral disks, in 7 (100%); and limited paraspinal or epidural inflammation, in 6 (86%). Images of all patients demonstrated healing or almost healed changes on the follow-up MR imaging studies.

CONCLUSION: Vertebral osteomyelitis can have MR imaging patterns mimicking osseous metastases. Recognition of these unusual imaging manifestations, together with clinical and histopathologic analysis, may aid in reaching the correct diagnosis.

SPINE

ORIGINAL RESEARCH

MR imaging has become the valuable technique of choice for early detection of osteomyelitis because of its excellent contrast resolution between the abnormal and normal bone marrow.[1-5] In pyogenic vertebral osteomyelitis and spondylodiskitis, several MR imaging characteristics have been described, including decreased signal intensity on T1-weighted images, increased signal intensity on T2-weighted images, and enhancement on contrast-enhanced MR images in the disk and adjacent vertebral bodies; erosion or destruction of at least 1 vertebral endplate; decreased disk height and an absent intranuclear cleft; and paraspinal and/or epidural inflammatory soft tissue, abscess formation, or both.[4-9] Relative preservation of the disk morphology and signal intensity has been reported in tuberculous and certain fungal infections.[10-12]

The route of hematogenous spread of microorganisms or septic emboli might involve osseous changes similar to those of hematogenous spread of other etiologies, such as malignant cells when the microorganisms are dislodged in the end arterioles. Thus, it is sometimes difficult to make the differential diagnosis of septic emboli versus osseous metastases. The unusual manifestations of vertebral osteomyelitis with MR imaging patterns of septic emboli mimicking osseous metastases, to our knowledge, have not been previously described in the literature. Therefore, the purpose of this study was to demonstrate and analyze the unusual MR imaging patterns of misdiagnosed vertebral osteomyelitis with intraosseous lesions, which may mimic osseous metastases.

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Methods

Study Population

From September 2000 to August 2007, a total of 214 patients with vertebral osteomyelitis or spondylodiskitis were diagnosed in our institute, of whom MR imaging studies were performed in 179. Although the written consent for contrast-enhanced MR imaging examination was obtained in each patient on the basis of clinical indications (eg, suggested spinal infection or osseous metastasis), our institutional review board approved this retrospective study and waived the requirement for written informed consent. The MR imaging reports of these patients were obtained from the radiologic information system and correlated with their final or histopathologic diagnosis. Of the 179 patients who had MR imaging studies, 35 had MR imaging only after the start of treatment or a surgical procedure, another 131 had typical known imaging presentations of infectious spondylitis and comparable radiologic reports, and the remaining 13 patients had misinterpreted radiologic MR imaging reports such as osseous metastases.

Among these 13 patients with misdiagnosed MR imaging studies, 7 had undergone CT-guided bone biopsy, whereas the remaining 6 had no tissue proof. Of the 7 patients who had bone biopsy, histopathologic analysis confirmed the diagnosis of osteomyelitis in 6 and fibrosis in 1; the patient with a biopsy result of fibrosis had a therapeutic diagnosis of osteomyelitis with follow-up MR imaging.

Table 1: Demographic data, histopathologic findings, and culture results in 7 patients with unusual manifestations of vertebral osteomyelitis

Patient No.	Sex/Age (yr)	Biopsy Sites and Histopathologic Findings	Culture Results of Microorganisms
1	M/53	CT-guided bone biopsy, L5 vertebra: chronic osteomyelitis	Bone: gram-positive cocci Blood: *S aureus*
2	M/42	CT-guided bone biopsy, S1 upper endplate: chronic osteomyelitis	Bone: (−) Blood: (−)
3	M/80	CT-guided bone biopsy, L1 vertebra: chronic osteomyelitis	Bone: (−) Blood: (−)
4	F/46	CT-guided bone biopsy, T11 vertebra: chronic osteomyelitis	Bone: (−) Blood: *Salmonella* organisms
5	M/56	CT-guided bone biopsy, T11 vertebra: chronic osteomyelitis	Bone: (−) Blood: (−)
6	F/53	CT-guided bone biopsy, L3 vertebra: chronic osteomyelitis, skin biopsy, shoulder: mycobacterial infection	Bone: (−) Blood: (−)
7	M/66	CT-guided bone biopsy, L3 vertebra: chronic fibrosis, lymph node biopsy, neck: mycobacterial infection	Bone: (−) Blood: (−)

Note:—(−) indicates negative.

