

MR Imaging of the Musculoskeletal Tumors

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<국문초록>

근골격계 종양의 자기공명영상

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근골격계 종양에서 자기공명영상의 이용가치를 알아보려고 23예의 골종양과 18예의 연부조직 종양환자에서 자기공명영상을 얻었다. 2.0T 초전도 자기공명영상 장치를 사용하여 스핀-에코 기법으로 축상면, 시상면 혹은 관상면의 T1 및 T2 강조영상을 얻었으며 단순 X-선 촬영 및 CT 소견과 비교분석하였다. 자기공명영상은 조직간의 대조도가 우수하고 다평면영상을 얻을 수 있어 종괴의 발견과 범위 판정이 단순 X-선 촬영이나 CT보다 우수하였는데 시상면 혹은 관상면의 T1 강조영상이 골수강내의 범위를, 축상면의 T2강조영상이 연부조직내 종괴의 범위를 파악하기에 좋았다. 골종양의 감별진단에 필요한 피질골의 파괴, 종양내 석회화, 골막반응의 관찰은 용이하지 않았으나 혈관종, 지방종 그리고 동맥류성 골낭종은 자기공명영상으로 조직학적 진단이 가능하였으며, 수술후에 종양이 재발한 예에서 섬유화와 종양의 재발과의 감별을 할 수 있었다.

Introduction

Musculoskeletal system is well suited for magnetic resonance(MR) imaging because of the absence of motion, the large difference in signal intensity among bone, cartilage, tendon, muscle and fat, and the absence of bone artifact seen on computed tomography(CT). MR imaging can enable better detection and delineation of bone and soft-tissue tumors because of its ability to provide high contrast resolution and imaging in any planes¹⁻³. In

order to evaluate the clinical usefulness of MR imaging in musculoskeletal tumors, our early experience with MR imaging of patients with bone and soft-tissue tumors was reviewed.

Materials and Methods

MR imaging was performed in 41 patients with musculoskeletal tumors or conditions mimicking tumors at Seoul National University Hospital. Three patients were diagnosed as metastatic bone tumors and received chemotherapy. Remaining 38 patients underwent surgery, 20 had bone tumors and 18 had soft tissue tumors. Table 1 lists the histopathologic diagnoses in the patients examined.

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MR examinations were performed with a 2.0T superconducting magnet (Spectro-20000, Goldstar, Seoul). Special receiving coils (surface coils) were used in the examination for small lesions of extremities, whereas body coil was preferred for examination of large lesion or lesions of pelvis and proximal thigh. In two cases, head coil was used for examination of both sides of lower extremities.

Spin-echo(SE) pulse sequences with multisection acquisitions were used. Relatively T1-weighted images were obtained using repetition time(TR) of 500 msec with echo-delay time(TE) of 30 msec. Relatively T2-weighted images were obtained with TR of 2,000 msec and TE of 60 msec.

Depending on the location of the mass, axial, sagittal and/or coronal images were obtained. All images were obtained with a 256×256 acquisition

matrix and one to four averagings. Contiguous slices of 5 to 10 mm thickness were obtained depending on the size of the mass.

All patients had plain film examination and 16 patients had CT scans before MR examination. MR studies were reviewed and correlated with plain films and CT scans simultaneously.

Results

Lesion Detection

All tumors were easily detected using MR imaging on both T1 and T2-weighted images. T1-weighted images clearly depicted the anatomy of the normal structures and most tumors had low signal intensity in this pulse sequence. Because of short T1 value of normal marrow fat, intraosseous lesion was easily detected (Fig. 1B, 2C, 3C). But

