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A BIWEEKLY REVIEW OF CLINICAL RADIOLOGIC PRACTICE

Imaging of Tumors of the Tibia

Willy Tjong, MD, and Scott Schiffman, MD

After participating in this educational activity, the radiologist should be better able to diagnose common and uncommon, benign and malignant tumors of the tibia.

Category: General Radiology
Subcategory: Musculoskeletal
Modality: MRI

Key Words: Tumors of the Tibia, Imaging of Tumors of the Tibia

Although the tibia can serve as the location for relatively common benign and malignant bone tumors, there are several more uncommon entities that occur almost exclusively in the tibia. For example, rare lesions such as adamantinoma, osteofibrous dysplasia, and chondromyxoid fibroma are seen predominantly in the tibia with infrequent involvement of other bones in the appendicular skeleton. This article reviews the imaging features of common and uncommon tibial tumors and provides a framework for formulating a differential diagnosis based on imaging and patient characteristics.

Diagnostic Approach

The accuracy of a differential diagnosis of tibial tumors is dependent on the patient history and relevant imaging findings. Similar to bone tumors elsewhere, tibial tumors have specific imaging characteristics that help to narrow the differential diagnosis of the broad array of possibilities (Figure 1). Clinically, the age and gender of the patient are important factors in formulating a differential diagnosis. On imaging, the following characteristics should be examined: longitudinal and axial location within the bone (epiphysis, metaphysis, diaphysis and central, eccentric, cortical, juxtacortical); pattern of bone destruction (zone of transition, endosteal scalloping, periosteal reaction, cortical destruction); and matrix formation (osteoid, chondroid or ground glass). Based on these characteristics, a relevant differential diagnosis can be formed.

Osteoid Lesions

Osteoid Osteoma

Osteoid osteomas are benign lesions typically found in adolescents with a male predilection. The classic clinical presentation is nocturnal pain that is relieved by nonsteroidal anti-inflammatory drugs (NSAIDs). Histologically, the lesion is composed of a central nidus (containing osteoid, woven bone, and osteoblasts) and a surrounding reactive zone (containing sclerotic bone and fibrovascular tissue).

On radiographs, the central nidus may appear as a cortically based, ovoid, lucent lesion with a central mineralized dot (Figure 2). Dense sclerotic bone (corresponding to the reactive zone) surrounds the nidus. CT can be used to help localize and assess the size of the nidus. The appearance on MRI is nonspecific and can mimic more aggressive lesions, as the extent of bone marrow edema may obscure the nidus. The nidus shows variable intensity on all sequences. Surrounding bone marrow edema and reactive soft tissue changes also can be seen.[1]

Osteoblastoma

Osteoblastomas are benign lesions that typically occur in young adults with a male predilection. They are most often located in the spine or flat bones (40%–55%, with a majority

Dr. Tjong is Diagnostic Radiology Resident, and Dr. Schiffman is Assistant Professor, Department of Imaging Sciences, University of Rochester Medical Center, 601 Elmwood Ave, Box 648, Rochester NY 14642; E-mail: willy_tjong@urmc.rochester.edu.

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Patient demographics	Location	Pattern of destruction	Matrix formation
•Age and gender	•Longitudinal •Epiphysis •Metaphysis •Diaphysis •Axial •Central •Eccenric •Cortical/ juxtacortical	•Zone of transition •Endosteal scalloping •Periosteal reaction •Cortical destruction	•Osteoid •Chrondroid •Ground glass

Figure 1. An example of a systematic approach to help formulate a differential diagnosis for a bone lesion.

in the posterior elements of the spine) and less frequently in long bones (25%). Although they have a histologic similarity to osteoid osteomas, they manifest clinically as pain with minimal response to NSAIDs (as opposed to osteoid osteomas, which are responsive to NSAIDs).

Radiographically, osteoblastomas appear as large (often >2 cm), expansile, lytic lesions, most frequently based within the cortex (Figure 3). There is a variable degree of internal mineralization, and the lesion can appear locally aggressive with cortical destruction and soft tissue extension (despite its benign nature). On MRI, the lesion has low to intermediate signal on T1- and T2-weighted images, with areas of internal low signal corresponding to mineralization. The lesion often is associated with adjacent bone marrow edema. Postcontrast images show avid enhancement secondary to tumor vascularity with enhancement of the adjacent soft tissue.[1]

An osteoblastoma can appear locally aggressive with cortical destruction and soft tissue extension despite its benign nature.