Of the 6 patients who did not undergo bone biopsy, follow-up MR imaging revealed resolution of the infection after empiric antibiotic treatment in 5; the remaining patient, with terminal leukemia who had no follow-up MR imaging, died during the course of chemotherapy and antibiotic treatment. Finally, a total of 7 patients with bone biopsy, 5 men and 2 women (mean age, 56.6 years; age range, 42–80 years) were included in this study (Table 1).

Patients' medical records, including clinical symptoms, laboratory data, biopsy sites and histopathologic findings, culture results of microorganisms, therapy, and clinical outcome after treatment, were reviewed.

MR Imaging Techniques

MR imaging was performed on a 1.5T system (Magnetom Vision or Magnetom Sonata; Siemens, Erlangen, Germany; or Signa Excite; GE Healthcare, Milwaukee, Wis). Our imaging protocol included T1-weighted spin-echo images (TR/TE, 500–700/10–17 ms), T2-weighted fast spin-echo images (TR/TE, 3000–5000/94–128 ms), short τ inversion recovery (STIR) images (TR/TE/TI, 3000–6500/27–82/150–170 ms), and contrast-enhanced T1-weighted spin-echo images (TR/TE, 500–700/10–17 ms) with and without fat suppression. Gadopentetate dimeglumine (Magnevist; Schering, Berlin, Germany) was administrated intravenously at a dose of 0.1 mmol per kilogram of body weight. MR imaging in coronal, sagittal, and axial planes was performed according to the anatomic location of the lesions in each patient.

Imaging Evaluation

Three experienced musculoskeletal radiologists (C.Y.H., C.W.Y., and T.T.F.S.) reviewed the MR images in consensus. The following data were evaluated in each patient's imaging presentation: location of the involved bones, number of the intraosseous lesions, signal intensity alterations and enhancement patterns of the intraosseous lesions, presence or absence of the rim sign and halo sign, involvement or preservation of the intervertebral disks, and associated soft-tissue inflammation and/or abscess if present.

The number of the intraosseous lesions was graded as solitary (single lesion) or multiple (>1 lesion). Signal intensity of the intraosseous lesions was graded on T1-weighted, T2-weighted, and STIR images as hypointense, isointense, or hyperintense in comparison with the signal intensity of normal bone marrow. After intravenous administration of contrast material, enhancement of the intraosseous lesions was graded as not enhanced, marginally enhanced, or globally enhanced. Signal-intensity alterations suggestive of osteomyelitis were low signal intensity on T1-weighted images, high signal intensity on T2-weighted and STIR images, and enhancement on contrast-enhanced MR images.[1-5,13-15]

The MR imaging criterion for the presence of the "rim sign" was a peripheral curvilinear area of low signal intensity on all pulse sequences in an osseous lesion.[13,14,16] The MR imaging criterion for the presence of the "halo sign" was a peripheral rim of high signal intensity on T2-weighted and STIR images around an osseous lesion with lower signal intensity.[17] The MR imaging criterion for the involvement of intervertebral disks was signal-intensity alterations with decreased disk height and an absent intranuclear cleft.[9,11] MR imaging criteria for the presence of soft-tissue inflammation were a swollen area of intermediate or low signal intensity compared with normal muscle tissue on T1-weighted images, high signal intensity on T2-weighted and STIR images, and enhancement on contrast-enhanced MR images confined to the soft tissue with ill-defined planes.[14,16] MR imaging criteria for the presence of soft-tissue abscess were an area of intermediate or low signal intensity on T1-weighted images, fluid-equivalent signal intensity on T2-weighted and STIR images, and rim enhancement on contrast-enhanced MR images.[7,9,18,19]

Follow-Up MR Imaging Studies

All patients underwent follow-up MR imaging studies in a period from 2 to 25 months (mean, 8 months) after their initial MR imaging studies. Of these patients, 5 (71%) had 1 follow-up study, and 2 (29%) had 3.