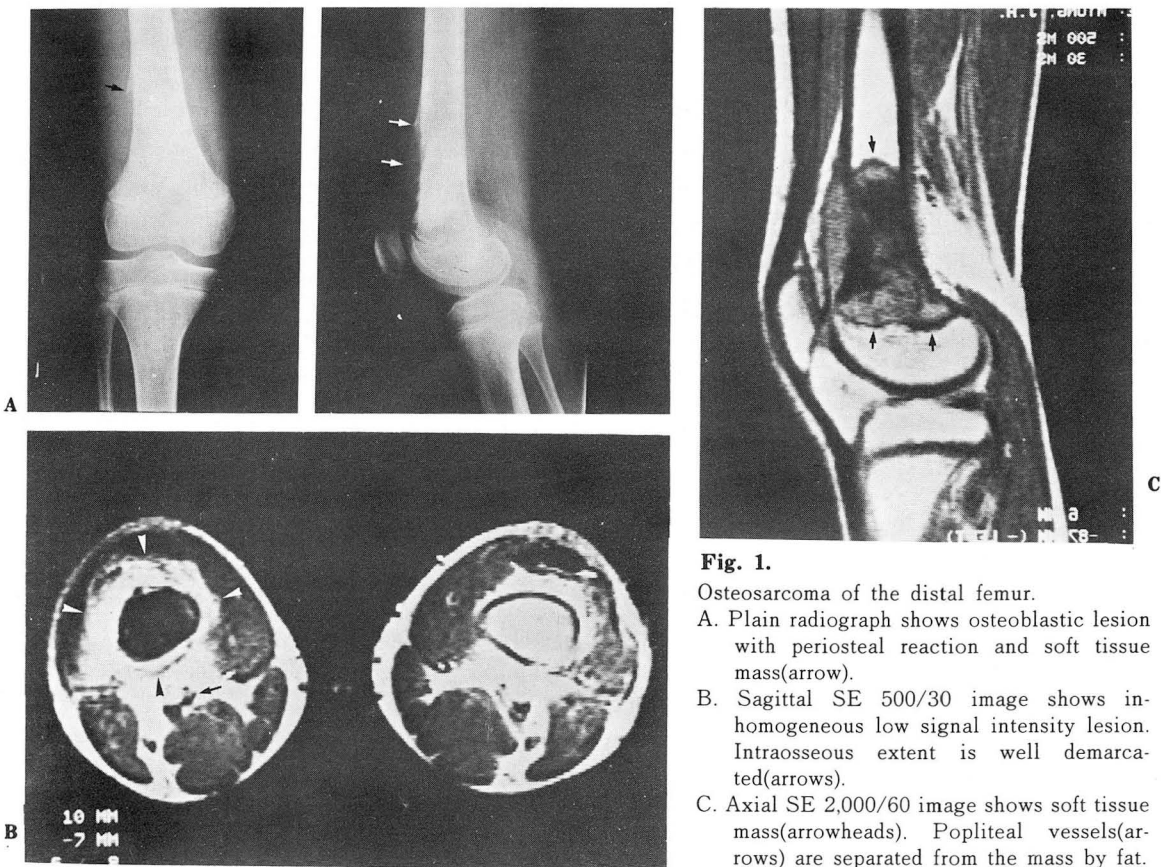


Fig. 1.

Osteosarcoma of the distal femur.

- A. Plain radiograph shows osteoblastic lesion with periosteal reaction and soft tissue mass (arrow).
- B. Sagittal SE 500/30 image shows inhomogeneous low signal intensity lesion. Intraosseous extent is well demarcated (arrows).
- C. Axial SE 2,000/60 image shows soft tissue mass (arrowheads). Popliteal vessels (arrows) are separated from the mass by fat.

Table 1. Diagnoses in the Patients Examined

Diagnosis	No. of Cases
Bone tumors	
Osteosarcoma	11
Parosteal osteosarcoma	2
Chondrosarcoma	2
Malignant fibrous histiocytoma	1
Eosinophilic granuloma	1
Giant cell tumor	1
Aneurysmal bone cyst	1
Chondromyxoid fibroma	1
Metastasis	3
Soft-tissue tumors	
Hemangioma	5
Fibromatosis	3
Chondrosarcoma	2
Xanthoma	2
Pigmented villonodular synovitis	2
Cyst	2
Lipoma	1
Neurofibromatosis	1

extrasosseous lesion was difficult to delineate because normal muscle had a signal intensity similar to that of the tumor in this pulse sequence(Fig. 2B). The difference in signal intensity between tumor and surrounding normal soft tissue was best seen on T2-weighted images and were easily detected because normal muscle had low signal intensity(Fig. 1C, 2D, 3D).

Extent Evaluation

MR imaging was excellent for evaluation of intra- and extrasosseous extent of tumors. Of the 22 patients with tumors of long bones, MR imaging was excellent in demonstrating the extent of abnormal bone marrow. Contrast between tumor and normal marrow was best on T1-weighted image. Imaging in the sagittal or coronal plane was valuable and provided a significant advantage over CT. Fig. 1, 2, 3 show patients with bone tumors in long bones in whom MR imaging clearly demonstrated the extent of the abnormality in the bone marrow.

For soft tissue tumors and the soft tissue components of bone tumors with extrasosseous extension, MR imaging was excellent in delineating between the lesion and the surrounding muscle, fat and neurovascular bundle. T2-weighted image provided the best technique for differentiation of tumor and muscle, because most tumors showed high signal intensity and muscle showed low signal intensity (Fig 1C, 2D, 3D, 4C). Although coronal or sagittal image was helpful in assessing the extent of extrasosseous lesion(Fig. 1B, 4C, 5C), axial image was easier to judge the relation of tumor to the neurovascular bundle. Fig. 1C demonstrated the boundary of extrasosseous component of osteosarcoma and popliteal vessels. Fig. 2D showed extension of tumor to subcutaneous fat through previous biopsy tract.

