

Radiologic Approach to Bone and Soft Tissue Sarcomas



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KEYWORDS

- Imaging • Radiology • Diagnostic evaluation • Bone lesion • Soft tissue mass
- Sarcoma

KEY POINTS

- Diagnostic imaging plays an important role in the evaluation and treatment planning of patients with musculoskeletal tumors.
- Following a thorough history and physical examination, imaging examinations may be requested to evaluate a palpable abnormality; soft tissue mass; or clinical symptoms, such as pain and swelling.
- In some cases, the clinical presentation including patient age, symptomatology, and past medical history may suggest a specific diagnosis, although in most cases the clinical examination is nonspecific.
- Whether detected incidentally or in the setting of clinical symptoms, musculoskeletal neoplasms can often be accurately characterized utilizing appropriate imaging examinations.

Diagnostic imaging is a critical component of a multidisciplinary approach to the diagnosis and treatment of musculoskeletal neoplasms. Following a thorough history and physical examination, imaging examinations may be requested to evaluate a palpable abnormality; soft tissue mass; or clinical symptoms, such as pain and swelling. In some cases, the clinical presentation including patient age, symptomatology, and past medical history may suggest a specific diagnosis, although in most cases the clinical examination is nonspecific. With greater accessibility to and use of advanced imaging modalities, musculoskeletal tumors may be identified incidentally on studies

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performed for other reasons. In any of these scenarios, the initial objective of diagnostic imaging is confirmation of the presence of a musculoskeletal neoplasm versus an alternative explanation of symptoms, such as traumatic injury or infection. When a mass is present, initial characterization of the tumor as benign or malignant is based on features, such as size, margins, enhancement pattern, and internal homogeneity versus heterogeneity. After the initial assessment of benignity versus malignancy, further evaluation may provide for a more specific diagnosis based on tumor characteristics, such as anatomic location, morphology, pattern of growth, and intrinsic tumor composition. Ideally, a subspecialized multidisciplinary review of the clinical history, diagnostic imaging, and histopathologic findings at a tertiary cancer referral center would direct optimal patient treatment planning.¹⁻⁴

This article discusses several important concepts in musculoskeletal tumor imaging and presents relevant imaging features of several common musculoskeletal neoplasms. A complete and thorough review of musculoskeletal tumor imaging is beyond the scope of this review, with numerous textbooks dedicated to the subject. In this article, we discuss the following:

- Imaging modalities most often used in the evaluation of musculoskeletal tumors including the advantages and disadvantages of each modality
- Our approach to the diagnostic evaluation of a newly suspected musculoskeletal neoplasm including determination of risk of malignancy
- An assessment of internal tumor composition allowing for a specific preoperative histopathologic diagnosis including features of several common soft tissue sarcomas
- Findings relevant to tumor staging and preoperative planning including response to neoadjuvant therapy
- Postoperative surveillance plans for local tumor recurrence following limb-salvage procedures

IMAGING MODALITIES

Several different diagnostic imaging examinations may be used in the initial evaluation of a suspected musculoskeletal neoplasm.⁵⁻¹⁰ Each modality presents unique advantages and disadvantages as shown in [Table 1](#). However, in most cases complementary information is provided by each study. For example, MRI provides greater soft tissue contrast than computed tomography (CT) and therefore often allows for better definition of internal tumor soft tissue composition/intrinsic elements of the tumor, whereas CT better demonstrates tumor mineralization than MRI. In another example, CT better depicts cortical bone involvement including pathologic fractures, whereas MRI better demonstrates medullary edema and bone marrow lesions including skip metastases not uncommonly seen in patients with primary bone tumors, such as osteosarcoma.

EVALUATION OF A NEWLY SUSPECTED MUSCULOSKELETAL TUMOR

Although a thorough clinical history and physical examination are important in the initial evaluation of a patient with a possible musculoskeletal neoplasm, symptomatology and physical findings are often nonspecific with significant overlap among presentations of neoplastic and nonneoplastic causes of musculoskeletal complaints.¹¹ Even when findings suggest the presence of a tumor, physical examination is often limited in differentiating benign and malignant neoplasms. As such, most patients with musculoskeletal symptoms are referred for diagnostic imaging. When imaging

Table 1
A comparison of imaging modalities commonly used in musculoskeletal tumors