For the follow-up studies, the sequential change between the initial and last study was graded as healing or healed, aggravated, or equivocal. MR imaging findings of decreased number and extent of infectious foci, gradual reconstitution of fatty marrow with a decreased osseous area of signal-intensity abnormality and enhancement, reduced soft-tissue inflammation, and absence of soft-tissue abscess were defined as healing. MR imaging of complete reconstitution of fatty marrow in previously affected bone was defined as healed. MR imaging findings of an increased number and extent of infectious foci, an increased osseous area of signal-intensity abnormality and enhancement, progressive osseous destruction or collapse, spread of involved osseous areas, and increased soft-tissue involvement were defined as aggravated. MR imaging of no substantial change was defined as equivocal.

Table 2: MR imaging findings in 7 patients with unusual manifestations of vertebral osteomyelitis

Patient No.	Involved Bones*	Intraosseous Lesions	SI of Intraosseous Lesions			Enhancement of Intraosseous Lesions	Rim Sign	Halo Sign	Preservation of Intervertebral Disks	Soft-Tissue Inflammation†
			T1W	T2W	STIR					
1	Spine (L5)	Solitary	↓	−− or ↑	↑	Global	Yes	Yes	Yes	Yes
2	Spine (S1)	Solitary	↓	↑	↑	Global	Yes	Yes	Yes	Yes
3	Spine (T10, L1, upper sacrum)	Multiple	↓	↑	↑	Global	Yes	Yes	Yes	Yes
4	Spine (T5-L5, upper sacrum), bilateral pelvic girdles	Multiple	↓	−− or ↑	↑	Global or marginal	No	Yes	Yes	Yes
5	Spine (whole spine), bilateral ribs	Multiple	↓	−− or ↑	↑	Global	Yes	Yes	Yes	No
6	Spine (whole spine)	Multiple	↓	−− or ↑	↑	Global or marginal	Yes	Yes	Yes	Yes
7	Spine (whole spine), bilateral ribs, sternum, bilateral pectoral girdles, bilateral pelvic girdles	Multiple	↓	−− or ↑	↑	Global or marginal	Yes	Yes	Yes	Yes

Note:—SI indicates signal intensity; T1W, T1-weighted MR images; T2W, T2-weighted MR images; STIR, short τ inversion recovery; ↑, hyperintense; −−, isointense; ↓, hypointense.
* Posterior element involvement of the vertebrae is noted in 3 patients (patients 5–7).
† Limited amount of the paraspinal or epidural inflammatory tissue is noted in 6 patients (patients 1–4, 6, and 7).

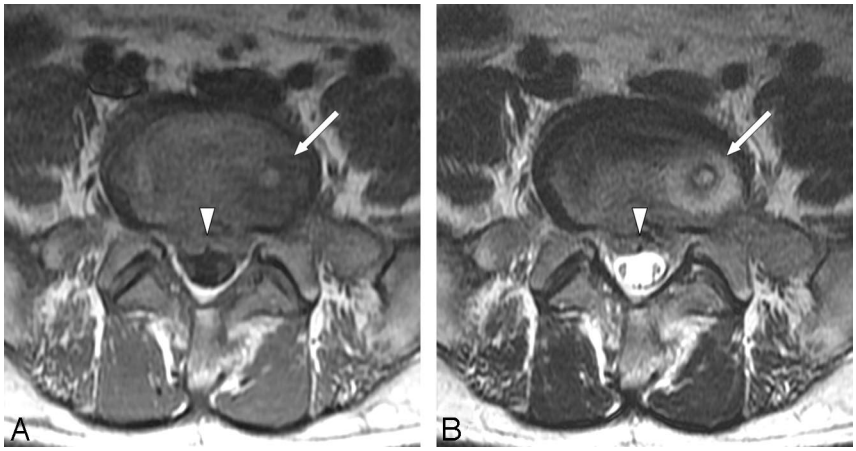

Fig 1. A 42-year-old man experienced low-back pain and fever for 5 days. *A* and *B,* Axial T1-weighted (TR/TE, 600/16) (*A*) and axial T2-weighted (TR/TE, 4900/111) (*B*) MR images show an intraosseous lesion of T1-weighted low signal intensity and T2-weighted high signal intensity with an inner rim sign and an outer halo sign (*arrow*) near the upper endplate of S1. Note the limited amount of epidural soft-tissue inflammation (*arrowhead*).

Results

Review of Clinical Data

Medical records were reviewed for each patient to investigate the clinical symptoms and laboratory data. These patients presented with fever ($n = 5$, 71%), progressive low-back pain ($n = 3$, 43%), or neck mass ($n = 1$, 14%) with a duration from 2 days to 3 months (mean, 25.9 days). The C-reactive protein level was elevated in 6 patients for whom we had that data and ranged from 7.44 to 22.89 mg/dL (mean, 13.19 mg/dL).