In 3 patients with bone or soft tissue tumor with flexion contracture, MR imaging was more excellent than CT in delineating the lesion because of multiplanar imaging capability(Fig. 6).

In 11 patients who had bone tumors and underwent both MR and CT examinations, CT was more accurate than MR imaging in showing cortical destruction(Fig. 3B).

Tumor Characteristics

Specific tumor characterization was difficult on the MR images in most cases. Judging from the signal intensity alone, there was no significant difference between benign and malignant tumors. MR imaging had difficulties in the evaluation of characteristics of periosteal reaction and margin of the lesion, which indicate biological activity of the bone tumor, and matrix calcification. Plain radiography was better than MR imaging in evaluation of periosteal reaction, tumor margin and matrix calcification.

However, there were some exceptions in tumor characterization with MR imaging. Five hemangiomas had heterogeneous high and low signal intensity pattern. Two of 5 hemangiomas showed

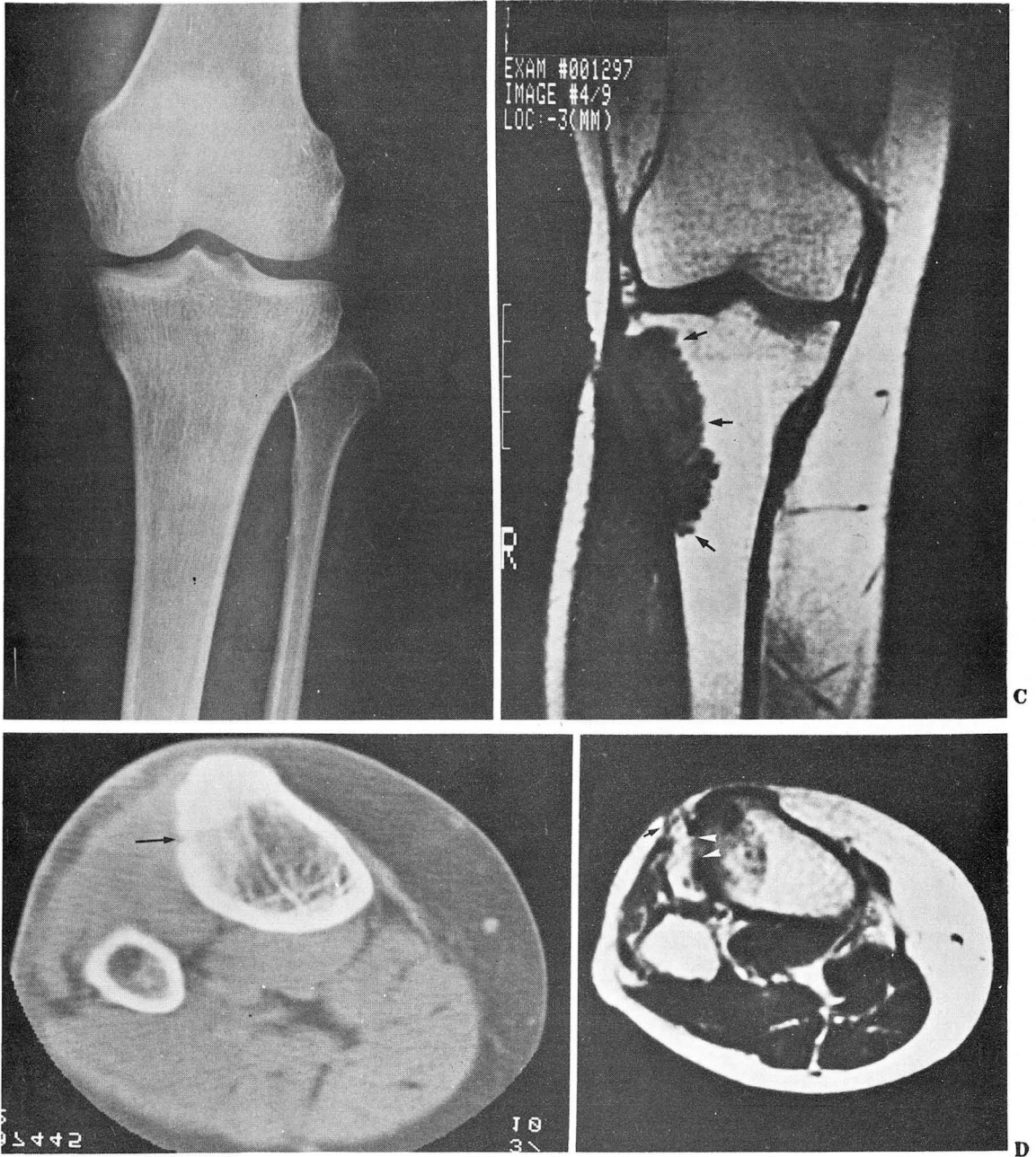


Fig. 2. Chondrosarcoma of the proximal tibia.
A. Plain radiograph shows no abnormality.
B. CT shows cortical disruption(arrow) and sclerosis. CT cannot demonstrate soft tissue mass.
C. Coronal SE 500/30 image shows abnormal marrow extent(arrows), but soft tissue involvement is not definite.
D. Axial SE 2,000/60 image shows cortical disruption(white arrow heads) and high signal of extraosseous mass. Note that soft-tissue mass extends through biopsy site(black arrows).