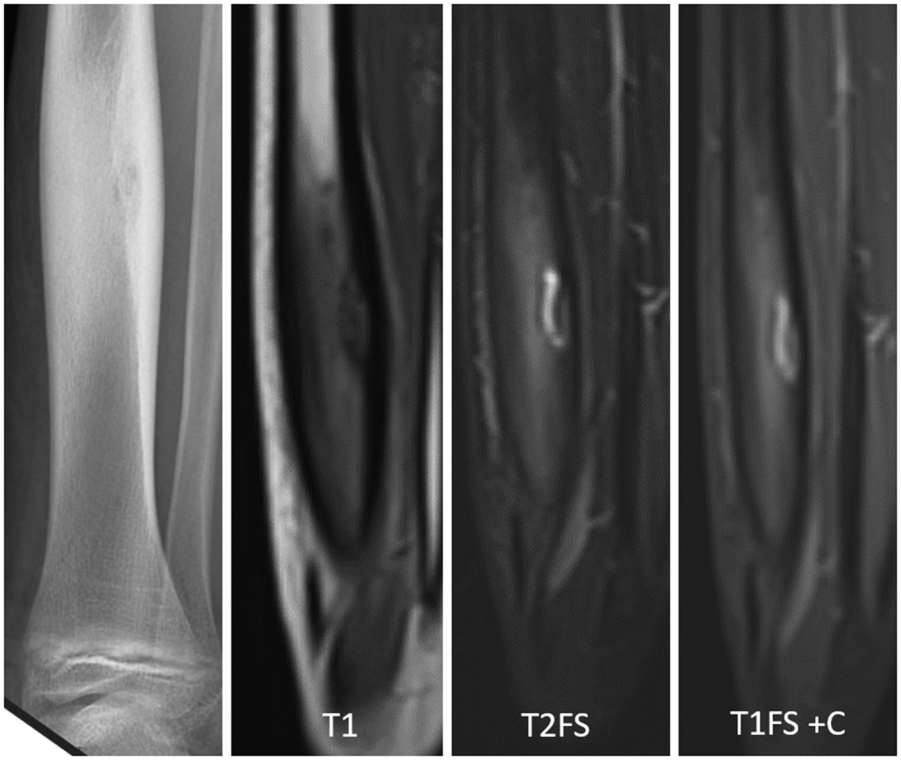

Figure 2. Osteoid osteoma in a 13-year-old adolescent girl. The radiograph shows an ovoid, cortically based, lucent lesion with adjacent marked cortical thickening. Bone marrow edema/inflammation is present adjacent to the nidus on MR images.

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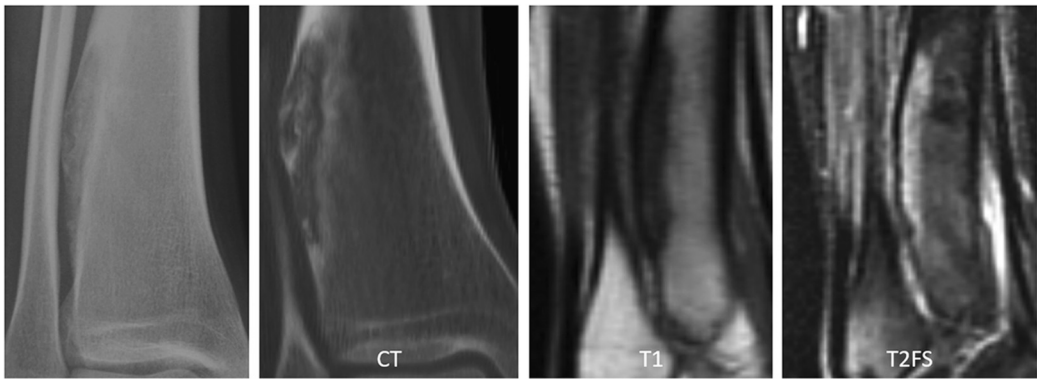

Figure 3. Osteoblastoma in a 14-year-old adolescent boy. Lytic, cortically based, expansile lesion with internal osteoid matrix/mineralization. Inflammatory changes are present in the adjacent bone marrow and soft tissues.

Osteosarcoma

Osteosarcomas are the second most common malignant primary bone tumor. There is a reported bimodal age distribution with an initial peak in patients age 10 to 20 years and a second peak in patients older than 50 years (usually a secondary cause related to prior Paget disease, osteonecrosis, or osteomyelitis). Multiple subtypes have been described based on the degree of differentiation and location in the skeleton.

On radiographs, osteosarcomas appear as permeative metadiaphyseal lesions with internal osteoid matrix (Figure 4). There is an associated aggressive periosteal reaction (eg, sunburst and Codman triangle) with a prominent soft tissue component. On MRI, there is heterogeneous signal on T1-weighted and T2-weighted images (depending on the degree of mineralization). Increased T2-weighted signal is present within the nonmineralized component along with peritumoral edema. The solid components of the lesion enhance on postcontrast images.[2]

Chondroid Lesions

Chondromyxoid Fibroma

Chondromyxoid fibromas are benign lesions (with an extremely rare probability of malignant degeneration) occurring primarily in adolescents and young adults, with a slight male predilection. The classic location is in the upper third of the tibia (approximately 25% of cases).

The classic location of a chondromyxoid fibroma is the upper third of the tibia (approximately 25% of cases).