Modality	Advantages	Disadvantages	Indications/Usefulness
Diagnostic radiography, orthogonal roentgenogram	• Diagnostic • Accessible • Inexpensive • Critical in evaluating bone tumors • Demonstrates tumor mineralization and adipocytic tumors	• Ionizing radiation • Limited evaluation of nonadipocytic soft tissue tumors	• Evaluation of bone tumor margin, matrix, and periosteal reaction • Soft tissue tumor density and internal mineralization
CT	• Accessible • Rapid acquisition/short scan time • Contiguous imaging of large anatomic regions • Greater spatial and temporal resolution than MRI	• Ionizing radiation • Less soft tissue contrast resolution compared with MRI	• Evaluate tumor matrix • Involvement of cortical bone including pathologic fractures • Tumor staging including chest CT for pulmonary metastases • CT-guided biopsy
MRI	• Greater soft tissue contrast resolution than CT • No ionizing radiation • Direct multiplanar imaging	• Small confined space; claustrophobia • Cost • Contraindications to MRI	• Evaluation of internal tumor composition • Local extent of disease including neurovascular involvement • Bone marrow involvement, skip metastases
Ultrasound	• Real-time imaging • Assess solid versus cystic mass and tumor vascularity (Doppler)	Limited ability to differentiate soft tissue masses	Ultrasound-guided biopsy
PET	Tumor/tissue viability, assessment of metabolic activity	• Ionizing radiation • Reimbursement in sarcomas	• May help differentiate benign and malignant tumors (ie, neurogenic tumors) • Evaluate tumor response to neoadjuvant therapy
Whole-body bone scan	Assessment of the entire skeletal system in a single examination	Ionizing radiation	Assessment of skeletal metastases and osteomyelitis

Abbreviation: CT, computed tomography.

is indicated, initial evaluation begins with orthogonal radiographs of the affected area, which may be followed by cross-sectional imaging, such as CT or MRI as shown in Fig. 1.

Step 1: Determination of Risk of Malignancy

The first and foremost role of imaging in the setting of a musculoskeletal neoplasm should be confirmation of the presence of a tumor and an assessment of tumor characteristics, which help predict benignity versus malignancy. After establishing the risk of malignancy, a further assessment of imaging findings providing for a more specific diagnosis is performed. With patient counseling based on the potential risk of malignancy, patients may be appropriately informed on treatment options, which may include surveillance, biopsy, or surgery. For example, consider a young patient with a geographic well-defined metadiaphyseal lytic lesion with circumferential marginal sclerosis. These findings suggest a low likelihood of malignancy and conservative observation may be preferred to biopsy. In cases of soft tissue tumors, the surgical

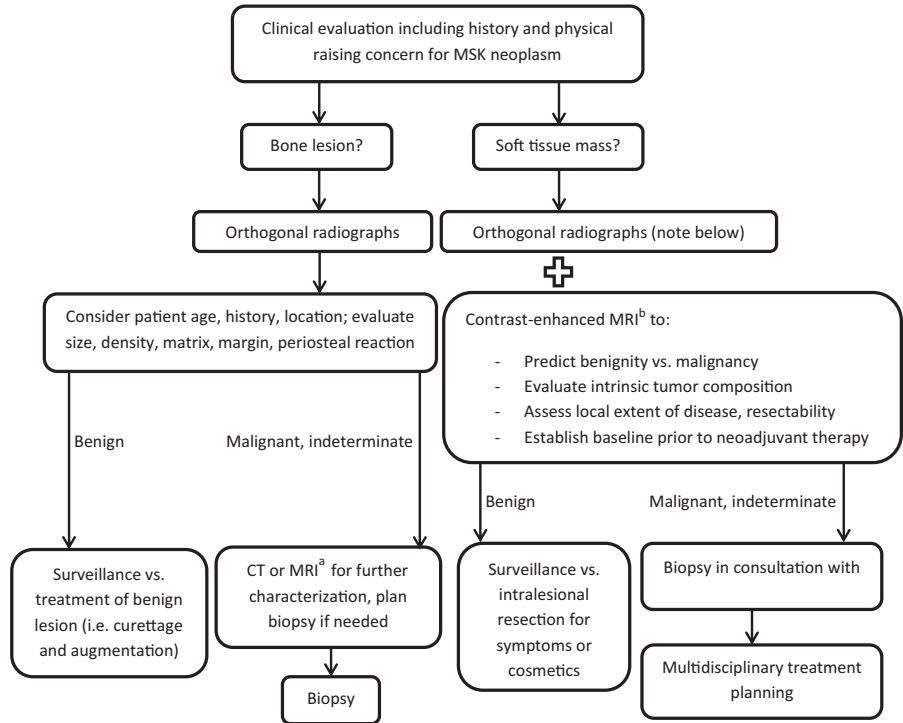


Fig. 1. Flowchart demonstrating our approach to the initial evaluation of a suspected musculoskeletal neoplasm. ^a See text for discussion of CT versus MRI. ^b MRI protocol for MSK neoplasm includes multiplanar imaging (axial, sagittal, and coronal) of the entire compartment obtaining T1-weighted imaging, a fluid-sensitive sequence (T2-weighted imaging or short tau inversion recovery [STIR]), a fat-suppressed sequence (STIR or chemically selective fat saturation technique), diffusion-weighted imaging, and fat-suppressed T1-weighted intravenous contrast-enhanced imaging. In practice, radiographs may not be considered before MRI in cases of suspected soft tissue tumors. However, whether obtained before or following MRI, radiographs are often useful in correlation with findings seen at MRI, particularly areas of mineralization. MSK, musculoskeletal.