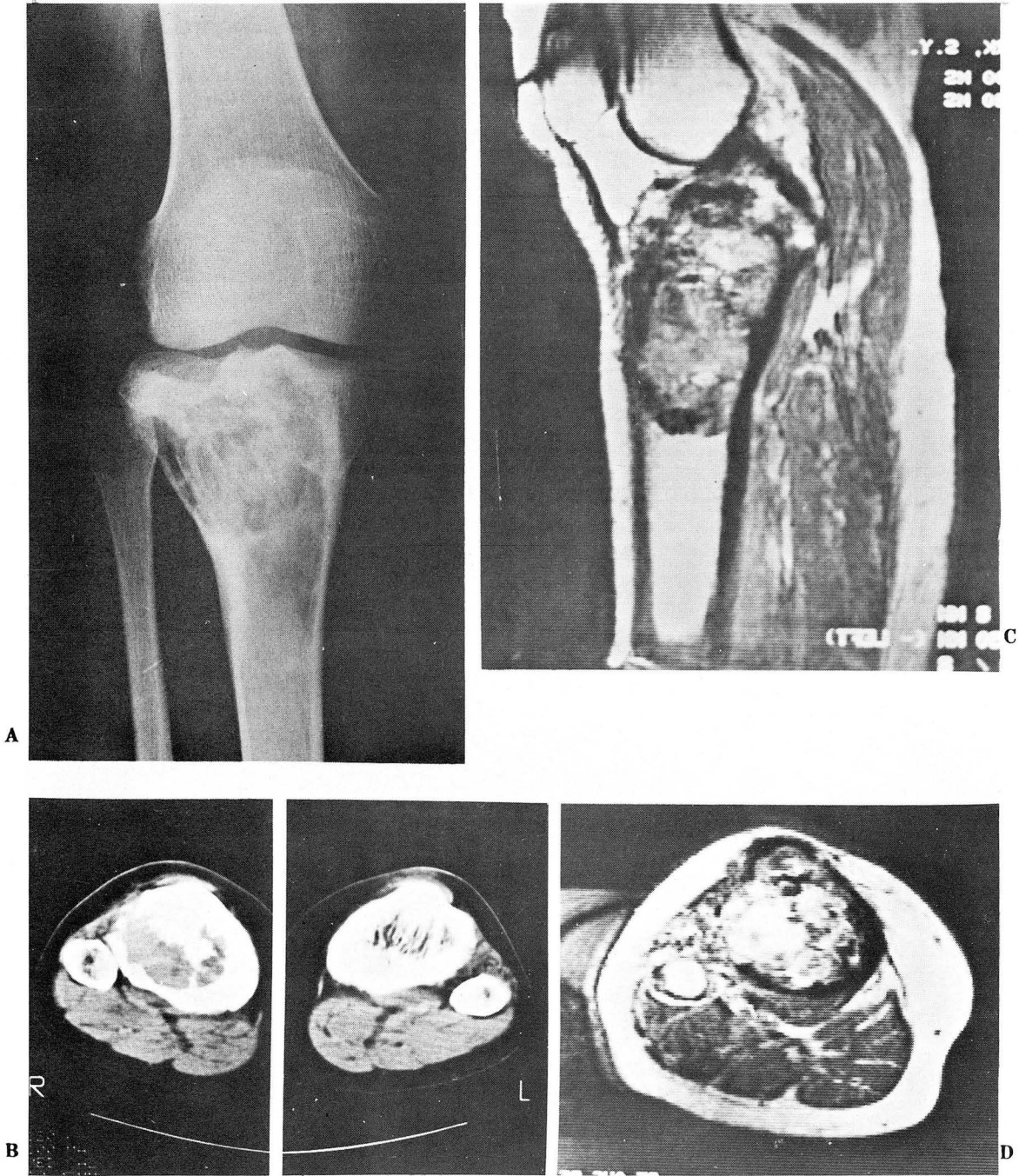


Fig. 3. Giant cell tumor(one year after surgery). Plain radiograph (A) and CT (B) show cortical disruption. Bony fragment and soft-tissue density replace the marrow. Sagittal SE 500/30 image(C) shows inhomogeneous low signal intensity lesion. Intraosseous extent is well demarcated. Axial SE 2,000/60 image(D) shows cortical disruption and abnormal marrow. High signal intensity lesion suggests tumor recurrence.