They appear radiographically as eccentric, lucent lesions with the long axis parallel to the long axis of the bone (Figure 5). A well-defined sclerotic margin is present with no associated periosteal reaction. Internal trabeculations also may be seen. The MR signal characteristics are typical for a chondroid matrix lesion, with decreased signal on T1-weighted sequences and increased signal on T2-weighted sequences. Peripheral nodular enhancement or diffuse enhancement may be present.[3]

Enchondroma

Enchondromas typically occur in younger patients and are primarily located within the medullary cavity of tubular bones

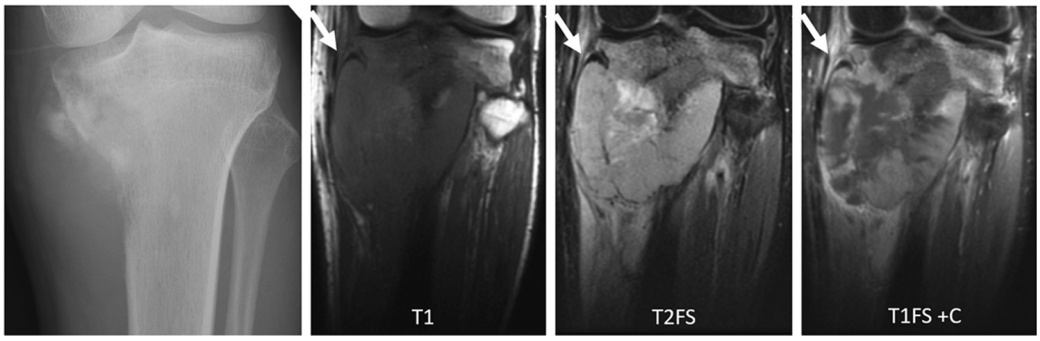

Figure 4. Osteosarcoma in a 17-year-old adolescent male. Poorly defined lytic lesion with associated cortical destruction, aggressive periosteal reaction, and cloud-like osteoid matrix are present on the radiograph. Marked signal heterogeneity on MR images represents nonmineralized soft tissue, mineralization, and necrosis. Prominent soft tissue extension is present (*arrows*).

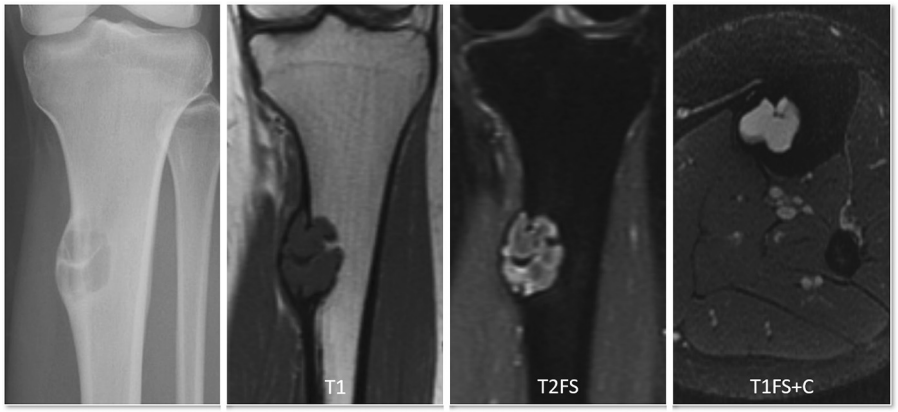

Figure 5. Chondromyxoid fibroma in an 18-year-old woman. Eccentric lytic lesion with internal trabeculations and a well-defined sclerotic margin are noted. Peripheral lobulated high signal is seen on T2-weighted images, and lobular enhancement is seen on the MR images.

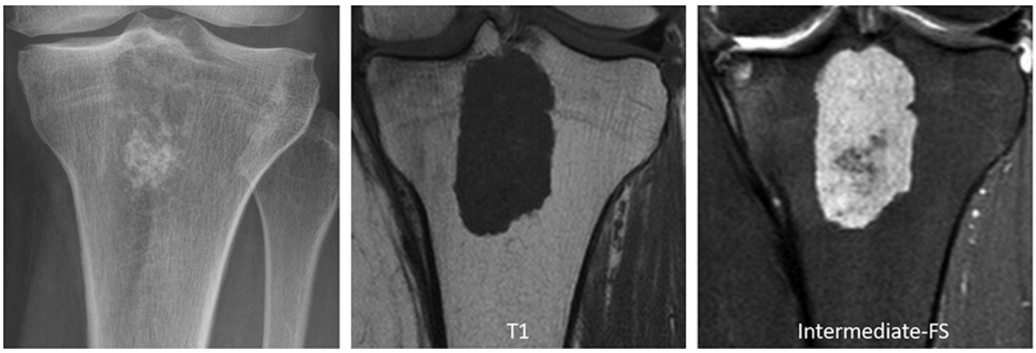

Figure 6. Enchondroma in a 68-year-old woman. Lytic lesion with chondroid matrix calcification and a narrow zone of transition on the radiograph. MR appearance is typical of a chondroid matrix lesion, with low signal on T1-weighted images and high signal on intermediate-weighted fat-saturated images. Internal low signal corresponds to calcified chondroid matrix.

