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# Cross-sectional Imaging in the Evaluation of Osteogenic Sarcoma: MRI and CT

By Leanne L. Seeger, Jeffrey J. Eckardt, and Lawrence W. Bassett

**B**EFORE the advent of cross-sectional scanning techniques, imaging of malignant bone tumors was confined to plain radiography and radionuclide bone scanning. While radiography remains the primary imaging modality for differential diagnosis, magnetic resonance imaging (MRI) and computed tomography (CT) have had a profound impact on the preoperative staging evaluation of bone tumors and their response to therapy.

In this article we will define the role of MRI and CT in the work-up of the patient with known osteogenic sarcoma (OGS), stressing imaging strategies that optimize information available to the clinician and assist in therapy planning. In order to achieve these optimal factors, communication with the referring physician and review of available radiographs and radionuclide bone scans before MRI or CT image acquisition is often essential.

## PREOPERATIVE EVALUATION

Under usual circumstances, the diagnosis of OGS should be made with radiographs and confirmed by biopsy, and the detection of skip lesions and distant metastases should be accomplished with radionuclide bone scanning. The role of MRI and CT scanning, therefore, is not for diagnostic purposes but rather to supply information that is otherwise inapparent or unavailable. This basic concept is often forgotten when cross-sectional images are obtained, resulting in studies that provide "pretty pictures," but add little or no additional useful information to the clinician who will ultimately be responsible

for treatment. Magnetic resonance imaging and CT image acquisition should address specific issues that are important to the surgeon and should be tailored according to tumor location and proposed surgical treatment, whether it be amputation or resection with limb salvage procedure.

The following discussion reflects the scanning principles and techniques we use for evaluating patients with OGS both preoperatively and post-operatively. This was derived from both our own experience and the experience of others as reported in the literature.<sup>1-3</sup> Regional differences in the management of patients with malignant bone tumors may alter this procedure. To become familiar with local treatment protocols, communicate directly with the surgeon who will ultimately be responsible for treatment.

The goals of cross-sectional imaging of patients with OGS include: (1) determining both the marrow and soft-tissue extent of tumor; (2) defining the relationship of tumor to major neural and vascular structures; (3) evaluating adjacent joints for intraarticular tumor and/or synovial infiltration; (4) detecting skip lesions; and (5) providing measurements needed for the anticipated surgical procedure.

It is prudent to image the involved bone in its entirety with MRI or CT. This will do the following: (1) allow evaluation of any additional suspicious-looking lesions on bone scan; (2) allow detection of unsuspected metastases that were not evident on the bone scan; and (3) provide reference points for measurements that aid in surgical planning.

Tumor resectability in the extremities will be in part determined by the ability to leave major neural and vascular bundles intact; therefore, limb salvage is not appropriate when tumor has encased or infiltrated these structures. Tumor that is either intraarticular or has extensively involved the synovial barrier also precludes limb salvage. Skip lesions will significantly alter surgical margins for OGS of the extremity. For primary pelvic tumors of the ilium or sacrum, preoperative imaging must identify infiltration into abdominal or pelvic soft tissues and the

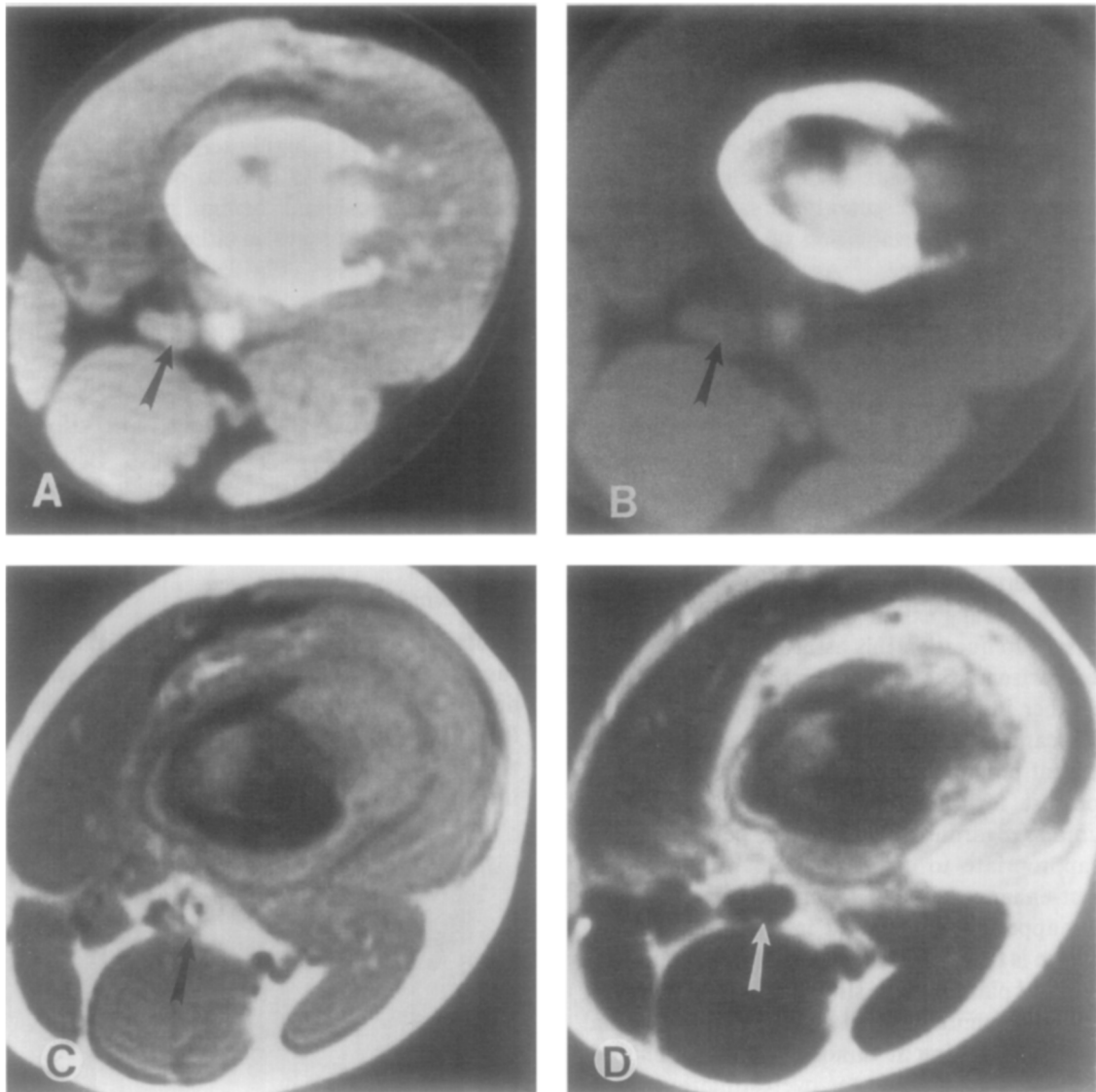
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**Fig 1.** Comparison of CT and MRI images of the same patient with OGS of the femur. (A) Contrast-enhanced CT image, soft-tissue window. (B) Contrast-enhanced CT image, bone window. (C) T1-weighted MR image (SE 343/30). (D) T2-weighted MR image (SE 2232/85). Despite contrast administration for the CT images, tumor soft-tissue boundaries are difficult to determine. The CT is, however, superior to MRI for depiction of cortical involvement by tumor. Both MRI and CT show the major neurovascular bundle (arrow) to be surrounded by fat, indicating it is free of tumor.