approach to percutaneous biopsy or resection differs based on the likelihood of malignancy. Here, we discuss imaging features of musculoskeletal neoplasms that help predict benignity versus malignancy.

Bone lesions

In cases of bone tumors, diagnostic orthogonal radiography (ie, anteroposterior and lateral) allows an assessment of radiographic density (osteolytic vs osteoblastic), size, location, margination, internal matrix, and periosteal reaction. Additionally, radiographs may demonstrate the presence of a pathologic fracture or an associated extraosseous soft tissue mass. These features allow prediction of tumor aggressiveness, growth rate, and risk of malignancy. In 1980, Lodwick and colleagues¹² first demonstrated a correlation between tumor margination and rate of growth. Subsequent contributions of Madewell and colleagues¹³ established three distinct types of osteolysis. Since their early works on this subject, a useful grading system to describe lytic bone lesions has been incorporated into clinical practice such that radiographic grade is commonly used to predict risk of malignancy.

In many cases, the radiographic appearance of a bone lesion alone provides sufficient information regarding biologic activity and risk of malignancy.¹⁴ More specifically, lesion margination, or zone of transition, described as narrow or wide, correlates with rate of growth. This important radiographic feature forms the basis of the current widely used grading system of lytic bone lesions. Lytic lesions are described as geographic (grade I) or nongeographic (grade II or III). Grade I lesions are further classified as IA, IB, or IC. Geographic lesions demonstrate a clear delineation between involved and uninvolved bone, and the margins of the lesion are generally described as well-defined with a sclerotic rim (IA), well-defined without a sclerotic rim (IB), or ill-defined with a wide zone of transition (IC). Grade II and III lesions are nongeographic moth-eaten and permeative bone lesions with an indistinct transition between normal and pathologic bone. Increasing grade correlates with increased rate of growth such that grade IA lesions are largely benign and IB lesions are indeterminate with a moderate risk of malignancy, whereas grade IC and higher lesions are considered malignant until proven otherwise. Our ongoing research hopes to expand the existing classification system to include lytic lesions with changing margination and radiographically occult bone lesions.

Although margination and grade assignment of a bone lesion may be most important in predicting risk of malignancy, other radiographic features provide information on tumor aggressiveness and histopathology.^{15–22} The presence or absence of periosteal reaction or an extraosseous soft tissue mass should be evaluated on bone radiographs. Periosteal reaction may be described as smooth, solid, or continuous most often in benign etiologies or irregular, lamellated, interrupted, or spiculated in malignant diseases. Cortical disruption with an extraosseous soft tissue mass is highly suggestive of a malignant bone tumor. Meanwhile, such findings as radiographic density (lytic or sclerotic) and the pattern of matrix mineralization (osteoid, chondroid, or ground glass) may point to a specific histologic diagnosis. Patient age and site of disease (long bone vs flat bone; central vs eccentric; epiphyseal vs metadiaphyseal) also contribute to the construction of a differential diagnosis (**Figs. 2 and 3**).

Soft tissue masses

When evaluating a soft tissue mass, the objective should first be differentiation of benign from malignant lesions, as in cases of newly diagnosed bone lesions. Even for experienced musculoskeletal radiologists, this can be more difficult than for bone lesions because there is significant overlap in the imaging appearance of benign

