**Specialty area:**  Bone Tumor Imaging

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**Highlights**
- MRI enables accurate diagnosis of certain primary and secondary bone tumors based on their tissue composition, morphology, and/or associated marrow edema pattern.
- MRI provides essential details about the local extent of bone tumors, which allows accurate selection of the most appropriate treatment and facilitates limb-salvage surgery.

**TALK TITLE: MRI of Common Bone Tumors**

**TARGET AUDIENCE:**  Radiologists or other physicians who interpret musculoskeletal MRI examinations and seek to update or refine their knowledge base.

**OUTCOME/OBJECTIVES:**  Learners will be better able to understand the strengths and limitations of MRI in assessing bone tumors.

**PURPOSE:**  Bone tumors and their mimics are encountered frequently in clinical practice, yet are often considered difficult to evaluate by radiologists.

**METHODS:**  The material is based on numerous articles from the literature, as well as 26 years of personal experience working in a tertiary cancer center.

**DISCUSSION:**

**MRI protocol**

Optimal characterization and staging of bone tumors at MRI involves certain basic requirements. High-resolution, small field-of-view axial T1-weighted and fat-suppressed T2-weighted images should be obtained through the entire tumor. The appropriate plane for longitudinal, small field-of-view T1-weighted and fat-suppressed T2-weighted images is selected by drawing a line through the center of the bone and the center of the extraosseous soft tissue component on a representative axial image.

T1-weighted images are used to distinguish normal marrow and tumor; demonstrate bone tumors against a background of normal fatty marrow; and show the presence of fat or hemorrhage within a tumor. Fat suppression is essential in the T2-weighted images to allow evaluation of bone marrow for tumor involvement or surrounding marrow edema pattern. Proton density images without fat suppression are of limited utility in the characterization of bone lesions, as tumor and surrounding marrow edema and marrow fat all may show similar signal, diminishing the conspicuity of the lesion.

Evaluation for intraosseous skip lesions is accomplished by obtaining longitudinal T1-weighted MR images through the entire affected bone.

Pre- and post-gadolinium fat-suppressed T1-weighted images frequently are helpful, distinguishing cystic from solid components and demonstrating necrotic portions of tumor.

**Approach to characterizing bone tumors at MRI**

Radiographs remain essential in the characterization of many bone lesions, and should not be neglected in the initial evaluation. The high contrast resolution of MRI, however, allows further characterization in some cases.

Most bone tumors have sharp boundaries with the surrounding normal marrow at MRI, as they replace normal marrow in a mass-like configuration. Such a boundary should not be misinterpreted as representing a narrow zone of transition — which is a purely radiographic criterion. That criterion, a key

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component of the Lodwick classification for bone tumors, is based on radiographic patterns of bone destruction; MRI, however, instead depicts bone tumors as regions of marrow replacement.

MRI may not depict calcifications unless they are large or very dense, limiting the utility of MRI in demonstrating calcified tumor matrix (such as in osteoblastoma and osteosarcoma).

On fat-suppressed T2-weighted images, hyaline cartilage lesions (enchondroma, low-grade chondrosarcoma) often can be diagnosed based on their consisting of multiple small lobules of fluid-like signal intensity (due to the high water content of hyaline cartilage). The distinction between enchondroma and low-grade chondrosarcoma is a common and difficult problem, however, resulting from lack of consensus on specific diagnostic criteria — both among pathologists and among radiologists. In general, a chondroid lesion in a long bone that shows deep endosteal scalloping, cortical buttressing (thickening), and/or extraosseous extension should be considered to represent at least low-grade chondrosarcoma unless proven otherwise.

The differential diagnosis for benign bone lesions surrounded by extensive marrow edema includes osteoid osteoma/osteoblastoma, chondroblastoma, Langerhans cell histiocytosis, and osteomyelitis; less commonly, solid aneurysmal bone cyst and giant cell tumor may show the same extensive marrow edema pattern. As a general (but not absolute) guideline, the greater the extent of surrounding marrow edema, the more likely the bone lesion is benign. Marrow edema of lesser extent may be present around malignant bone tumors, in which case it constitutes the reactive zone of the tumor.

Calcific tendinitis is an important pitfall in the diagnosis of bone tumors, because it can produce erosions in subjacent bone (most commonly the humeral tuberosities or femoral trochanters) and an associated marrow edema pattern. Recognition of the overlying tendinous abnormality (at MRI and/or at radiography) will help prevent misinterpretation of the subjacent bony changes as representing a metastasis.

Lytic bone metastases generally show moderately increased signal throughout the lesion on fat-suppressed T2-weighted images, whereas blastic lesions often show such increased signal only in a surrounding rim (“halo”). This "halo," when present, can be particularly helpful in distinguishing between a blastic metastasis and a bone island — the latter showing low signal on all pulse sequences.