epidural space, and define the relationship of tumor to sacral and sciatic nerves, major vessels, and hip and sacroiliac joints.

Cross-sectional imaging of OGS should be tailored to the proposed surgical therapy. If amputation is planned, definition of the proximal tumor margin and measurement of the distance to the proximal joint take priority. When limb salvage is anticipated, surgical resection and manufacture of a custom endoprosthesis require

knowledge of the length of both the soft-tissue and marrow extent of tumor and the distance from tumor margins to the nearest joint. For midshaft lesions, measurements to both the proximal and distal joint surfaces should be made. The distance from the tumor margin to the greater trochanter is an additional useful measurement in planning surgery for femoral lesions.

Magnetic resonance imaging and CT can answer many crucial questions with regard to

preoperative evaluation of OGS and provide useful measurements. Usually, one of these cross-sectional imaging studies will suffice alone. There are, however, advantages to each modality, and the one used depends largely on the experience of the referring physician and radiologist.

There have been several comparisons of MRI and CT for the evaluation of OGS and other primary bone tumors.<sup>3-9</sup> As these studies address a variety of different aspects of tumor evaluation, it is difficult to determine if one modality is indeed superior overall. There is, however, fairly uniform agreement that MRI is superior to CT for determining margins of tumor with respect to adjacent normal muscle, and that CT is superior in the evaluation of subtle cortical invasion (Fig 1).

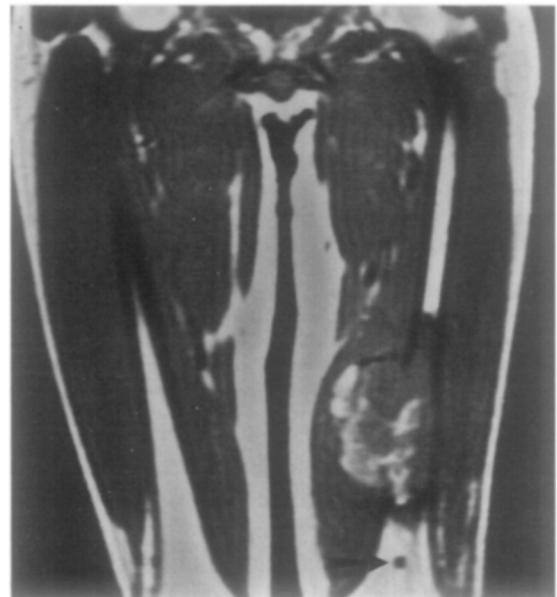
With one exception,<sup>7</sup> these investigators also state that MRI more accurately detects the intramedullary extent of tumor. There are two reasons to question this assertion. In most of the comparisons, the authors either fail to identify whether intravenous (IV) contrast was used for CT scanning<sup>4,8</sup> or specify that it was not.<sup>6,9</sup> Since current practice standards include the use of IV contrast for the CT evaluation of malignant tumors, regardless of location or cell origin, it is inappropriate to compare MRI with non-contrast-enhanced CT. A second reason that MRI may appear superior to CT in evaluating marrow disease is that CT images can only be acquired in the axial plan. A 1-cm slice thickness is standard for CT scanning, but at 1 cm there will be partial volume averaging at tumor margins with subsequent underestimation or overestimation of tumor extent in the order of millimeters. In the above cited comparison studies, the interslice gap was not noted in two instances,<sup>5,7</sup> and a gap of up to 15 mm was used in two additional studies.<sup>4,6</sup> However, in actual clinical practice the tumor-free margin used for the level of bone resection is far greater than this, averaging 4 to 6 cm. For these reasons and based on our own experience, we agree with Gillespy et al<sup>8</sup> and Pettersson et al<sup>7</sup> that in the hands of individuals experienced in evaluating the scans, MRI and CT are comparable in their ability to determine intramedullary tumor margins to a clinically significant level. This is especially true if CT scans are acquired with the routine use of IV contrast and thin section images are obtained through tumor mar-

gins. It is nonetheless true that the direct multi-planar imaging capabilities of MRI are attractive in providing longitudinal images of the involved bone.