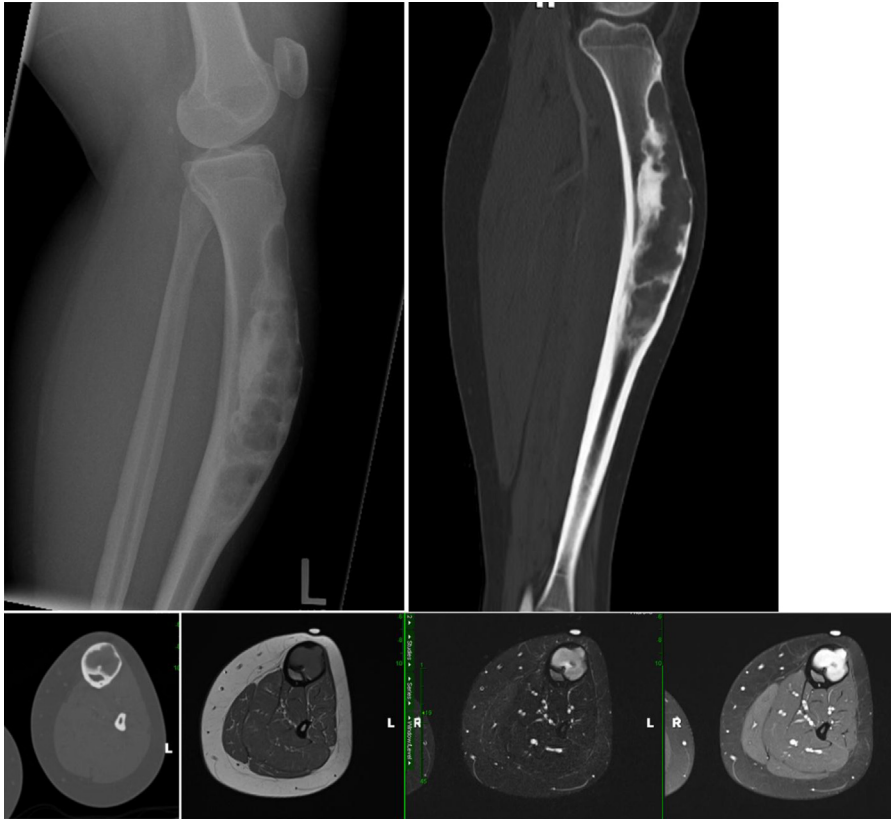


Fig. 2. Benign bone lesion in a 15-year-old girl. (*Top*) Lateral radiograph and sagittal CT reconstruction of the left tibia demonstrate a well-defined, geographic, cortically based, diaphyseal mixed lytic and sclerotic lesion along the anterior tibia with marginal sclerosis and areas of dense osteoid mineralization. (*Bottom*) Axial CT, T1-weighted, STIR, and contrast-enhanced MRIs demonstrate a lytic lesion with fibrous matrix involving the anterior tibial cortex with circumferential sclerosis, which encroaches on but does not invade the medullary cavity. Biopsy-confirmed osteofibrous dysplasia.

and malignant tumors, particularly when small and superficial. However, certain imaging features are helpful when evaluating a soft tissue mass and predicting whether it is more likely to be benign or malignant.

In cases of soft tissue tumors, initial diagnostic radiography can provide valuable information regarding tumor density (ie, adipocytic tumors), mineralization with a soft tissue mass (ie, synovial sarcoma and liposarcoma), involvement of the underlying bone, and nonneoplastic processes that mineralize (ie, myositis ossificans).^{23,24} However, most soft tissue masses are referred for cross-sectional imaging. In the absence of any contraindication, for reasons discussed previously, we typically perform multiplanar, multiweighted, and contrast-enhanced MRI of the entire compartment (joint-to-joint coverage) suspected to be involved by a musculoskeletal tumor. Several imaging features help differentiate benign from malignant neoplasms.^{25–29} Benign lesions tend to be small, homogeneous, and superficial to the investing fascia when arising in the extremities, whereas soft tissue masses that are large (>4 cm), heterogeneous, and deep-seated are more worrisome for malignancy