All patients had undergone CT-guided percutaneous needle biopsy of the infected bone after MR imaging. Blood cultures were performed in all patients. The reports of histopathologic and microbiologic analysis from collected biopsy samples and the results of blood cultures were recorded. The diagnosis of osteomyelitis was confirmed on the basis of positive histopathologic findings of bone biopsy in 6 (86%) patients and of a therapeutic diagnosis with follow-up MR imaging findings in 1 (14%) (Table 1).

Location of Involved Bones and Number of Intraosseous Lesions

MR images demonstrated the location of bone infection and the number of intraosseous lesions of the 7 patients (Table 2). Imaging revealed involvement of the following spinal regions: cervical ($n = 3$, 43%), thoracic ($n = 5$, 71%), lumbar ($n = 6$, 86%), and sacral ($n = 6$, 86%). In addition, involvement was seen in the following bones: pelvic girdles ($n = 2$, 29%), ribs ($n = 2$, 29%), sternum ($n = 1$, 14%), and pectoral girdles ($n = 1$, 14%). Of the 7 patients with vertebral osteomyelitis, 2 (29%) had a solitary lesion (Fig 1) and 5 (71%) had multiple lesions (Figs 2 and 3). Involvement of the posterior elements of the vertebrae was found in 3 (43%) patients (Fig 3).

Signal-Intensity Alterations and Enhancement Patterns of Osteomyelitis

The signal-intensity characteristics and enhancement patterns of the intraosseous lesions in the 7 patients are summarized in Table 2. T1-weighted images of all patients showed low signal intensity of the lesions (Figs 1*A*, 2*A*, and 3*A*). T2-weighted images of 5 (71%) patients showed mixed intermediate and high signal intensity of the lesions; and imaging of the other 2 (29%) revealed high signal intensity of the lesions (Fig 1*B*). STIR images of all patients showed high signal intensity of the lesions (Fig 2*B*). Contrast-enhanced MR images of 3 (43%) patients showed global or marginal enhancement of the lesions and in 4 (57%) patients revealed only global enhancement of the lesions (Fig 3*B*).