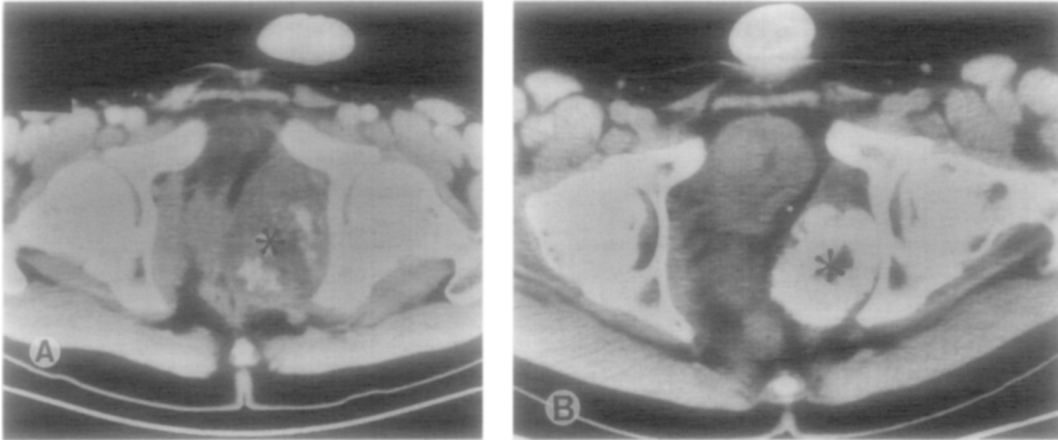
Because MRI is highly sensitive to alterations of marrow fat, it is easy to overread areas of edema or incidental benign processes in the marrow or soft tissues as either tumor extension or skip metastases (Fig 2).<sup>10</sup> This is especially true if the patient is imaged while or soon after receiving chemotherapy, when significant edema may surround the tumor. It may be useful to image a patient both before and following chemotherapy in order to determine alterations in tumor size and matrix calcification before surgery (Fig 3). There is a higher incidence of both local recurrence and metastatic disease in those tumors that do not respond to chemotherapy.

#### *Magnetic Resonance Imaging*

Both T1- and T2-weighted images are needed for complete evaluation of OGS. We strongly discourage the use of proton-density imaging in lieu of true T1-weighting for two reasons. First, the former may increase the signal intensity of intramedullary tumor, leading to underestima-



**Fig 2.** OGS of the femur. T1-weighted MR image (SE 500/20). The low signal intensity lesion (arrow) distal to the primary tumor was initially felt to represent a skip lesion. CT scan (not shown) revealed a dense, well-defined, benign-appearing focus in the corresponding location, proven at surgery to represent a bone island.<sup>10</sup>



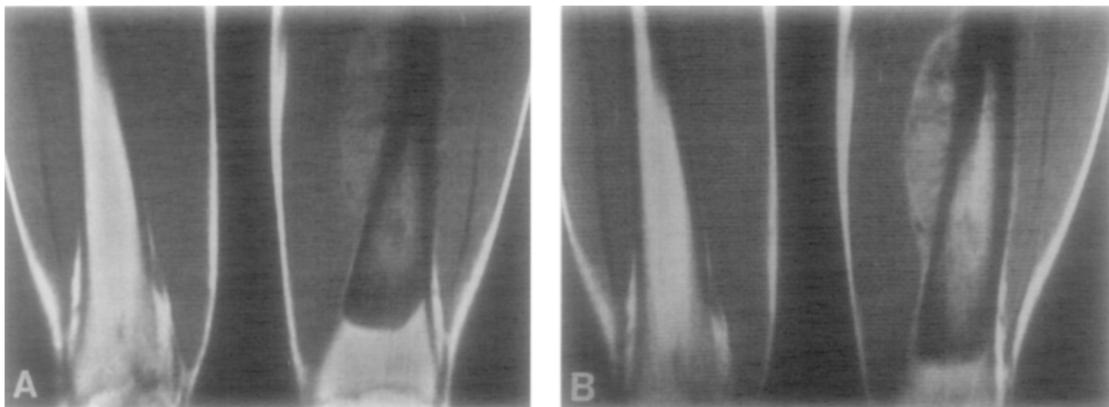
**Fig 3. OGS(\*) of the left ilium, prechemotherapy and postchemotherapy. (A) Prechemotherapy CT scan. (B) Postchemotherapy CT scan at the same level. Following chemotherapy the tumor significantly decreased in size and became heavily calcified, a good prognostic sign. The patient subsequently underwent internal hemipelvectomy.**

tion of lesional extent (Fig 4).<sup>11</sup> Second, similarities in tissue contrast may render it difficult to differentiate fluid and fat if only proton-density and T2-weighted images are available. Although differences will be found at various magnetic field strengths, we have found that with spin-echo imaging, it is advisable to not exceed a TR of 500 ms and a TE of 30 ms when acquiring T1-weighted images.

A complete preoperative evaluation of OGS of the extremity should at a minimum include (1) large field-of-view T1-weighted longitudinal images through the whole host bone and (2) axial T1- and T2-weighted images through the tumor. If there is a possibility of involvement of an

adjacent joint, high resolution, thin-section images through the joint are also necessary. Table 1 outlines a typical protocol for preoperative MRI of a distal femoral OGS. The specific scanning procedure will vary according to tumor location, tumor size, and planned surgical approach.