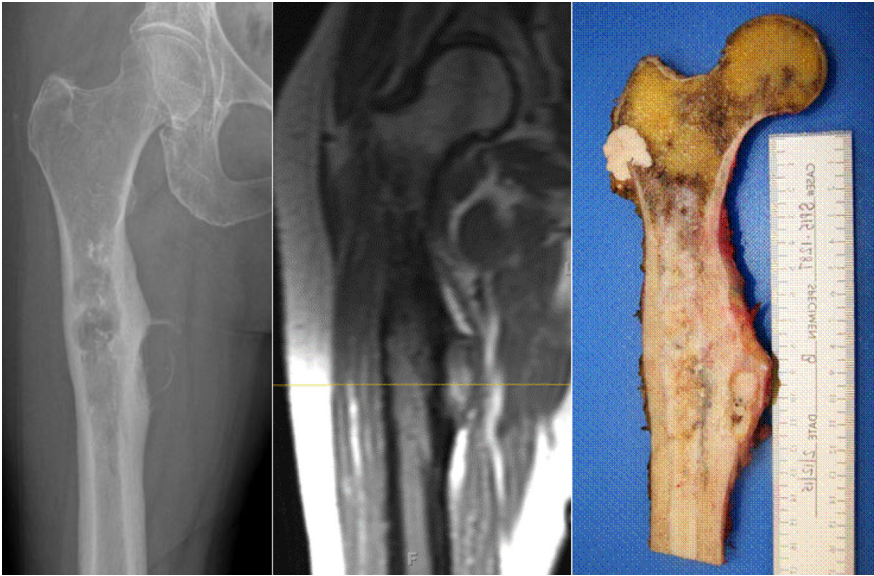


Fig. 3. Malignant bone lesion in a 56-year-old man. Anteroposterior radiograph of the proximal right femur demonstrates a geographic, but poorly margined lytic medullary lesion with chondroid mineralization, moderate endosteal scalloping with medial cortical thickening, and elevation of the periosteum suggesting an extraosseous soft tissue mass. Coronal T1-weighted MRI demonstrates extent of medullary cavity involvement and confirms a medial extraosseous mass. Gross pathology specimen correlated with MRI-confirmed chondrosarcoma.

(Figs. 4 and 5). Malignant tumors often demonstrate enhancement with areas of internal necrosis and hemorrhage contributing to tumor heterogeneity. Although cystic lesions, such as ganglia, and fluid collections, such as postoperative seromas, do not enhance or show thin smooth peripheral rim enhancement, most benign and malignant solid neoplasms demonstrate intravenous contrast enhancement. However, benign masses are more likely to demonstrate mild patchy or uniform homogeneous enhancement than malignant tumors, which often demonstrate internal areas of nonenhancing necrosis and/or hemorrhage. Associated findings, such as a hypointense pseudocapsule and hyperintense peritumoral edema (reactive zone) on T2-weighted or short tau inversion recovery (STIR) imaging, are more commonly seen in soft tissue sarcomas than benign soft tissue masses. Finally, regional lymphadenopathy (albeit less common in sarcoma than other primary cancers) and satellite nodules or distant sites of disease concerning for metastases may be present with malignant soft tissue tumors.

Step 2: Assessment of Tumor Composition to Predict a Specific Histopathologic Diagnosis

Following an assessment of tumor aggressiveness, a specific histopathologic diagnosis or concise differential diagnosis can be presented for most musculoskeletal neoplasms by evaluating the internal matrix or intrinsic composition of a mass. Demographic information, such as age and gender, site of disease, and pattern of growth, also contributes to the construction of a differential diagnosis. The internal matrix of a bone lesion is best evaluated at radiography or CT and points to cell lineage

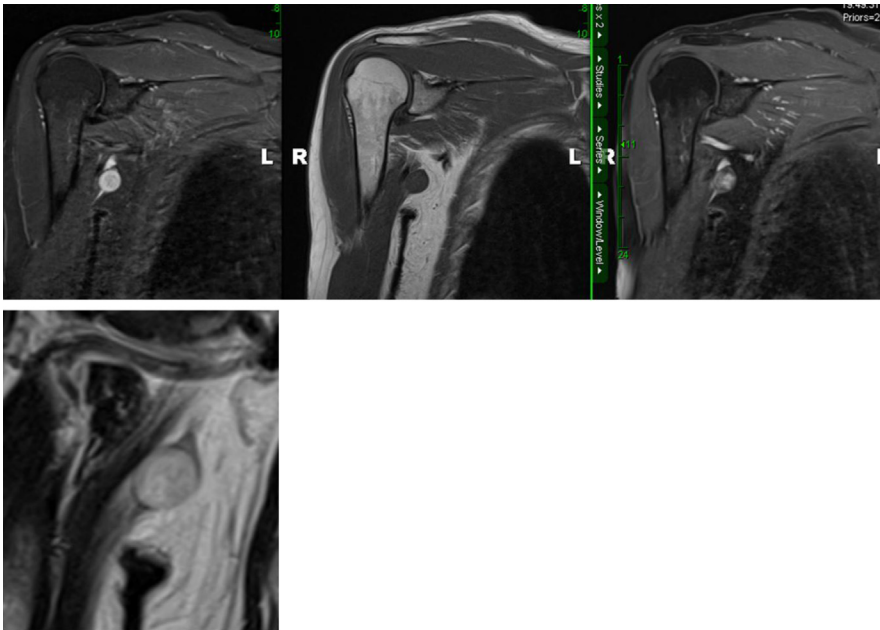


Fig. 4. Benign soft tissue mass. (Top) Coronal STIR, T1-weighted, and contrast-enhanced MRIs demonstrate a small, superficial, well-defined, and smoothly margined soft tissue nodule with mild intravenous contrast enhancement, features typical of benign soft tissue neoplasms. (Bottom) After assessing risk of malignancy, further evaluation of internal tumor composition and identification of any pathognomonic findings, such as a “string sign” in this example of a benign peripheral nerve sheath tumor, allows for a specific diagnosis.