The presence of dot-like or curvilinear flow voids (representing small, high-flow vessels) within a lytic bone lesion at MRI suggests metastasis from a renal cancer primary.

A malignant bone tumor may occasionally percolate through the Haversian canals of the cortex without causing substantial cortical destruction, and grow as a mass beyond the cortex. This phenomenon occurs more frequently in lymphoma than in other bone tumors.

Fluid-fluid (blood-fluid) levels have been reported in a wide range of benign and malignant bone (and soft tissue) tumors. A bone lesion composed entirely of fluid-fluid levels separated by thin septa is consistent with a primary aneurysmal bone cyst. If thick septa or soft tissue nodules also are present within the lesion, other diagnoses must be considered, such as a secondary aneurysmal bone cyst engrafted on another bone tumor, or a telangiectatic osteogenic sarcoma. Gadolinium-enhanced images are useful in assessing for soft tissue elements within an otherwise cystic tumor; subtraction of pre- and post-contrast images also may be beneficial if blood products are present within the tumor.

**Staging of bone tumors at MRI**

Imaging is used to locally stage a bone tumor to help plan appropriate treatment (surgery, chemotherapy, and/or radiation therapy). Amputation, formerly done in >80% of osteogenic sarcomas, now is performed in ~10%. Limb-salvage surgery, which results in a superior functional result with at least comparable oncologic control of tumor, now can be performed instead in most patients with bone tumors; accurate, detailed preoperative imaging is required to determine which patients are eligible. MRI is generally the preferred technique for staging bone tumors, although contrast-enhanced CT can provide considerable valuable information in characterizing and staging such tumors, and is a viable alternative imaging modality in those patients with contraindications to MRI or if MRI is unavailable.
The Musculoskeletal Tumor Society staging system for musculoskeletal tumors defines Stage I tumor as a low grade tumor; Stage II as a high grade tumor; and Stage III as a tumor of any grade in the presence of metastasis. Stages I and II are subclassified as:

A Tumor confined to one compartment (intracompartmental disease, such as an entirely intraosseous tumor)

B Tumor involving more than one compartment (extracompartmental disease, such as extracompartmental extension of bone tumor into an adjacent joint or muscle).

The American Joint Committee on Cancer (AJCC) staging system for malignant bone tumors defines a T1 bone tumor as measuring ≤ 8 cm in maximal dimension; T2 as > 8 cm in maximal dimension; and T3 as the presence of at least one skip lesion within the same bone. Regional nodal metastases constitute N1 disease. Lung metastases are classified as M1a, with other types of distant metastases being M1b.

For the orthopedic surgeon, detailed local staging of a malignant bone tumor requires determination of the extent of tumor involvement within the bone of origin, as well as of involvement of adjacent joints, bones, muscles, tendons/ligaments, and major vessels and nerves.

Malignant bone tumors often percolate through the cortical Haversian system and extend into the subperiosteal space to produce a soft tissue mass contained by elevated periosteum (the latter visible as a thin, low-signal line on T2-weighted MR images). An extracortical soft tissue mass that extends beyond elevated periosteum is more aggressive than one contained by periosteum; such extension should be specifically reported, as it may influence the extent of resection undertaken in an attempt to obtain clear surgical margins. Transarticular extension into a neighboring bone is uncommon, but when present, typically occurs via direct extension along normal anatomic structures (such as the ligamentum teres of the hip or a cruciate ligament of the knee).

Various pitfalls exist in the staging of bone tumors at MRI. Red marrow deposits (focal or diffuse) that develop in the setting of marrow-stimulation therapy (such as with growth-colony stimulating factor [G-CSF]) given during neoadjuvant chemotherapy can simulate metastatic disease unless interpreted in the appropriate clinical context. The “reactive zone” of edematous tissue surrounding the extraosseous component of a bone tumor may result in overestimation of tumor extent at imaging, particularly on fat-suppressed T2-weighted or STIR sequences. Joint invasion can be diagnosed with confidence only when gross tumor is visible within the joint; simple contact between tumor and the margin of the joint, even in the presence of a joint effusion, does not prove that the synovial cavity has been violated. Similarly, neurovascular encasement should be differentiated from simple contact, as tumor usually can be dissected away from vessels and nerves that appear contacted and displaced at imaging. Assessment for an intervening fat plane should be performed on T1-weighted images, not on fat-suppressed images, to avoid false-positive diagnosis of encasement.

**CONCLUSION:** The material presented provides a framework for characterizing and staging common bone tumors at MRI.

**REFERENCES**


Author has no relevant financial interests or relationships to disclose.