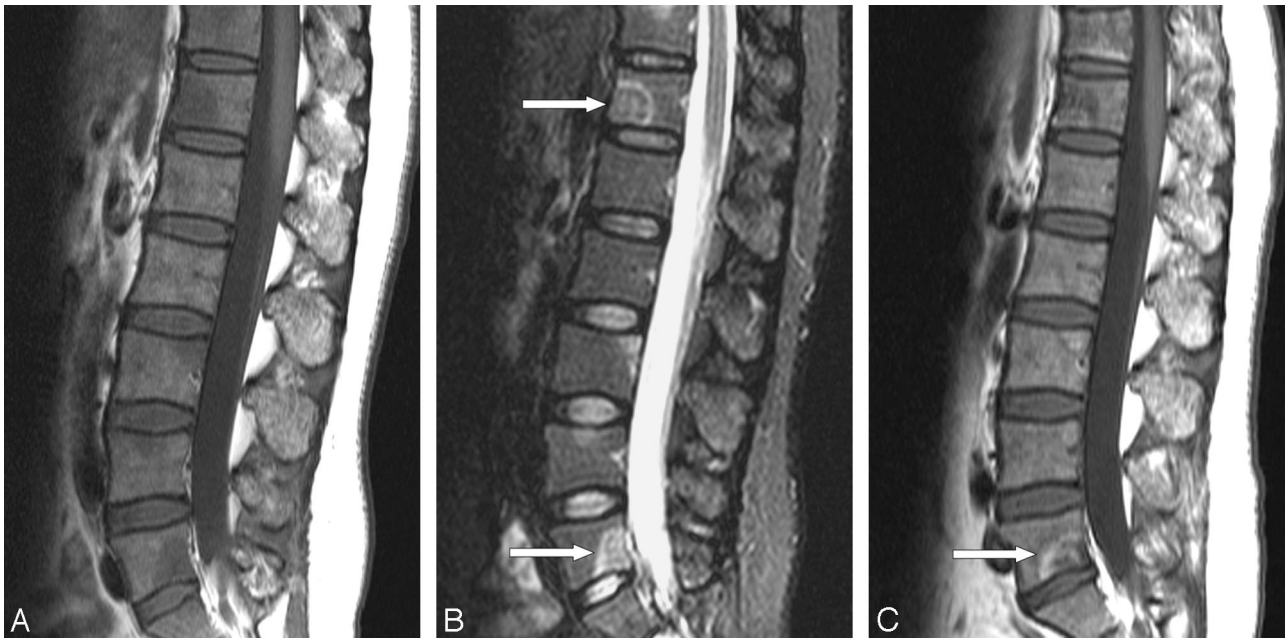

Fig 2. A 46-year-old woman with fever for 2 days. *A* and *B,* Sagittal T1-weighted (TR/TE, 550/12) (*A*) and sagittal STIR (TR/TE/TI, 3130/65/160) (*B*) MR images show multiple intraosseous lesions of T1-weighted low signal intensity and STIR high signal intensity. Note some osseous lesions with a positive halo sign (*arrows*) and the absence of paraspinal or epidural inflammatory soft tissue. *C,* Sagittal T1-weighted (TR/TE, 550/12) follow-up MR image obtained 12 months later shows gradually reconstituted fatty marrow with a decrease in the number and extent of infectious foci. Note a peripheral rim of increased signal intensity (*arrow*) in a residual subchondral lesion of low signal intensity at the lower endplate of L5.

Rim Sign, Halo Sign, Intervertebral Disks, and Soft-Tissue Inflammation

MR images demonstrated the presence or absence of the rim sign, halo sign, and associated soft-tissue inflammation and/or abscess in the 7 patients (Table 2). The rim sign was found in 6 (86%, Figs 1 and 3) and the halo sign, in 7 (100%, Figs 1*B* and 2*B*) of our patients. Of the 7 patients with osteomyelitis involving the spine, all had relative preservation of intervertebral disks. Six (86%) patients had a limited amount of paraspinal or epidural inflammatory tissue (Fig 1), and none had soft-tissue abscess.

Biopsy and Culture Results

Histopathologic analysis of the CT-guided bone biopsy samples confirmed the diagnosis of chronic osteomyelitis in 6 (86%) of the 7 patients; and the remaining patient (14%) had chronic fibrosis (Table 1). All specimens from the bone biopsy revealed no evidence for malignancy. Culture results of the bone biopsy samples yielded a positive result with gram-positive cocci in only 1 (14%) patient.

Blood cultures were positive in 2 (29%) of the 7 patients (Table 1). We cultured the following pathogens: *Staphylococcus aureus* ($n = 1$) and *Salmonella* organism ($n = 1$). These 2 patients with positive blood cultures also had histopathologically proved chronic osteomyelitis from bone biopsy.

Therapy, Follow-Up MR Imaging Studies, and Clinical Outcome

The therapy, follow-up MR imaging, and clinical outcome after treatment in the 7 patients are summarized in Table 3. All patients were clinically improved or cured, without evidence of any sequelae; and the follow-up MR imaging correlated well with clinical outcome. Of the 7 patients with osteomyelitis, evidence of the healing process in imaging changes was seen in all who also appeared clinically improved after treatment (Figs 2 and 3). One (14%) patient who appeared clinically cured had almost-healed imaging changes on the 25-month follow-up MR imaging (Fig 3*D*).

Discussion

Although the characteristic findings of vertebral osteomyelitis are well-known, they could possibly be misinterpreted among the cases with unusual presentations. The unique MR imaging patterns with infected intraosseous lesions that might spread from hematogenous routes as septic emboli may mimic the imaging patterns of osseous metastases. Awareness of these unusual manifestations might be helpful in accurately suggesting the diagnosis of vertebral osteomyelitis in the earlier stage.