(ie, osteoid, chondroid, or fibrohistiocytic), whereas MRI better demonstrates internal soft tissue elements within a soft tissue mass (ie, lipomatous, myxomatous, or fibrous). Imaging features of common components and associated findings of osseous and soft tissue neoplasms are presented in [Table 2](#).

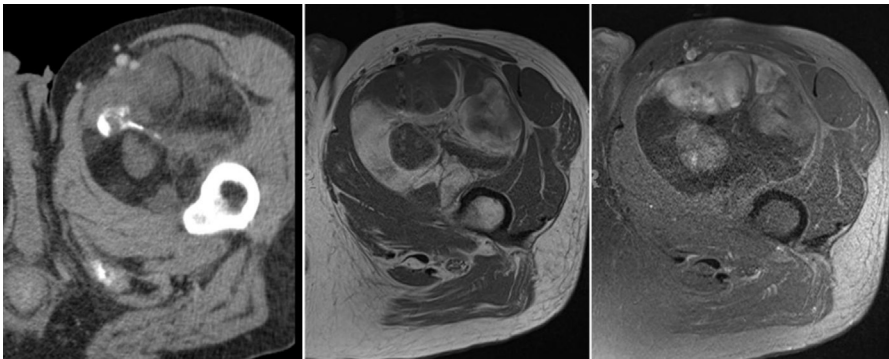


Fig. 5. Malignant soft tissue mass. Axial contrast-enhanced CT, T1-weighted, and contrast-enhanced MRIs demonstrate a large, heterogeneous, deep-seated soft tissue mass in the anterior proximal thigh, features typical of malignant soft tissue neoplasms. Further inspection of the internal composition of the mass demonstrates intrinsic fat indicating a lipomatous neoplasm with areas of mineralization and nonadipocytic soft tissue elements consistent with dedifferentiated liposarcoma.

Table 2
Imaging findings of common components of musculoskeletal neoplasms

Tissue Composition	Radiography or CT	MRI
Bone tumors		
Osteoid matrix	Dense, sclerotic, amorphous, cloud-like mineralization	Dark signal intensity on T1- and T2-weighted imaging
Chondroid matrix	Punctate, stippled, linear, or rings and arcs mineralization; lucent lesion with lobular pattern of growth and endosteal scalloping	Bright signal intensity on T2-weighted imaging with peripheral and internal septal pattern of enhancement
Fibrohistiocytic matrix	Radiolucent ground glass appearance without evidence of mineralization	Variable with somewhat whorled appearance, often with areas of dark T2-weighted signal
Soft tissue masses		
Lipomatous tissue	Radiolucent; low density on CT with negative Hounsfield units similar to subcutaneous fat	Bright signal intensity on T1- and T2-weighted imaging; signal drop out with fat suppression techniques
Myxomatous tissue	Hypodense on CT with similar attenuation to fluid	Markedly bright signal on T2-weighted imaging similar to fluid, but with intravenous contrast enhancement
Fibrous tissue	Similar density to skeletal muscle on CT	Dark signal intensity on T1- and T2-weighted imaging with variable enhancement; often infiltrative pattern of growth
Hemorrhage ^a	Hyperdense on CT	Hyperintense signal on T1-weighted, heterogeneous; hemosiderin appears dark with "blooming" susceptibility artifact on gradient echo imaging caused by iron
Necrosis	Hypodense on CT without enhancement	Bright T2-weighted signal intensity without enhancement
Pseudocapsule	Difficult to delineate on CT	Dark rim of signal intensity on T2-weighted imaging
Peritumoral edema	Hypodense, but difficult to delineate on CT	Infiltrative-appearing, bright signal intensity on T2-weighted imaging surrounding a mass

^a Appearance of hemorrhage depends on acuity/chronicity of blood products.

The initial evaluation of a soft tissue mass should begin with orthogonal radiographs. Radiography is most helpful in cases of adipocytic and mineralizing neoplasms.²⁴ Fatty tumors, such as lipomas, atypical lipomatous tumors, and liposarcomas, demonstrate radiolucency relative to skeletal muscle, whereas most other soft tissue masses demonstrate density similar to muscle and are not well defined on radiographs. Some tumors and nonneoplastic lesions demonstrate patterns of mineralization specific to the diagnosis. For example, long-standing adipocytic tumors can demonstrate metaplastic, mature-appearing bone formation. Soft tissue hemangiomas commonly present with numerous rounded and lamellated phleboliths. Synovial sarcoma often demonstrates irregular dystrophic mineralization. Myositis ossificans demonstrates a typical pattern of peripheral mineralization allowing for diagnosis despite a nonspecific mass-like appearance on cross-sectional, which may mimic a soft tissue sarcoma.