(with 50% involving the hands and feet). There are two recognized clinical syndromes: Maffucci (enchondromas with soft tissue venous malformations and increased risk of malignant transformation to chondrosarcoma) and Ollier (multiple enchondromas, primarily involving the metaphyses).

Maffucci syndrome consists of enchondromas with soft tissue venous malformations and an increased risk of malignant transformation to chondrosarcoma.

Radiographically, enchondromas appear as lytic lesions with internal chondroid matrix calcification (Figure 6). The MR appearance is as expected for a chondroid matrix lesion with lobulated increased T2 signal, peripheral enhancement, and internal low-signal zones corresponding to mineralization. There are no aggressive imaging features such as endosteal scalloping, periostitis, or cortical destruction. Despite these typical imaging characteristics, an enchondroma may be indistinguishable from a low-grade chondrosarcoma.[4]

Chondrosarcomas

The malignant counterpart to the enchondroma is a chondrosarcoma, which typically occurs in patients in the fourth through seventh decades of life with a slight male predilection. They most commonly involve the long bones (45%) and the pelvis (45%). Chondrosarcomas can be primary (dedifferentiated, clear cell) or secondary (from malignant transformation of an enchondroma or an osteochondroma).

High-grade chondrosarcomas have a typical aggressive imaging appearance with associated endosteal scalloping, periostitis, or cortical destruction/soft tissue spread (Figure 7). The lesion tends to have more heterogeneously increased T2-weighted signal and heterogeneously avid lobular enhancement.[5]

Fibrous Lesions

Nonossifying Fibroma

Nonossifying fibromas are the most common benign bone tumor of childhood (occurring in up to 30%–40% of healthy children). There have been reported associations with other clinical entities such as neurofibromatosis type I, fibrous dysplasia, and Jaffe-Campanacci syndrome.

Nonossifying fibromas are the most common benign bone tumor of childhood, but eventually they heal and become sclerotic in the mature skeleton.

These lesions are characteristically located eccentrically in the metaphysis, with a "soap-bubble" lucent appearance and a thin sclerotic rim (Figure 8). Cortical expansion and thinning may be present. Eventually, these lesions heal and become sclerotic as the skeleton matures. The MR appearance is dependent on the stage of healing, with initially high signal on T2-weighted images, followed by low signal and variable enhancement patterns as the lesion heals.[6]

Fibrous Dysplasia

Fibrous dysplasia is a benign entity caused by a defect in osteoblastic activity, which results in the formation of immature woven bone. It occurs predominantly in children and young adults (75% younger than 30 years) and can be part of the following clinical syndromes: McCune-Albright (with skin and endocrine abnormalities) and Mazabraud (intramuscular myxomas).

Lesions often are located centrally within the medullary canal of the metaphysis or diaphysis. The radiographic appearance can vary from completely lytic to sclerotic or ground glass (Figure 9). Given their benign nature, these lesions are

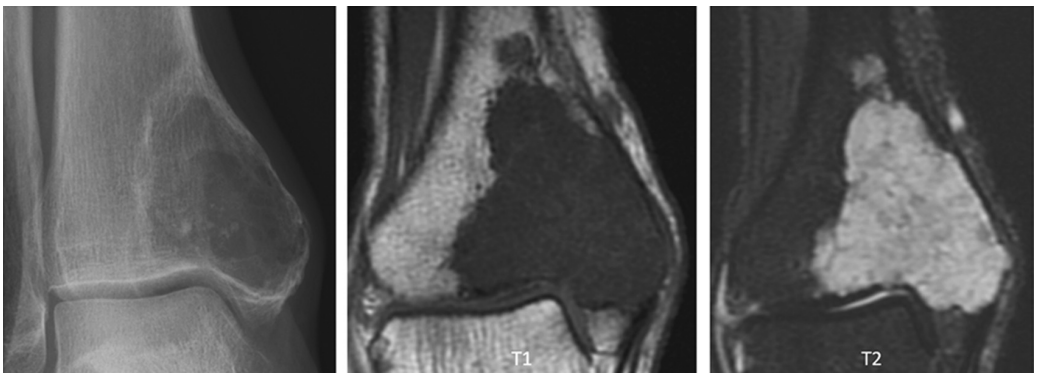

Figure 7. Chondrosarcoma in a 75-year-old man. Large (5 cm) lytic lesion with internal chondroid matrix/mineralization. Associated endosteal scalloping and cortical thinning are present. No definite soft tissue component extends beyond the cortex on the MR images.