On the contrast-enhanced MR images of spinal infection, evidence of gadolinium enhancement has been reported in areas of vascularized inflammatory tissues, whereas marginal enhancement has been reported in areas of inflammation surrounding necrotic or devitalized tissues.[1,13-15] In our study, the intraosseous lesions were either globally or marginally enhanced on contrast-enhanced MR images in all patients with vertebral osteomyelitis. However, the bone marrow findings of osteomyelitis on MR imaging are nonspecific. A variety of bone diseases, such as noninfectious inflammatory conditions and metastatic lesions, may simulate the signal-intensity alternations and enhancement patterns seen in osteomyelitis.[1,3,13,14]

Hematogenous infection in mature bone commonly involves the spine, where branches of the equatorial and metaphyseal arteries are the end arterioles.[13,14,20,21] If microorganisms or septic emboli dislodge in these areas, they may lead to venous thrombosis, retrograde capillary occlusion, and marrow necrosis. Any end-capillary or end-arteriole occlusion could cause an area of avascular necrosis, which may explain

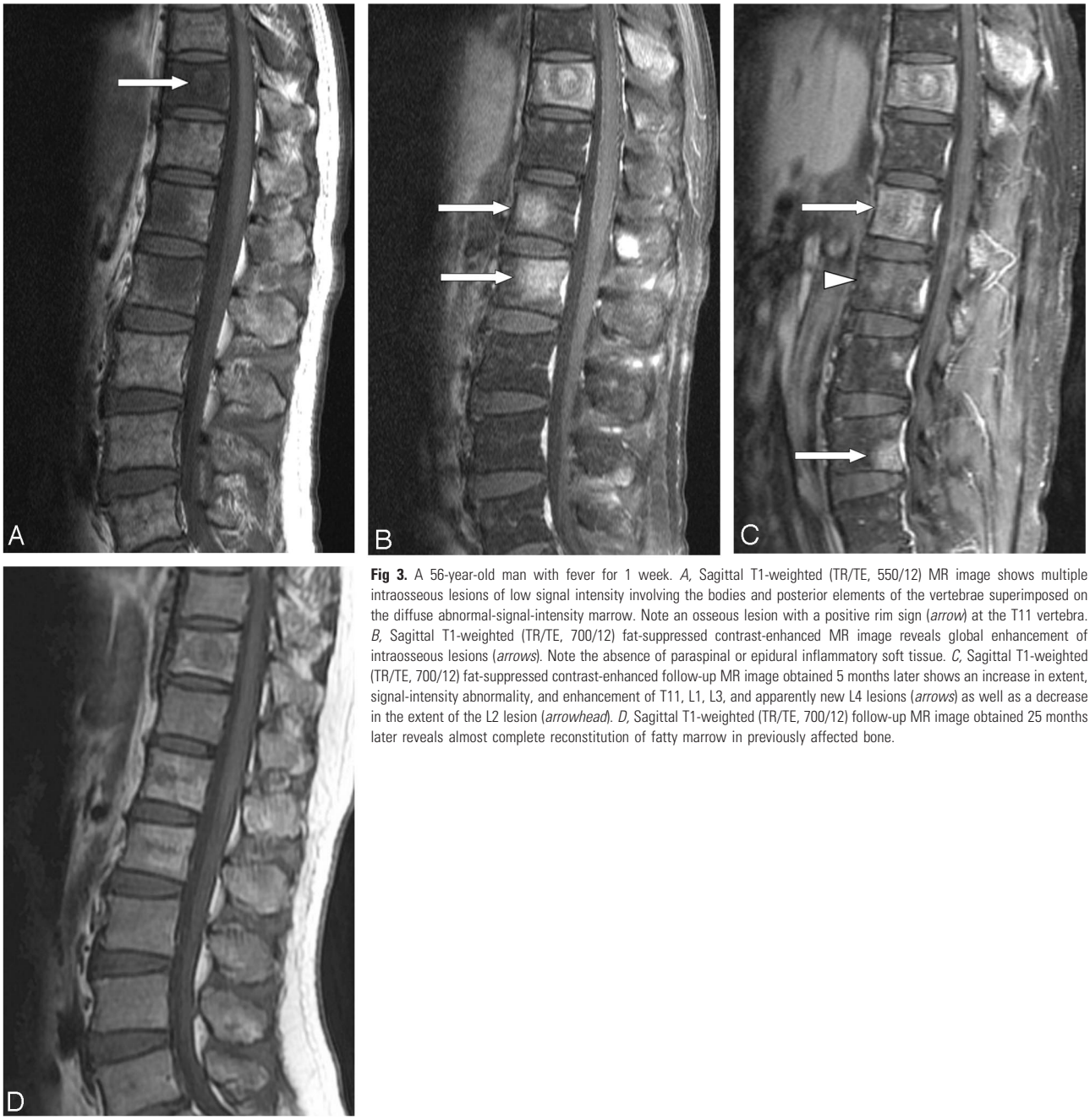

Fig 3. A 56-year-old man with fever for 1 week. *A,* Sagittal T1-weighted (TR/TE, 550/12) MR image shows multiple intraosseous lesions of low signal intensity involving the bodies and posterior elements of the vertebrae superimposed on the diffuse abnormal-signal-intensity marrow. Note an osseous lesion with a positive rim sign (*arrow*) at the T11 vertebra. *B,* Sagittal T1-weighted (TR/TE, 700/12) fat-suppressed contrast-enhanced MR image reveals global enhancement of intraosseous lesions (*arrows*). Note the absence of paraspinal or epidural inflammatory soft tissue. *C,* Sagittal T1-weighted (TR/TE, 700/12) fat-suppressed contrast-enhanced follow-up MR image obtained 5 months later shows an increase in extent, signal-intensity abnormality, and enhancement of T11, L1, L3, and apparently new L4 lesions (*arrows*) as well as a decrease in the extent of the L2 lesion (*arrowhead*). *D,* Sagittal T1-weighted (TR/TE, 700/12) follow-up MR image obtained 25 months later reveals almost complete reconstitution of fatty marrow in previously affected bone.

Table 3: Therapy, follow-up MR imaging studies, and clinical outcome in 7 patients with unusual manifestations of vertebral osteomyelitis

Patient No.	Therapy	Interval between Initial and Subsequent MRI (months)	Sequential Change between Initial and Last MRI	Clinical Outcome after Treatment
1	Antibiotic	2	Healing	Improved
2	Surgical debridement and antibiotic	5	Healing	Improved
3	Antibiotic	4	Healing	Improved
4	Antibiotic	3, 8, 12	Healing	Improved
5	Antibiotic and anti-TB	5, 10.5, 25	Almost healed	Cured