T1-weighted longitudinal images depict the intramedullary extent of tumor, identify skip lesions (Fig 5), and allow measurements to be made of the distance between tumor margins and adjacent joints (Fig 6). Partial volume averaging can best be avoided with the use of thin-section imaging. If necessary, scans may be interleaved. As these images should be heavily T1-weighted, scan time is minimal.



**Fig 4. OGS of the distal femur, demonstrating the profound effect the choice of pulse sequence can have on tumor appearance. Coronal MR images through the tumor. (A) SE 300/30. (B) SE 800/30. Although the 800/30 image is often considered to be T1-weighted, it resulted in a significant increase in the signal intensity of the tumor in the central marrow and soft tissues. If this high signal had been present throughout the intramedullary tumor, it could have led to a significant underestimation of the intramedullary extent of tumor. (Reprinted with permission from Martin Dunitz Ltd.<sup>11</sup>)**

**Table 1. An MRI Scanning Protocol for Distal Femoral OGS**

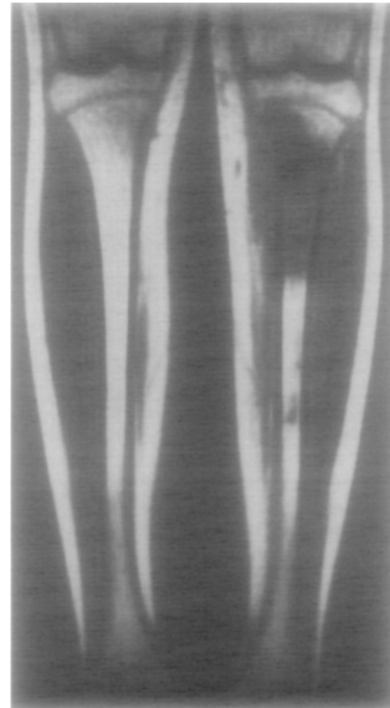
1. Position patient in scanner with surface coil around tumor.
2. Use body coil and large field of view for axial scout through the middle of host bone.
3. Use axial scout to align cursors for sagittal scout.
4. Use sagittal scout to align T1-weighted coronal-to-axial oblique images along long axis of host bone (see Fig 7).
5. Connect surface coil; acquire T1- and T2-weighted axial images through entire tumor (and adjacent joint if indicated).

The scan plane for longitudinal images will be determined by tumor location. For tumors of the lower extremity, the coronal plane is ideal. Tumors of the proximal humerus are usually best depicted in the sagittal plane.

With femoral lesions, it is often difficult to position the thigh in an orthogonal coronal plane, and patients with a large tumor may not be able fully to extend the extremity. Alignment for image acquisition can be determined by first obtaining an axial scout image, followed by a sagittal scout (Fig 7). Cursors for coronal-to-axial oblique images can then be aligned along the major long axis of the bone. If feasible, the entire host bone should be included in a single image. In the adult, both the natural curvature of long bones such as the femur and humerus and limitations of the MRI image resolution when using a very large field of view often preclude imaging the entire bone. In this situation, it is best to acquire two sets of overlapping longitudinal T1-weighted images. Optimally, both should image the entire tumor, with one set including the proximal joint, and the other, the distal joint.

Determination of tumor soft-tissue extent, muscle infiltration, relationship to major neurovascular structures, and evaluation of adjacent joints is accomplished by comparing true T1-weighted and heavily T2-weighted images in the axial plane. Although time constraints generally preclude axial MRI through the entire bone, scans should cover the entire tumor. Slice thickness for axial scans is determined by the size of the lesion. To assure imaging through the entire tumor, the T1-weighted longitudinal image may be used for cursor alignment. Slice thickness may then be varied until the entire lesion is included. Extensive tumors may require more than one set of axial images to cover the entire lesion.

If suspicion of joint involvement exists, additional thin-section T1- and T2-weighted axial



**Fig 5. Skip lesions with OGS. Coronal SE 500/30 MRI image through the tibia. The primary tumor is evident proximally. Ill-defined foci of low-signal intensity in the midshaft (arrow) represent skip metastases, which would not have been detected if the field of view had been limited to the primary tumor.**

images are needed to determine the integrity of the synovium and joint capsule (Fig 8). T1-weighted images highlight contrast differences between intermediate signal intensity tumor within the joint and high-signal intensity synovial fat. T2-weighted images are useful for determining the integrity of the low-signal intensity fibrous joint capsule. Differentiation of fat and fluid may be difficult if only proton-density and T2-weighted images are acquired (Fig 9).

When acquiring both T1- and T2-weighted images in the same plane, it is advantageous to use the same slice location, thickness, and intervals for both sets of images. This allows exact comparisons of tissue signal characteristics and assists in differentiating fat and fluid from tumor in soft tissues and around joints.