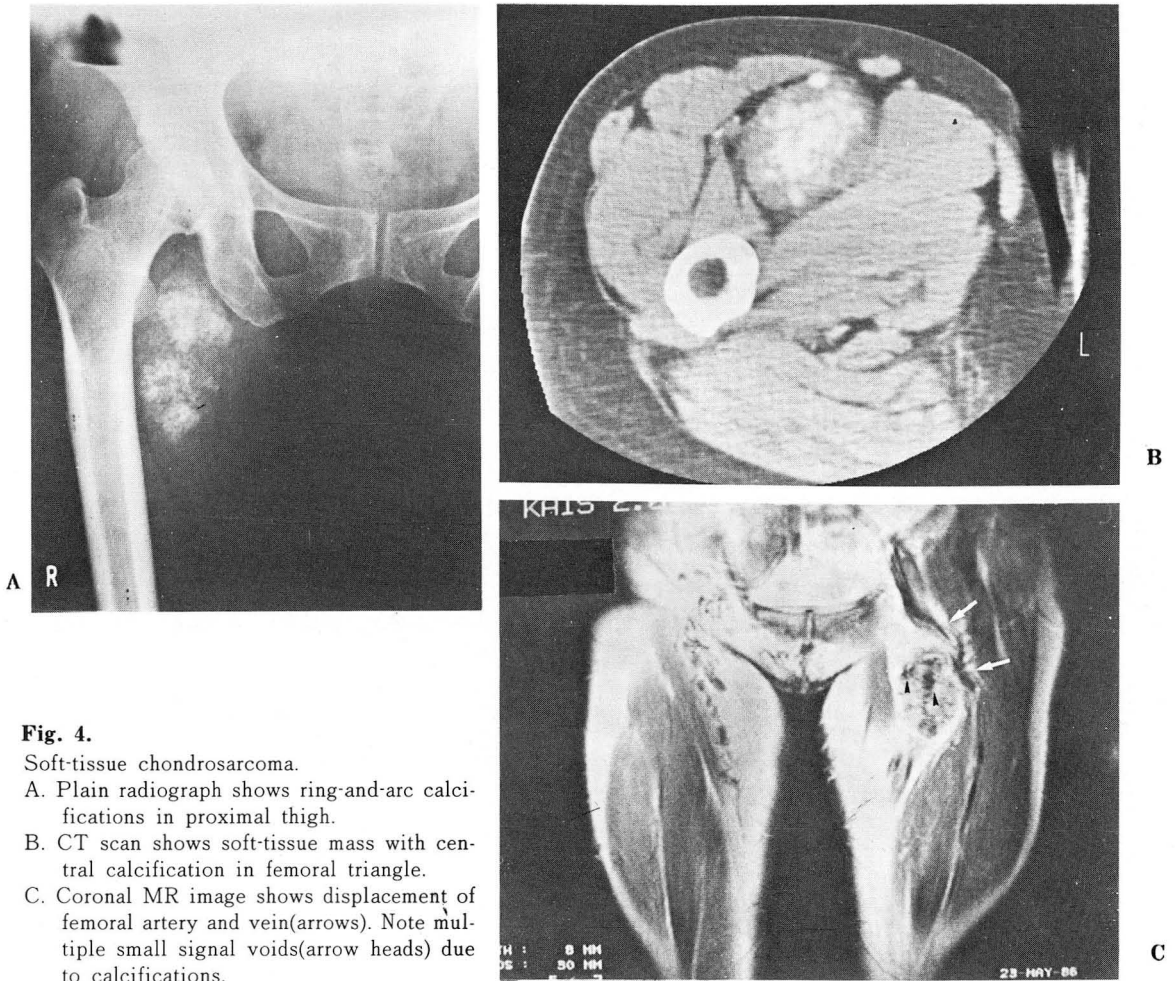


Fig. 4.

Soft-tissue chondrosarcoma.

- A. Plain radiograph shows ring-and-arc calcifications in proximal thigh.
- B. CT scan shows soft-tissue mass with central calcification in femoral triangle.
- C. Coronal MR image shows displacement of femoral artery and vein (arrows). Note multiple small signal voids (arrow heads) due to calcifications.

dilated tortuous vascular structures of low signal intensity on both T1 and T2-weighted images (Fig. 6). These most likely represented either a feeding artery or draining veins with high blood flow. With these MR findings, diagnosis was possible prior to angiography or surgery.