6	Antibiotic and anti-TB	6.5	Healing	Improved
7	Antibiotic and anti-TB	7	Healing	Improved

Note:—MRI indicates MR imaging; TB, tuberculosis.

the MR imaging finding of intraosseous lesions or halo sign seen in our patients with vertebral osteomyelitis mimicking osseous metastases.

A peripheral curvilinear area of low signal intensity (the rim sign) on all pulse sequences corresponding to the fibrous changes or reactive bone in an osseous lesion has been reported in 93% of patients with chronic osteomyelitis.[13,14,16] The rim sign seen in our study was consistent with that previ-

ously reported. A peripheral rim of high signal intensity (the halo sign) around an osseous lesion with lower signal intensity on T2-weighted images, thought to represent the mucinous or cellular tissue in a space secondary to the destruction of trabeculae, was most common in osteoblastic metastases from prostate cancer.[17] Even so, the halo sign was also observed in all of our patients with osteomyelitis. The halo sign seen in our study may reflect the hypervascular granulation tissue, a hyperemic response adjacent to thickened trabeculae, at the periphery of the fibrotic or necrotic focus of osteomyelitis.

Involvement of the intervertebral disks and paraspinal soft-tissue inflammation have often been reported in spinal infection.[6,9] Posterior-element abnormalities of the vertebrae have been described as causing difficulty in differentiating tuberculous infection from neoplasm.[21] Of our 7 patients with osteomyelitis involving the spine, the preserved intervertebral disks in all (100%), the limited paraspinal or epidural inflammatory tissue in 6 (86%), and the posterior element involvement in 3 (43%) made the MR imaging findings equivocal and mimicking osseous metastases. Although soft-tissue abscess corresponding to the cellular inflammatory zone around the nonenhanced necrotic center was not infrequently seen in spinal infection,[7,9,18,19] this finding was not observed in our patients with vertebral osteomyelitis.

Kapeller et al[22] reported that focal back pain and fever have been described in 90% and 61% of patients with pyogenic spondylodiskitis, respectively. We agree that the lower prevalence (43%) of back pain and the slightly higher prevalence (71%) of fever in our study, which seems to be an interesting finding, are opposite to findings previously reported. As compared with the reported spinal infection with involvement of the intervertebral disks, the lower prevalence of back pain in our study may be related to the intraosseous lesions and preserved intervertebral disks. Although these clinical symptoms are relatively nonspecific, the high prevalence of fever may remind the clinicians and radiologists to raise the suspicion of infection rather than malignancy.