#### *Computed Tomography*

Although CT image acquisition is restricted to the axial plane, this modality can effectively be used for the evaluation of OGS. Image acquisi-

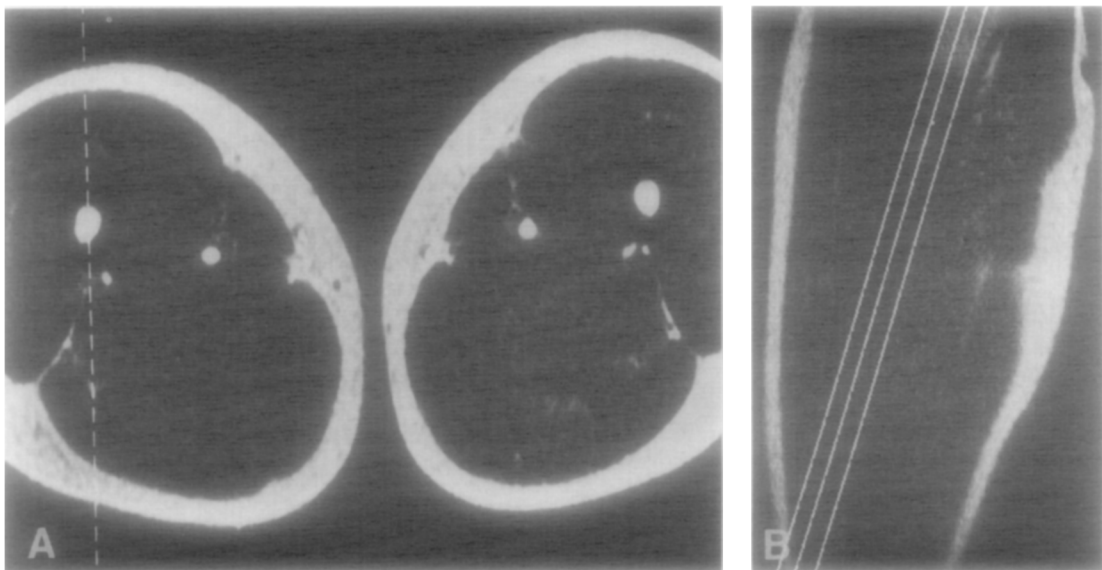


**Fig 6. Coronal T1-weighted MR image (SE 500/28) showing measurement (cursor) before limb salvage procedure. In this situation, it was important for the orthopaedic surgeon to know the exact distance of proximal extent of tumor to knee joint.**

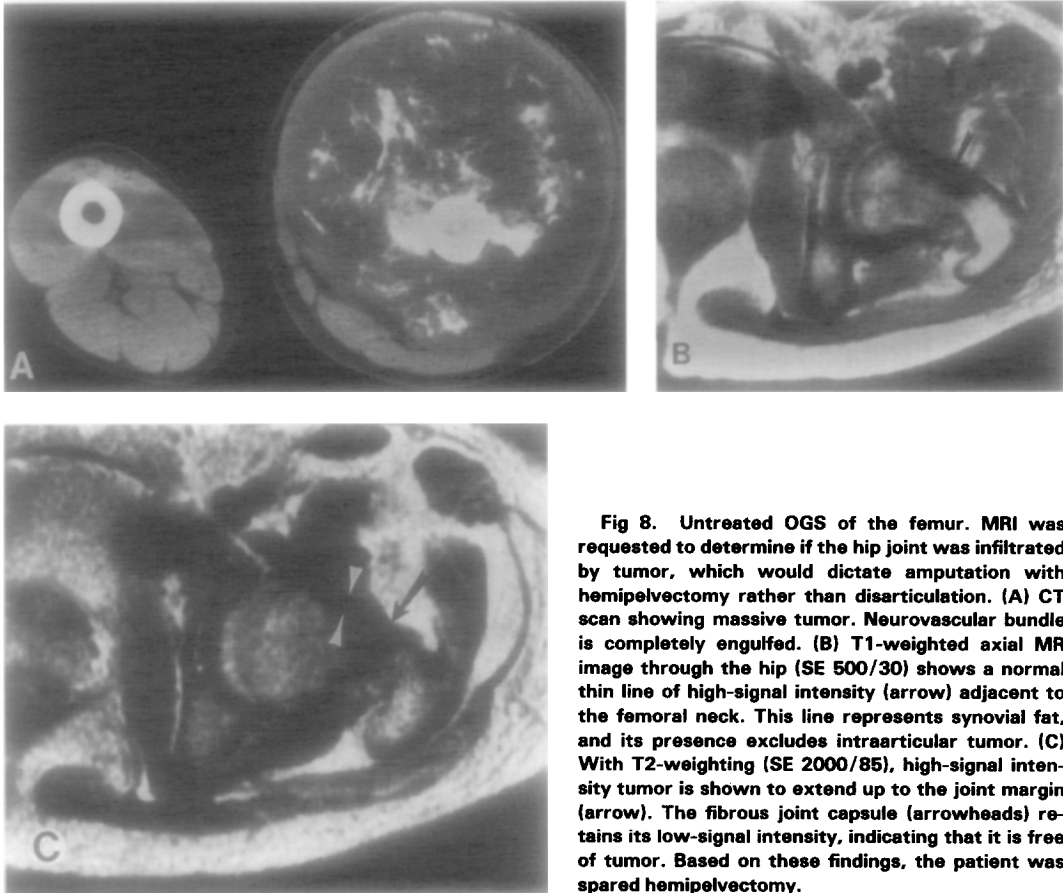
tion should be geared to address the same clinical questions as those for MRI.