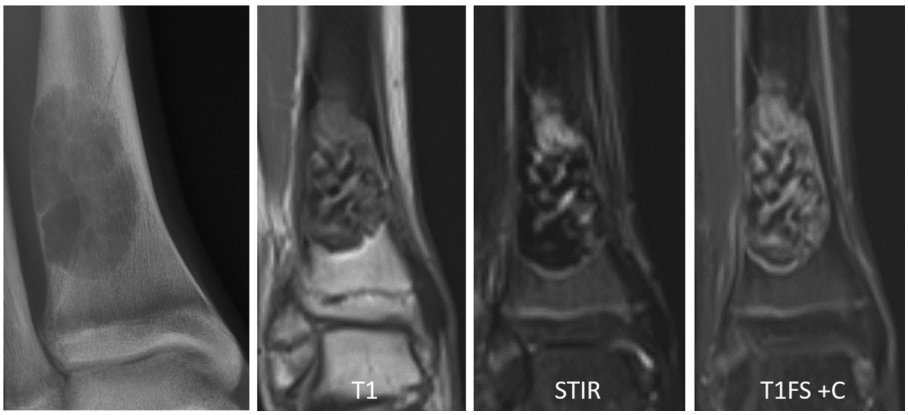

Figure 8. Nonossifying fibroma in a 16-year-old adolescent male. Eccentric, lytic lesion in the metadiaphysis with a soap-bubble appearance on the radiograph. Heterogeneous, low signal on T1-weighted and STIR sequences suggests fibrous tissue. The internal septations show mild enhancement. A nondisclosed pathologic fracture is present on the radiograph.

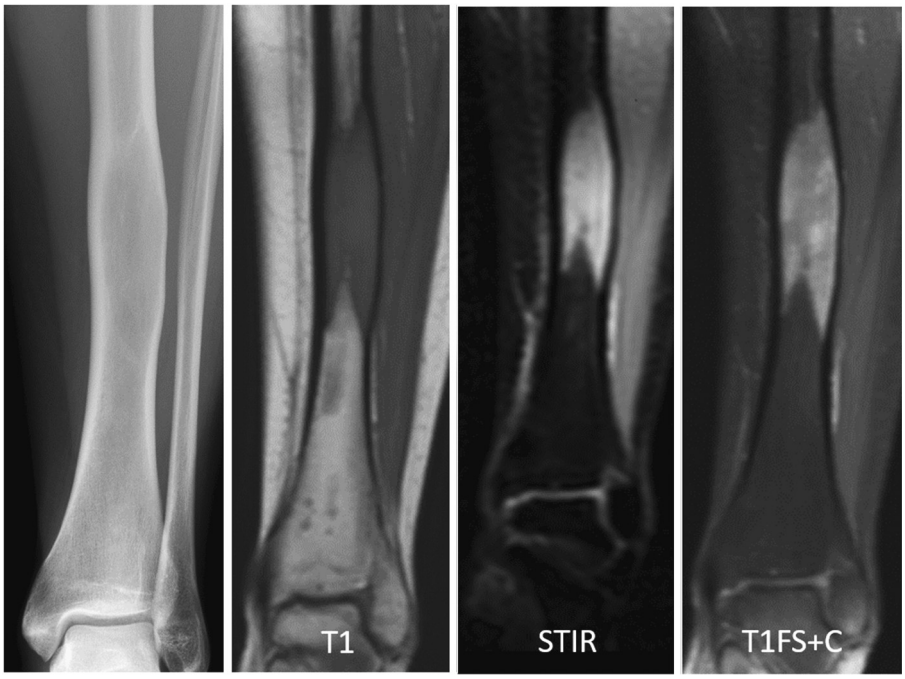

Figure 9. Fibrous dysplasia in a 24-year-old woman. Expansile, ground-glass lesion in the diaphysis with lateral endosteal scalloping and medial cortical thickening is noted on the radiograph. There is no cortical disruption or periosteal reaction.

typically well-circumscribed with a narrow zone of transition. On MRI, lesions are typically intermediate signal on T1-weighted sequences and high signal on T2-weighted sequences with heterogeneous enhancement.[7]

Adamantinoma/Osteofibrous Dysplasia

Adamantinomas and osteofibrous dysplasia are thought to be part of a disease spectrum, in which adamantinomas are the malignant version of osteofibrous dysplasia. These tumors occur in childhood with a slight male predilection. Osteofibrous dysplasia also has been described previously as an ossifying fibroma or Campanacci lesion.

On radiographs, osteofibrous dysplasia appears as an eccentric lucent lesion arising from the anterior mid-diaphyseal cortex (Figure 10). As expected of a benign lesion, there is a well-defined sclerotic margin and no periosteal reaction.