One patient with aneurysmal bone cyst showed expansile osteolytic lesion in proximal humerus. MR imaging demonstrated well defined, expansile mass with multiple internal septations forming cysts, containing fluid levels (Fig. 7). Cyst was high signal intensity in upper portion and low in dependent portion separated by fluid levels on both

T1- and T2-weighted images.

One case of lipoma had the same signal intensity as the surrounding normal fat on both T1- and T2-weighted images.

Fig. 3 was post-curettage and bone graft state of giant cell tumor. Plain radiography and CT could not confirm the recurrence. MR imaging diagnosed the tumor recurrence because of high signal intensity on T2-weighted image.

Discussion

Musculoskeletal imaging has become the most

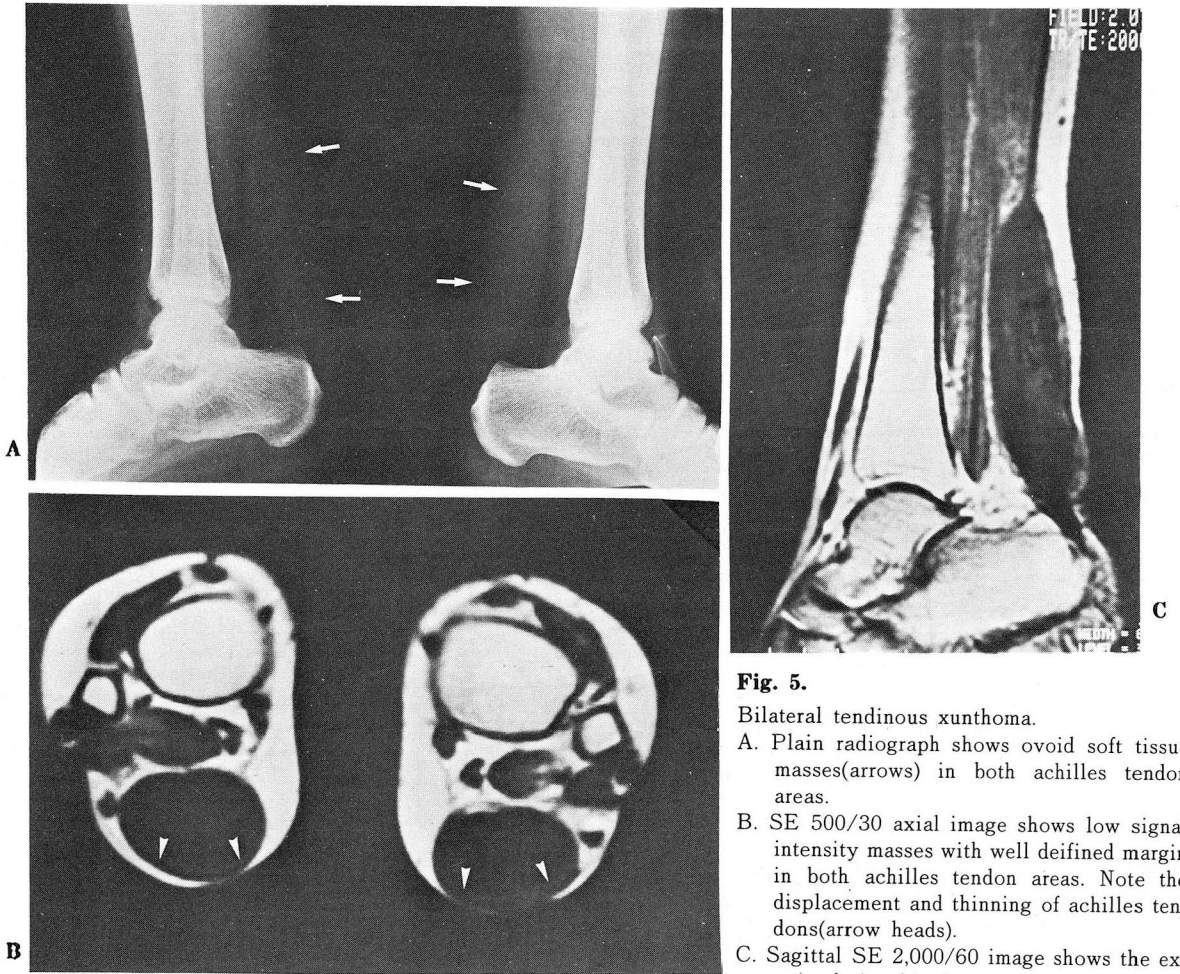


Fig. 5.

Bilateral tendinous xunthoma.