Optimal visualization of the extraosseous and intramedullary soft-tissue extent of OGS usually requires administration of intravenous contrast. We have found that bolus infusion immediately before scanning with a continuous drip infusion during image acquisition usually provides suffi-

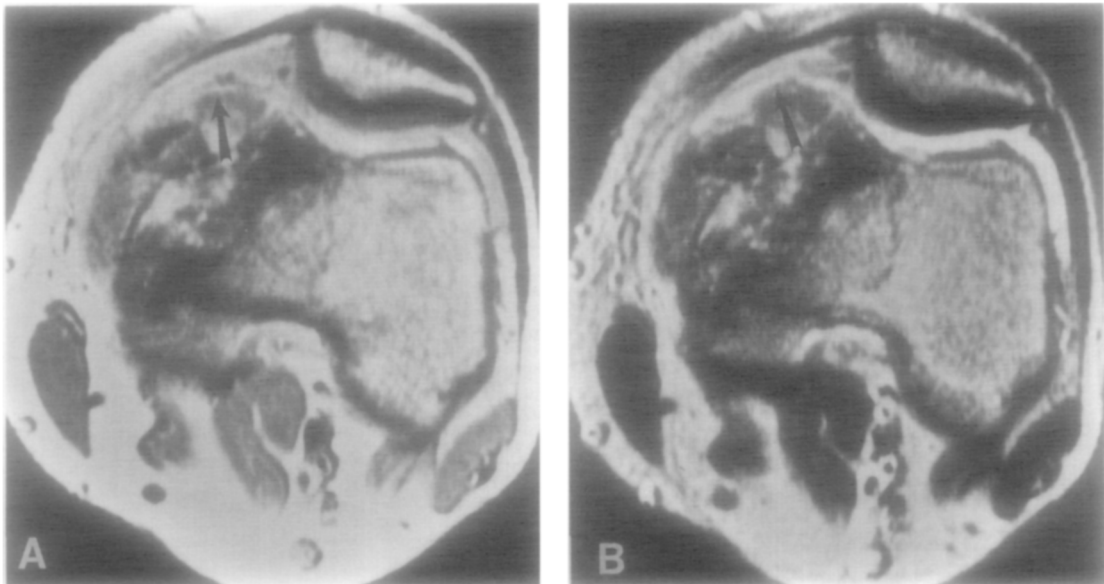
cient soft-tissue contrast to allow differentiation of tumor from normal muscle and marrow. Whether to use oral contrast should be determined by tumor location and the amount of tumor matrix mineralization. If radiographs reveal little or no calcified tumor matrix, the oral contrast agent may be useful in determining the presence or absence of intrapelvic soft-tissue



**Fig 7. Scout images used for aligning longitudinal images through a long bone. (A) Single slice axial image is used to align cursor for a single slice sagittal image. (B) Sagittal scout is then used to align cursors in a coronal-to-axial plane along the long axis of the bone.**

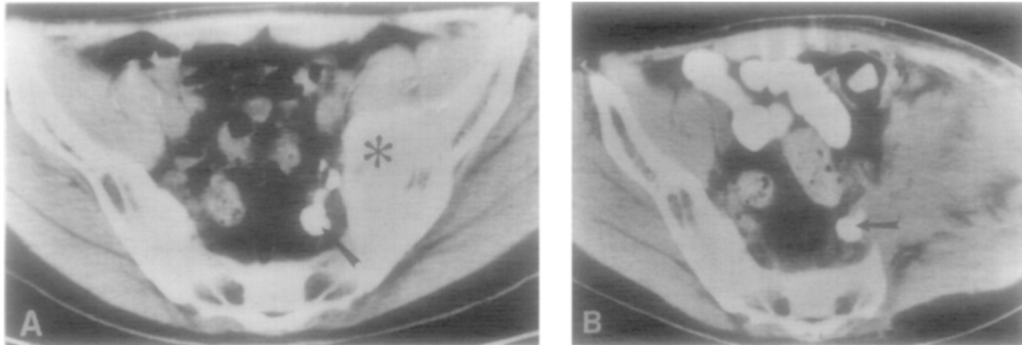


**Fig 8. Untreated OGS of the femur. MRI was requested to determine if the hip joint was infiltrated by tumor, which would dictate amputation with hemipelvectomy rather than disarticulation. (A) CT scan showing massive tumor. Neurovascular bundle is completely engulfed. (B) T1-weighted axial MR image through the hip (SE 500/30) shows a normal thin line of high-signal intensity (arrow) adjacent to the femoral neck. This line represents synovial fat, and its presence excludes intraarticular tumor. (C) With T2-weighting (SE 2000/85), high-signal intensity tumor is shown to extend up to the joint margin (arrow). The fibrous joint capsule (arrowheads) retains its low-signal intensity, indicating that it is free of tumor. Based on these findings, the patient was spared hemipelvectomy.**



**Fig 9. Double-echo axial MR images. Distal femoral OGS. (A) SE 2500/22 (proton density). (B) SE 2500/80 (T2-weighted). There is little differentiation in tissue contrast between these two images. Tumor abuts the joint medially (arrow). The high-signal intensity intraarticular fluid cannot be differentiated from the fat-laden synovium.**





**Fig 10.** (A) Preoperative CT image, obtained without oral contrast. Left iliac OGS (\*). There is a trail of very dense tumor extending posteromedial to the primary lesion (arrow). (B) Postinternal hemipelvectomy CT image at the same level. Oral contrast was administered. A dense focus (arrow) adjacent to the surgical resection was initially felt to represent a contrast-filled loop of bowel. It was only by comparing to the preoperative scan performed without oral contrast that it became evident that this was unresected tumor.

invasion. However, if the tumor is highly mineralized, it may become difficult to differentiate blastic tumor from contrast-filled loops of bowel (Fig 10).

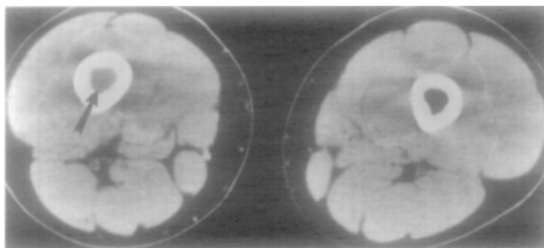
The CT scout and axial images both should include the entire host bone to allow adequate coverage of tumor margins and detection of skip metastases.