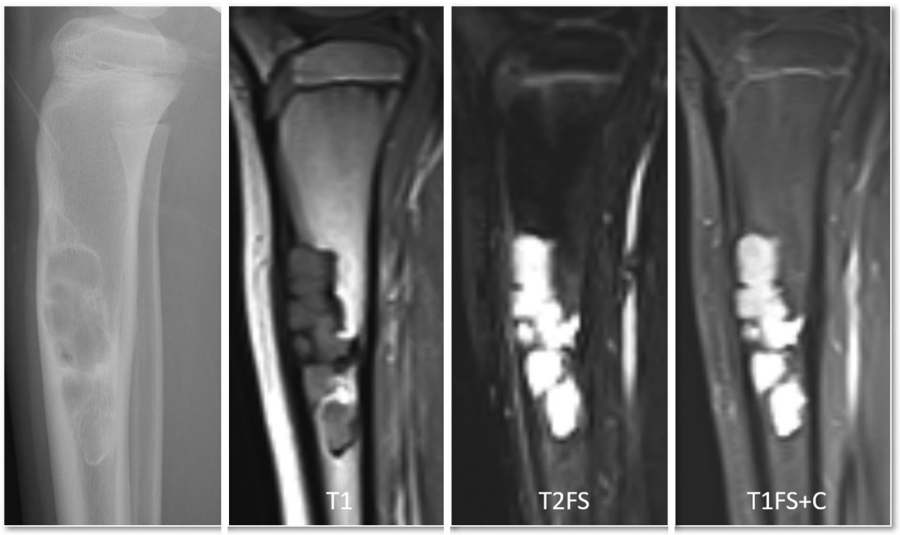

Figure 10. Osteofibrous dysplasia in a 9-year-old boy. There is a well-defined, eccentric, bubbly, lucent lesion in the anterior tibial diaphysis on the radiograph. Intermediate T1-weighted signal and high T2-weighted signal with diffuse avid enhancement are present.

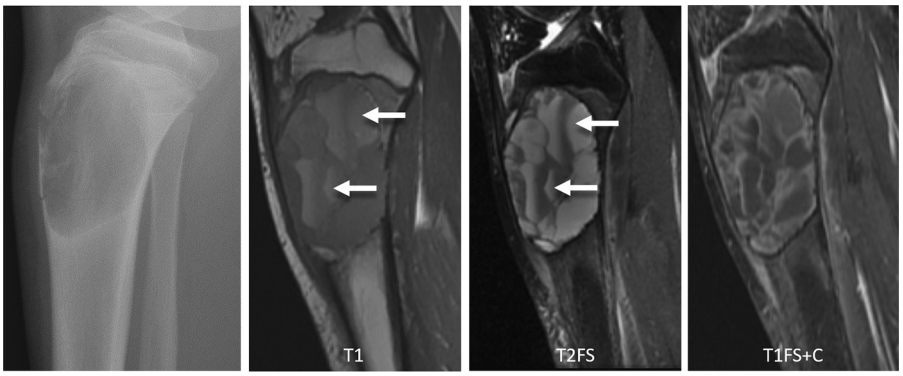

Figure 11. Aneurysmal bone cyst in a 12-year-old boy. Expansile, lytic lesion with a narrow zone of transition and a thin sclerotic border on the radiograph. MRI shows a multiseptated cystic lesion with multiple fluid-fluid levels.

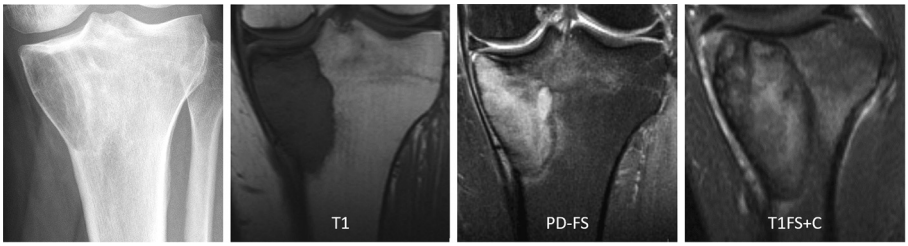

Figure 12. Giant cell tumor in a 53-year-old man. Eccentric, lytic lesion involving the metaphysis and epiphysis and abutting the intra-articular surface. Adjacent bone marrow edema is present on the MR sequences.

Anterior bowing may be present. On MRI, the lesion appears as intermediate signal on T1-weighted images and intermediate-to-high signal on T2-weighted images with avid heterogeneous enhancement.[8]

Cystic Lesions

Aneurysmal Bone Cyst

An aneurysmal bone cyst is a benign lesion consisting of cystic blood cavities and commonly occurs in patients younger than 20 years. They can be primary (70%) or secondary to other lesions such as giant cell tumor, osteoblastoma, or nonossifying fibroma.

These lesions are located most commonly in the metaphysis and appear radiographically as an expansile, eccentric lytic lesion with a thin sclerotic margin and internal trabeculation (Figure 11). On MRI, the lesions display multiple fluid-fluid levels on all sequences with thin peripheral and septal enhancement.[2]

Giant Cell Tumor

Giant cell tumors result from an abnormal proliferation of osteoclasts. The tumor only occurs in patients with fused growth plates; the peak incidence is from age 20 to 50 years, with a slight female predilection. Although the majority are benign, approximately 5% can be malignant (either primary or secondary after prior resection or radiation of a giant cell tumor).