Following radiography, cross-sectional imaging is often performed to further characterize musculoskeletal neoplasms with the goal of providing a specific preoperative histopathologic diagnosis.³⁰ CT and MRI provide different but complementary information. CT has the advantage of better depiction of tumor matrix mineralization and cortical bone involvement, such as depth of endosteal scalloping seen in cartilaginous bone tumors. Although fat within an adipocytic neoplasm is well demonstrated by both CT and MRI, greater soft tissue contrast afforded by MRI often allows for differentiation of other intrinsic elements, such as myxomatous or fibrous components, which may allow for a more specific preoperative diagnosis. The selection of CT or MRI for tumor characterization largely depends on the clinical question to be answered. However, in most cases, MRI provides greater soft tissue contrast and definition of internal tumor composition, internal necrosis, hemorrhage, and associated findings common to soft tissue sarcomas, such as a pseudocapsule and peritumoral edema.

When evaluating a soft tissue mass on cross-sectional imaging, we first attempt to determine whether the mass contains any intrinsic fat given the incidence of benign and malignant lipomatous neoplasms among most patient populations. The presence of internal fat within a mass typically indicates an adipocytic neoplasm.^{31,32} Fat appears hypodense on CT and hyperintense on T1- and T2-weighted MRI similar to subcutaneous tissues with evidence of signal suppression on chemically selective fat-suppressed imaging or STIR. Adipocytic tumors tend to demonstrate a somewhat lobulated pattern of growth. Simple lipomas are comprised entirely of fat without any internal nodularity or thickened septations, although smooth thin (<2 mm) bands may be seen. The presence of internal fat stranding ("dirty fat") or nodularity on STIR or contrast-enhanced imaging may indicate atypical lipomatous tumor or well-differentiated liposarcoma. Continuing along the spectrum of adipocytic neoplasms, the presence of nonadipocytic soft tissue elements within a fatty mass indicates liposarcoma. This may include myxomatous tissue seen as markedly T2-weighted hyperintense and enhancing areas on MRI in cases of myxoid liposarcoma.³³ The hallmark of dedifferentiated liposarcoma is the presence of nonadipocytic enhancing soft tissue elements.³² Pleomorphic liposarcoma typically presents as an indeterminate heterogeneous mass, which may not demonstrate any obvious macroscopic fat on CT or MRI.³²

When intrinsic fat is not identified at cross-sectional imaging within an aggressive-appearing soft tissue mass, we then consider nonadipocytic soft tissue sarcomas, such as undifferentiated high-grade pleomorphic sarcoma (UPS) and leiomyosarcoma (LMS) among other sarcomas depending on additional factors, such as patient age and site of disease. UPS, formerly referred to as malignant fibrous histiocytoma, typically presents as a large, heterogeneous enhancing mass with extensive internal hemorrhage and necrosis, a pseudocapsule, and peritumoral edema.³⁴ UPS is the most

common soft tissue sarcoma among elderly patients. LMS tends to appear as a mostly solid, avidly enhancing hypervascular soft tissue mass with less necrosis than typical of UPS commonly arising from a large blood vessel, such as the inferior vena cava, pulmonary artery, or peripheral vessel, such as the femoral vein.³⁵ LMS often grows into the lumen of the vessel of origin and may result in thrombosis. LMS also may arise from smooth muscle cells of the retroperitoneum, genitourinary or gastrointestinal tract, or hair pillars of the skin and should be considered in cases of small, superficial, solid enhancing soft tissue masses, features more common among benign lesions.

Several other soft tissue sarcomas demonstrate characteristic imaging features warranting mention. Rhabdomyosarcoma has a predilection for the head and neck in pediatric patients.³⁶ Synovial sarcoma also tends to occur in the adolescent and young adult patient population in a periauticular location with a propensity for internal hemorrhage, mineralization, regional lymph node metastases, and osseous invasion.³⁷ Benign and malignant fibrous neoplasms, such as fibromatosis, myxofibrosarcoma, and adult fibrosarcoma, typically demonstrate intrinsic fibrous elements appearing hypointense on T1- and T2-weighted MRI with variable enhancement often arising along fascial planes with a characteristic "fascial tail."³⁸ Myxofibrosarcoma is often microscopically infiltrative with higher rates of local tumor recurrence than other soft tissue sarcomas. Angiosarcoma is often an infiltrative vascular neoplasm with a propensity for the scalp and breast.