In cases of osteomyelitis, culture results of the bone biopsy samples have been described as disappointingly low, ranging from 38% to 50%.[23,24] The yield ratio (14%) of culture-positive osteomyelitis in our study was much lower than that reported in earlier series. Our inability to identify a pathogen may be related to inadequate sampling of the lesion with a small-bore biopsy needle or the natural evolution of the infection.[25] On the contrary, the accuracy of histopathologic findings in the diagnosis of osteomyelitis has been described as relatively high.[23,25,26] The accuracy rate (86%) of histopathologic analysis in our study was consistent with the data previously reported. Our results support the consensus that the addition of histopathologic analysis to the microbiologic cultures of bone biopsy samples may improve overall diagnostic performance of the procedure in patients with suspected osteomyelitis.[23,25,26]

Diffuse-weighted imaging (DWI) can be used for noninvasive tissue characterization and has been discussed in evaluating bone marrow pathologies.[27] Although substantial signal-intensity aberration reflecting high diffusivity has been observed in aggressive osteomyelitis, both tuberculous and pyogenic spondylodiskitis may cause restricted diffusion, resulting in increased signals on DWI and low apparent diffusion coefficient values, which mimic malignancy.[27,28] Because of the difficulty in differentiating osseous metastasis from osteomyelitis, superparamagnetic iron oxide (SPIO)-enhanced MR imaging has been used in detecting bone marrow lesions.[29] MR signal intensity reduction by SPIO particles, which are phagocytosed by macrophages, in the region of osteomyelitis is significantly more than that in the osseous metastasis, suggesting the potential of SPIO in differentiating between these conditions.[29]

Although clinical outcomes after treatment in osteomyelitis have been described to be difficult to study because of the heterogeneous nature of the infection as well as the need for an unusually long period (at least 6 months) of follow-up, a percentage (69.4%) of patients was reported to be healed apparently when outcomes were measured in a large series.[30] After medical or surgical treatment, all of our 7 patients with vertebral osteomyelitis appeared clinically improved or cured, without evidence of any sequelae; this outcome was much better than the data previously reported.

In the follow-up MR imaging, a peripheral rim of T1-weighted increased signal intensity corresponding to the fatty replacement in previously affected bone marrow has been described to represent the healing edge.[1,13,16,31] This finding was seen in all of our 7 patients, who had healing or almost healed imaging changes. The use of MR imaging for following the response to treatment has not been well supported in 1 series.[5] Follow-up MR imaging may not correlate with the clinical pictures, in that MR imaging findings may continue to indicate deterioration or treatment failure despite clinical improvement.[5,31] In that case, follow-up should be based on the response to treatment and the overall health of the patient, rather than on only the MR imaging findings. Even so, the follow-up MR imaging in our study still correlated well with clinical outcome and played an important role.

There are some limitations to this study. First, our study is a retrospective one with an inherent selection bias. The small number of patients selected in this study group may make it impossible to include all unusual MR imaging patterns of vertebral osteomyelitis. Even so, our purpose was to emphasize the unusual manifestations of osteomyelitis with MR imaging patterns of septic emboli, which would be easily misdiagnosed during imaging interpretation. Histopathologic analysis of bone biopsy samples could be helpful in reaching the correct diagnosis of osteomyelitis and excluding the possibility of osseous malignancy. Second, 3 of our patients underwent follow-up MR imaging studies in less than 6 months after the initial studies, though the images demonstrated healing changes and the findings correlated well with clinical outcome. Because of the heterogeneous nature of the infection, a longer period (at least 6 months) of follow-up may be necessary to evaluate the temporal evolution of osteomyelitis.

Conclusion

Vertebral osteomyelitis arising from hematogenous spread of septic emboli can have different imaging patterns and may present as solitary or multiple intraosseous lesions, manifested as low signals on T1-weighted images, mixed or high signals on T2-weighted images, high signals on STIR images, global or marginal enhancement, and preserved intervertebral disks, mimicking osseous metastases. Although there are no patho-

gnomonic MR imaging findings, recognition of these unusual imaging manifestations, together with clinical and laboratory presentations and histopathologic analysis of the bone biopsy samples, may aid us in reaching the correct diagnosis and management of vertebral osteomyelitis.

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