- A. Plain radiograph shows ovoid soft tissue masses (arrows) in both achilles tendon areas.
- B. SE 500/30 axial image shows low signal intensity masses with well defined margin in both achilles tendon areas. Note the displacement and thinning of achilles tendons (arrow heads).
- C. Sagittal SE 2,000/60 image shows the exact relationship between tumor and surrounding structures.

important nonneurological application of MR imaging. The most important reason for this phenomenon is the ability of MR imaging to provide high contrast between tissues. Certain technical capabilities are also important. A major asset is the flexibility with which the tomographic plane of section may be oriented with respect to the body. Sections may be oriented transaxially, sagittally, coronally, and obliquely. The freedom of MR imaging from impediments such as the beam-hardening artifact in CT, which can hinder visualization of soft tissue adjacent to bone, is of special note in musculoskeletal imaging. Major applications

account for most musculoskeletal MR examinations are bone and soft-tissue masses, acute and chronic injuries, and osteonecrosis¹⁻⁶.

This study suggests that there are two major advantages to using MR imaging rather than plain radiography and CT in the evaluation of bone and soft-tissue masses.

First, the increased contrast differentiation between the mass and normal tissue on MR imaging facilitates lesion identification for the observer. Every tumor in the present study was visible on MR images. Primary musculoskeletal tumors do not always present with clear-cut clinical findings.



Fig. 6. Cavernous hemangioma of lower extremity. Sagittal SE 2,000/60 images(A, B) show infiltrative inhomogeneous hyperintense lesion. Entire extremity is delineated in spite of severe flexion contracture. Note the dilated vascular channels(arrows).

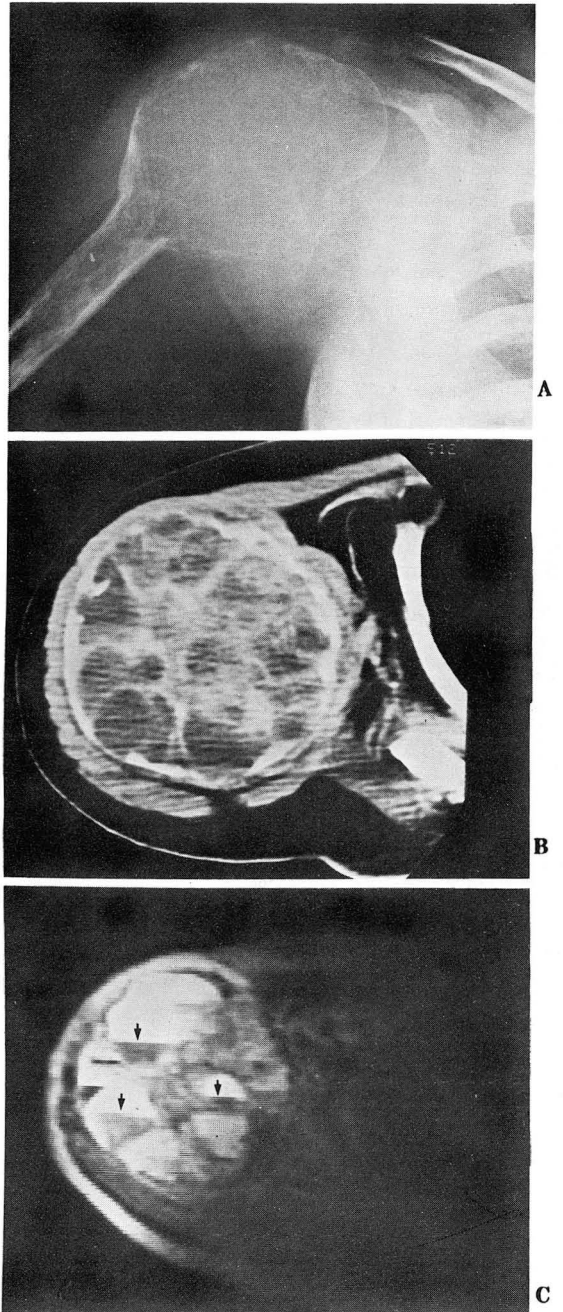


Fig. 7. Aneurysmal bone cyst of the proximal humerus. A. Plain radiograph shows expansile osteolytic lesion in proximal humerus. B. CT scan shows expansile mass with multiple internal septations. C. Axial SE 500/30 image shows multiple cysts with fluid levels(arrows).

This is particularly true for sarcomas, which is ideally should be diagnosed at the earliest stage possible, when clinical findings may be uncertain and other imaging techniques are of limited value. A properly performed MR imaging examination can be used to confirm or exclude the presence of an abnormal soft-tissue mass with high confidence⁷⁻⁹).