For large lesions of the extremities distant from the articular surface, 10 mm-thick images at 10 mm intervals will be sufficient for preoperative evaluation of the tumor extent and possible neurovascular involvement. If the primary lesion is near a joint, thin-section images through the joint are necessary to evaluate the integrity of the joint capsule and synovium. For pelvic tumors in the vicinity of the sacrum, the sacral foramina, their exiting nerves, and the epidural space must be clearly depicted.

All images should be photographed with both bone and soft-tissue window settings. Bone win-

dows will best display calcified tumor matrix and cortical involvement. Soft-tissue window settings are needed to evaluate the marrow space for tumor invasion (which appears as loss of the normal low density fat [Fig 11]), extraosseous soft-tissue extension, and the relationship of tumor to major neurovascular structures.

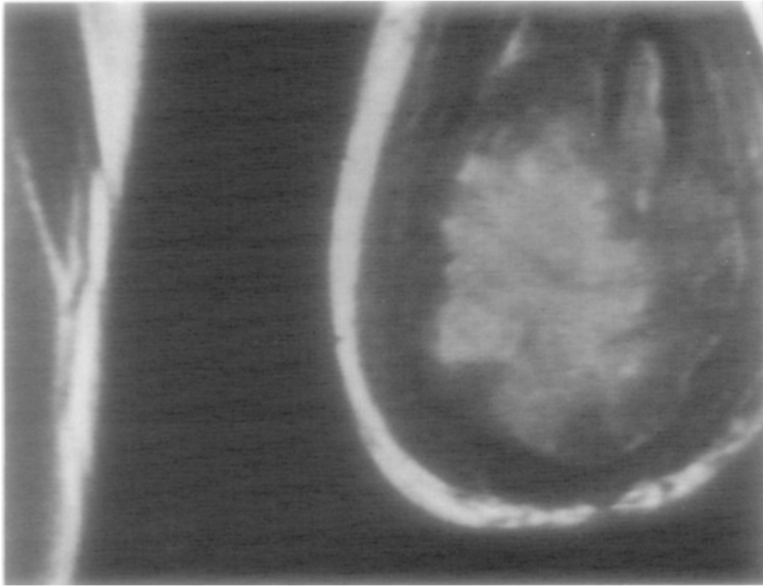
By identifying the slice location of tumor margins on the scout image, measurements can be provided regarding tumor length and distance to adjacent joints which are comparable to those obtained through coronal MR images (Fig 12).



**Fig 11.** CT scan above the level of radiographically evident tumor, soft-tissue windows. The increased soft-tissue density (arrows) replacing the normal marrow fat represents intramedullary tumor (arrow).



**Fig 12.** CT scout showing method for measurements before limb salvage procedure. Tumor extent is determined from axial images, and the location is indicated on the scout image. Measurements are then made from the inferior margin of the tumor to the femoral head articular cartilage and to the greater trochanter.



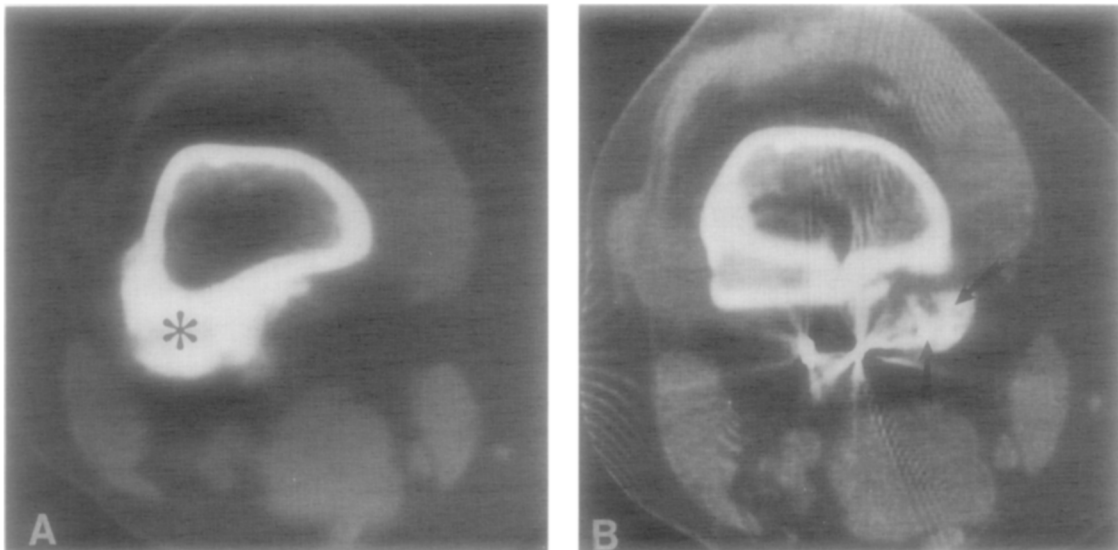
**Fig 13. Recurrent OGS following above-the-knee amputation. Coronal T1-weighted T1-weighted MR image (SE 500/30). High-signal intensity within the soft-tissue mass represents bleeding and tumor necrosis. (Reprinted with permission of Martin Dunitz Ltd.<sup>11</sup>)**