Giant cell tumors only occur in patients with fused growth plates; their peak incidence is from age 20 to 50 years.

The tumor originates in the metaphysis and extends eccentrically toward the subarticular surface of the epiphysis (Figure 12). Most lesions are well-circumscribed and lack a sclerotic margin. They also can display more aggressive behavior with cortical destruction and soft tissue extension. On MRI, the lesion has low-to-intermediate signal on T1-weighted sequences with a low-signal peripheral rim, heterogeneously high signal on T2-weighted sequences, and heterogeneous enhancement on postcontrast images.[9]

Small Round Blue Cell Tumors

Eosinophilic Granuloma

Eosinophilic granuloma is a benign proliferation of Langerhans cells, which occurs primarily in patients younger than 20 years with a slight male predilection. It most commonly involves the skull and long bones.

The imaging appearance is widely variable and is dependent on the stage of the lesion (Figure 13). Early lesions may appear aggressive, with cortical destruction and periosteal reaction. The primary location is within the diaphysis/metadiaphysis. On MRI, the lesion may appear as intermediate-to-low signal on T1-weighted images, high signal on T2-weighted images, and diffuse enhancement on postcontrast images. Lesions typically are associated with adjacent bone marrow edema.[10]

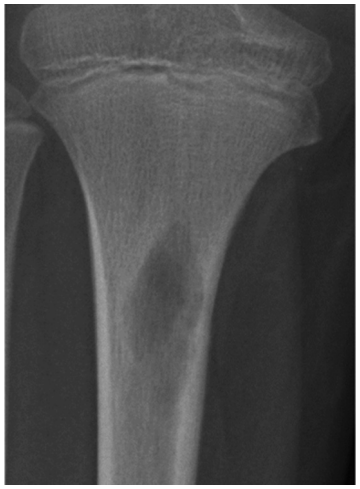

Figure 13. Eosinophilic granuloma in an 8-year-old girl. Eccentric, slightly expansile, lytic lesion in the diaphysis with associated endosteal scalloping. No cortical disruption or significant periosteal reaction is seen.

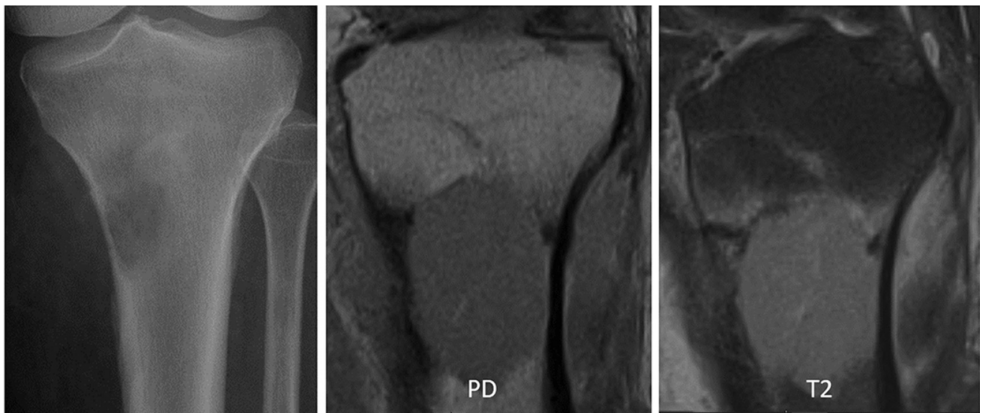

Figure 14. Multiple myeloma in a 59-year-old woman. Poorly defined, lytic lesion with intermediate signal on proton density sequences and high signal on T2-weighted sequences. Surrounding bone marrow edema is present.

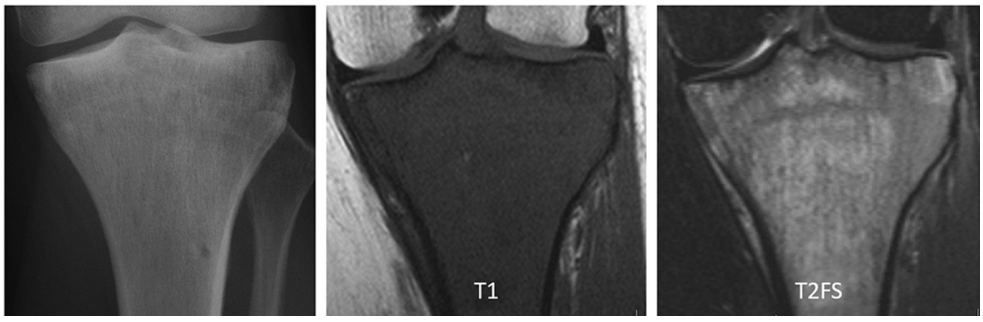

Figure 15. Lymphoma in a 35-year-old woman. The radiograph is unremarkable. MR images show diffuse abnormal marrow signal with decreased T1-weighted signal and increased T2-weighted signal.