TUMOR STAGING, RESPONSE TO NEOADJUVANT THERAPY, AND POSTOPERATIVE SURVEILLANCE

Tumor staging in the setting of a musculoskeletal neoplasm includes an assessment of local extent of disease and an evaluation of distant metastatic disease.³⁹ Because most soft tissue sarcomas tend to respect compartmental boundaries, imaging of the primary site of disease should include the entire compartment to visualize the entirety of the mass and detect any intracompartmental skip metastases, more common in bone tumors, such as osteosarcoma, but occasionally seen in soft tissue sarcomas. Local extent of disease directs treatment planning and attention must be directed to identify neurovascular involvement and contiguous bone involvement via direct extension. Lymph node metastases are uncommon in most soft tissue sarcomas, although several types more commonly spread to locoregional lymph nodes including synovial sarcoma, epithelioid sarcoma, clear cell sarcoma, and angiosarcoma. Pulmonary metastases are the most common site of distant disease and we recommend unenhanced chest CT for this reason, although some argue that chest radiographs are sufficient to identify significant pulmonary nodules. Whole-body bone scan and PET/CT are not routinely performed in our practice in the initial staging of soft tissue sarcomas. Of note, experience has shown that myxoid liposarcomas have a propensity for retroperitoneal and paraspinal soft tissue metastases and therefore contrast-enhanced CT of the chest, abdomen, and pelvis is typically performed in these patients.

Neoadjuvant chemotherapy and/or radiation therapy is often used in patients with large tumors at increased risk for local recurrence or to improve the likelihood of a margin-negative surgical resection. Response to neoadjuvant chemotherapy also yields prognostic information in cases of osteosarcoma. Restaging examinations are commonly performed following neoadjuvant therapy immediately before surgery. Several imaging findings identified on MRI are consistent to assess response to therapy.^{40,41} An overall decrease in tumor size or tumor volume indicates a positive response. In some cases of neurovascular abutment or partial encasement, the tumor may retract from the neurovascular bundle providing for a surgical plane between the

tumor and the bundle. Alternatively, a tumor may increase in size following treatment, while the amount of viable enhancing neoplastic tissue decreases. In these cases, enlargement is caused by tumor necrosis and hemorrhage in response to therapy. Diffusion-weighted MRI has more recently shown the ability to identify changes in apparent diffusion coefficients in response to therapy.⁴² Densely packed tumor cells exhibit limited diffusivity of water molecules in the interstitial space, which manifests as areas of restricted diffusion on diffusion-weighted MRI. Cell death in response to therapy creates increased interstitial space allowing for increased mobility of interstitial water molecules via brownian motion. Increased movement of water results in a quantifiable change in diffusivity depicted on diffusion-weighted images as higher apparent diffusion coefficients values.

Given risk of local tumor recurrence, patients with surgically resected soft tissue sarcomas should undergo postoperative surveillance imaging of the operative bed. The frequency of surveillance imaging depends on the patient's risk of local recurrence determined by tumor size, grade, histology, and margin status following surgery. Early recurrence typically presents as a small enhancing soft tissue nodule within the operative field. Recurrent disease usually demonstrates similar signal characteristics to the primary tumor and therefore comparison with preoperative and postoperative baseline examinations is imperative.⁴⁰ Knowledge of the surgical procedure including reconstruction technique and soft tissue changes following adjuvant radiation therapy aids interpretation of postoperative scans. Radiation-induced soft tissue changes are usually infiltrative and geographic with demarcated borders conforming to the radiation field. Patchy, ill-defined bone marrow edema may indicate radiation-induced osteitis. Postoperative seromas are common and demonstrate internal fluid signal intensity with thin rim enhancement without mural nodularity. Hematomas may be heterogeneous on MRI with increased T1-weighted signal, variable T2-weighted signal, and often a peripheral hypointense rim caused by mural hemosiderin deposition.

Following clinical assessment of a newly suspected musculoskeletal neoplasm, diagnostic imaging plays an important role in initial tumor characterization, tumor staging, treatment planning, evaluation of response to therapy, and postoperative surveillance. We have presented our diagnostic algorithm for the initial work-up of primary bone and soft tissue tumors. We have also reviewed the advantages and disadvantages of different imaging modalities and the complementary information each provides, discussed pertinent imaging features that help predict the likelihood of benignity versus malignancy, and highlighted intrinsic imaging characteristics defining internal tumor composition that allow for specific preoperative histopathologic diagnoses. Despite dramatic improvements in imaging technologies, expertise in image interpretation, improved understanding of tumor biology, and advancements in neoadjuvant/adjuvant therapies and limb-salvage surgical options, musculoskeletal sarcomas remain exceedingly rare in comparison with visceral carcinomas and hematologic malignancies and continue to carry a significant risk of disease-related morbidity and mortality. For these and other reasons, we advocate a multidisciplinary approach to the diagnosis and treatment of musculoskeletal neoplasms preferably at a local or regional tertiary care center with specialized physician and ancillary services in the management of these tumors.

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