#### POSTOPERATIVE EVALUATION

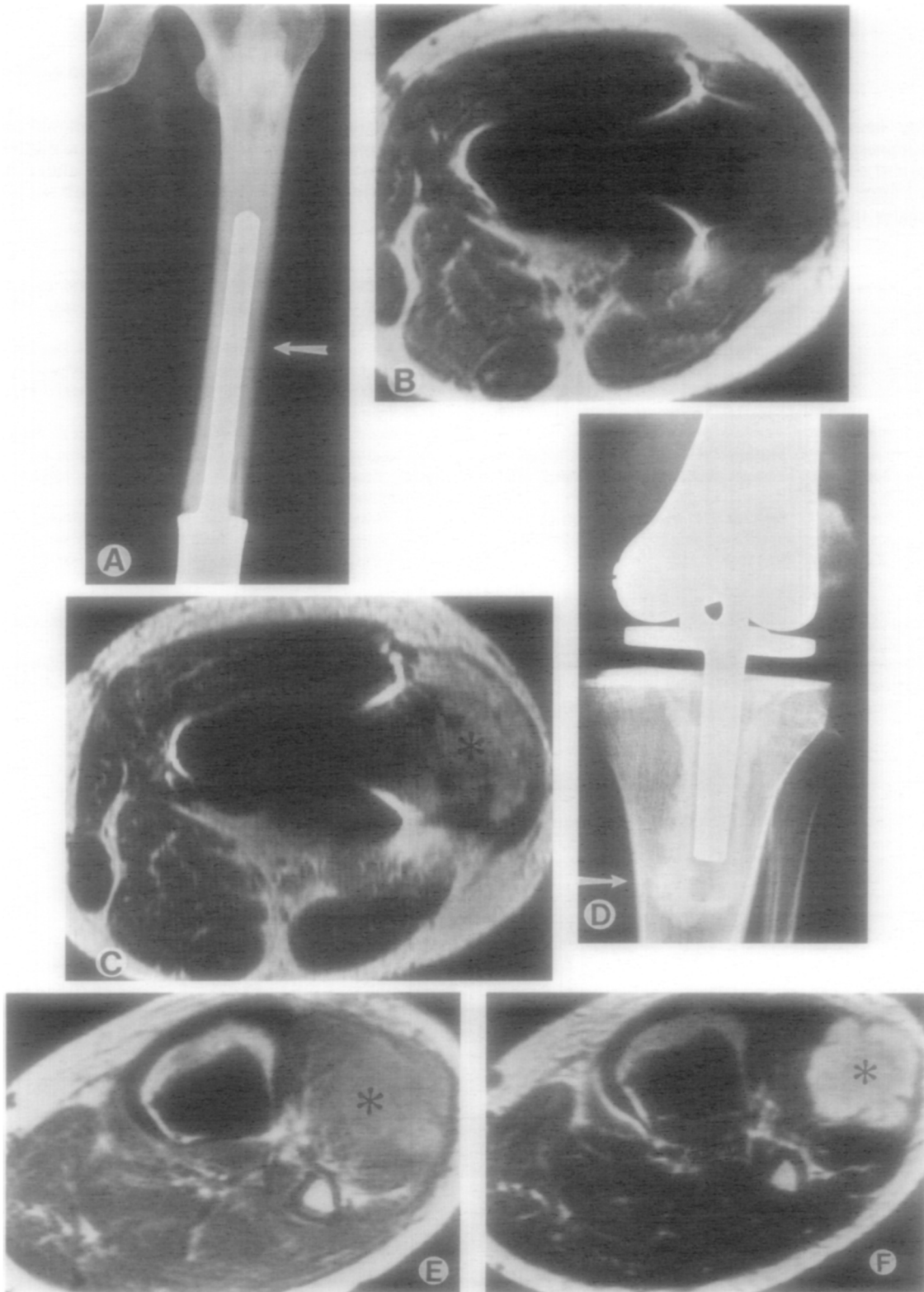
Either MRI or CT may be used in the postoperative evaluation of patients who have undergone amputation, hemipelvectomy, or local tumor excision for OGS (Figs 13,14). As in the preoperative period, the choice of imaging method should be determined by the degree of tumor mineralization as evident on radiographs.

Despite metal-induced artifacts which may at times be quite severe, cross-sectional studies may be useful in identifying recurrent tumor in patients who have undergone limb salvage procedures (Fig 15). This is especially true if the region of concern lies either proximal or distal to the endoprosthesis.

In cases of limb salvage, methylmethacrylate



**Fig 14. Recurrent parosteal OGS. (A) Preoperative CT scan (\* = tumor). (B) The tumor was locally resected. Bone graft was placed over the site of excision and fixated with screws. Despite artifact from the screws, recurrent tumor (arrows) is readily apparent adjacent to the site of resection.**



**Fig 15. Recurrent soft-tissue OGS both proximally and distally following limb salvage procedure. (A) Anteroposterior radiograph of the stem of the femoral component. Arrow denotes level for images B and C. Soft tissue recurrence is not evident on radiographs. (B) Axial T1-weighted MR image (SE 500/28). Despite significant artifact from the endoprosthesis, recurrent tumor (\*) is evident laterally. There is disruption of normal muscle planes and loss of intramuscular fat. (C) The signal intensity of the tumor (\*) increases with T2-weighting (SE 2000/84). (D) Anteroposterior radiograph of the tibial component. Arrow denotes level for images E and F. Soft tissue recurrence is not evident on radiographs. (E) Axial T1-weighted MR image (SE 500/28). The central marrow space is replaced by a well-defined, homogeneous signal void representing methylmethacrylate cement and the polyethylene plug at the end of the prosthesis. There is no metal artifact. The intermediate signal intensity mass (\*) in the soft tissue laterally is recurrent tumor. (F) Axial**

bone cement is frequently used to fixate the endoprosthesis stem into the host bone. Both this cement and the polyethylene plugs at the stem tip will appear as a well-defined region of very low density in CT images and a signal void with all

pulse sequences in MR images.<sup>12</sup> This should not be mistaken for residual or recurrent intramedullary blastic tumor. Confusion can be avoided by correlating the MR or CT image with radiographs.

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