Multiple Myeloma

Multiple myeloma is the most common primary malignant bone tumor and results from a neoplastic proliferation of plasma cells. Multiple manifestations have been described, including a disseminated form, a solitary plasmacytoma, and osteosclerotic myeloma.

The classic imaging manifestation of the disseminated form is multiple well-circumscribed, "punched out" intramedullary lytic lesions (Figure 14). Myeloma also may appear only as generalized osteopenia. MRI is more sensitive in detecting myeloma involvement and shows diffuse low signal on T1-weighted images and diffuse high signal on T2-weighted images. Postcontrast images typically show avid enhancement; a wash-out enhancement pattern also has been described.[2]

Lymphoma

Lymphoma can be either a primary bone lesion or secondary to disseminated lymphoma. In general, bone lymphoma is considered primary if there is a single bone lesion without distant spread for 6 months, although rarely it can be multifocal. Lymphoma most commonly occurs in bones with persistent red marrow, and diffuse large B-cell lymphoma is the most common subtype.

The initial radiograph may appear normal, and there is a wide spectrum of lymphoma appearance on radiographs, including a lytic permeative lesion with associated periosteal reaction. MRI is more sensitive than radiography in detecting lymphomatous involvement in bone and shows diffusely decreased signal on T1-weighted images and increased signal on T2-weighted images throughout the marrow (Figure 15). The tumor will enhance avidly, but the normal residual marrow will not enhance. Similar to other small round blue cell tumors, lymphoma can extend into the soft tissues without significant cortical destruction.[2]

MRI is more sensitive than radiography in detecting lymphomatous involvement in bone, and shows diffusely decreased signal on T1-weighted images and increased signal on T2-weighted images throughout the marrow.

Conclusion

Many tumors can occur in the tibia, including some that rarely occur in other parts of the skeleton. When approaching a lesion in the tibia, it is important to identify the salient imaging features to classify the lesion properly and provide a relevant differential diagnosis. This CME activity emphasizes that the radiologist must be aware of the typical clinical presentation and imaging features of various tibial bone lesions to recognize lesions that require further workup or treatment.

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1. All of the following are imaging features of a high-grade chondrosarcoma *except*
- **A.** low signal on T1-weighted images
- **B.** high signal on T2-weighted images
- **C.** endosteal scalloping on radiographs
- **D.** internal chondroid mineralization on radiographs
- **E.** absent periostitis on radiographs

2. All of the following are radiographic features of a nonossifying fibroma, *except*
- **A.** eccentric, metaphyseal lesion
- **B.** "soap-bubble" lucent lesion
- **C.** associated cortical expansion
- **D.** aggressive malignant transformation in adulthood
- **E.** thin sclerotic rim

3. The predominant location of an adamantinoma is
- **A.** femur
- **B.** fibula
- **C.** tibia
- **D.** radius
- **E.** ulna

4. Which one of the following bone lesions is characterized by internal fluid-fluid levels on all MR sequences?
- **A.** Aneurysmal bone cyst
- **B.** Osteoblastoma
- **C.** Eosinophilic granuloma
- **D.** Chondromyxoid fibroma
- **E.** Multiple myeloma

5. Which one of the following characterizes the MR appearance of the bone marrow in lymphoma?
- **A.** Normal T1-weighted signal, normal T2-weighted signal
- **B.** Increased T1-weighted signal, increased T2-weighted signal
- **C.** Decreased T1-weighted signal, decreased T2-weighted signal
- **D.** Increased T1-weighted signal, decreased T2-weighted signal
- **E.** Decreased T1-weighted signal, increased T2-weighted signal

6. All of the following are MR features of a tibial chondromyxoid fibroma, *except*
- **A.** associated periosteal reaction
- **B.** decreased T1-weighted signal
- **C.** increased T2-weighted signal
- **D.** peripheral enhancement
- **E.** location in the proximal third of the bone

7. Which one of the following is a feature of an osteoblastoma?
- **A.** Female predilection
- **B.** Excellent pain relief with NSAIDs
- **C.** Histologic similarity to osteoid osteoma
- **D.** Elderly most commonly are affected
- **E.** Most commonly involves the tibia

8. Enchondromas are associated with which one of the following clinical syndromes?
- **A.** Mazabraud
- **B.** Maffucci
- **C.** McCune-Albright
- **D.** Jaffe-Campanacci
- **E.** Neurofibromatosis type I

9. A 20-year-old man presents with nocturnal knee pain relieved by NSAIDs. Radiographs of the tibia show a subcentimeter, cortically based, ovoid, lucent lesion with surrounding sclerotic bone. The *most* likely diagnosis is
- **A.** osteoblastoma
- **B.** enchondroma
- **C.** nonossifying fibroma
- **D.** osteoid osteoma
- **E.** osteosarcoma

10. Which one of the following is the *most* common primary malignant bone tumor in adults?
- **A.** Osteosarcoma
- **B.** Multiple myeloma
- **C.** Chondrosarcoma
- **D.** Giant cell tumor
- **E.** Adamantinoma