Second, MR imaging can give excellent depiction of the local extent of the tumor. MR imaging depicted all the cases of bone and soft-tissue masses in this series. Recent publications

comparing the efficacy of MR imaging and CT, MR imaging was found to be of equal or greater than CT assessing the extent of tumor in majority of cases^{7,8,10-13}). Several factors were important in realizing this advantage including the use of multiplanar imaging (coronal, sagittal and transaxial) and the choice of proper pulse sequences. Direct sagittal or coronal image is valuable in delineating the longitudinal extent of malignant tumor in the medullary canal. This longitudinal extent is of critical importance in planning the level for amputation or the limits of resection for limb salvage operation¹⁴). Also MR images can show the presence or absence of joint and epiphyseal involvement, which is not well depicted on CT because of the axial format of CT. Coronal and sagittal images also aid in clarifying the anatomic relationship between a soft-tissue mass and a normal anatomic structures such as vessel, nerve and muscle. However, in many cases the transaxial images are necessary to determine the extent of the lesion. It is well known that MR imaging is able to show high-contrast differences between soft-tissue structures which have similar density on CT^{7,10-13}). This contrast superiority of MR imaging is most commonly used in distinguishing a soft-tissue mass from skeletal muscle, which are of about equal density on CT not enhanced by contrast material. Unlike CT, MR signal intensity is determined by many factors, including proton density, proton relaxation times (T1 and T2), and flow¹⁵). It is important to optimize the pulse sequences for obtaining a image with high contrast between tumor and surrounding structures. It is often necessary to use at least two pulse sequences: a T1-weighted image for maximal contrast between lesion and fat, including bone marrow fat, and a T2-weighted image for optimal contrast between the lesion and adjacent muscle. Blood vessels appear black, white or targetlike, depending on the flow velocity and pulse sequence. The combination of the two sequences depicted lesions well in this study.

MR imaging is not useful in providing diagnostic information. A major reason for the failure of MR imaging in diagnosis is that tumor matrix calcification, ossification, details of cortical bone destruction, and periosteal reaction are less easily evaluated than on plain radiographs^{10,11}). Calcification and cortical bone produce no signal on MR imaging, although identification is still often possible by recognizing the signal void. Quantitative determination of relaxation times has not proved to be of clinical value in identifying tumor types, and the measurements are fraught with technical difficulties^{7,11,12}).

In most cases of this study, no tissue characteristics could be identified on the MR images that allowed differentiation between malignant and benign tumors. Images of both benign and malignant lesions revealed areas that produced decreased and increased signal intensities on T1- and T2-weighted imaging sequences. This may be related to the inhomogeneity of the lesion with areas of necrosis and hemorrhage¹²). In this series, all malignant tumors showed inhomogeneous internal structure, however some benign tumors also showed inhomogeneity. Nevertheless, homogeneous internal structure enabled a reliable predication of benignancy. The margination of the masses was helpful in differentiating malignancy from benignancy but was not infallible⁹).

Some kinds of tumors had characteristic findings. MR imaging of a patient with aneurysmal bone cyst showed characteristic findings including multiple internal septations, cysts with fluid-fluid levels of varying intensity. The different relaxation parameters probably reflect intracystic hemorrhage of different ages¹⁶). Five cases of hemangioma showed inhomogeneous signal intensity and two of them demonstrated tortuous dilated vessels. In addition to increased number of vascular channels, hemangioma may be composed of adipose tissue, fibrous tissue and smooth muscle. Inhomogeneity of signal intensity reflects this histologic

characteristics^{16,17}). Serpiginous, curvilinear areas of low signal intensity, represent large tortuous vessels, may make histologic diagnosis without angiography. One case of lipoma showed similar signal intensity to subcutaneous fat on both T1- and T2-weighted images. Since the benign lipomas are composed of the same cell type as normal adipose tissue, the intrinsic relaxation parameters(T1, T2, and spin density) are the same for lipomas and normal fat. While benign lipomas have a relatively specific MR appearance, old hematomas may exhibit similar signal intensity, even if two different imaging sequences are performed⁸). However, differential diagnosis between lipoma and old hematoma is readily accomplished with CT.

Differentiation between tumor and scar tissue was possible in patient who had history of operation due to giant cell tumor. Plain film and CT were unreliable in distinguishing tumor from scar tissue. Because scar tissue, consists of dense collagen, is manifested as low signal intensity on both T1- and T2-weighted images, tumor tissue, showing high signal intensity on T2-weighted image, can be easily distinguished¹⁰).

The approach to management of malignant primary tumors of the extremity has changed substantially in the past decade. Surgical emphasis has shifted from radical measures such as amputation to more conservative regional resection techniques with limb salvage, if possible¹⁴). These changes have increased the importance of imaging in the preoperative evaluation. Because MR imaging provides a more reliable assessment of the extent of the tumor, including bone marrow and neurovascular bundle involvement, MR imaging could be a problem-solving tool for management planning of malignant musculoskeletal tumors.

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