

BONE AND SOFT TISSUE TUMORS

A MULTIDISCIPLINARY REVIEW
WITH CASE PRESENTATIONS



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Chapter 2

Radiology overview of soft tissue and bone tumors

RADIOLOGY

Sarcoma imaging is a challenging and at times daunting task for the radiologist. There are a myriad of differing tumors that occur throughout the musculoskeletal system and the imaging appearances of the benign and malignant tumors have extensive overlap. The radiologist plays a crucial role in the multidisciplinary care of a patient with sarcoma. In this section, we will discuss the imaging modalities, imaging strategies and the various tasks of the radiologist in caring for sarcoma patients.

The radiologist fulfills multiple roles in the care of sarcoma patients. At some institutions, the diagnostic or interventional radiologist may acquire the tissue for diagnosis by performing imaging guided percutaneous needle biopsy of a lesion. This should always be done after conferring with the sarcoma surgeon to assure that an appropriate biopsy route is used. There is a potential for tumor seeding of the needle tract and many surgeons will actually excise the needle tract to assure local tumor control. An error in biopsy route could potentially prevent limb salvage surgery resulting instead in unnecessary amputation. Also, the physician performing the biopsy should carefully consider the target area within a tumor. The non-enhancing portion of a tumor could represent matrix or necrotic material and may not yield diagnostic tissue for the pathologist. Some tumors have large feeding or draining vessels, these should be avoided to minimize potential hemorrhage risk. Depending on the vessels and surgical setting, interventional radiologist at some institutions will provide preoperative embolization of tumors to mitigate surgical blood loss.

Diagnostically, the radiologist has a difficult and often humbling task in sarcoma imaging. The referral environment of a given case affects the radiologist's role. In the United States, a primary care provider ordering, say an MR exam of a new palpable mass may be a physician assistant, nurse practitioner or a physician. Each may work in relative isolation or may have ready access to specialist consultation. The radiologist must be responsive to these differing practice situations to be optimally helpful to the patient. Our recommendations to 'follow up' or 'correlate clinically' may be pointless without detailed instructions. As a radiologist, we need to specify the imaging modality to be used and time frame for follow up. Also, we must specify what exactly is to be clinically correlated. Typically, masses that are painful or enlarging are much more ominous for malignancy, and we should be explicit about these symptoms and history being important for correct interpretation of the imaging study. Best is for the radiologist to contact the referring provider to discuss the findings and specific next steps. Of course, if the referring provider is a sarcoma specialist, then such detailed instructions are likely superfluous.

As for diagnostic interpretation, the radiologist should provide basic information such as tumor size, location and effect on adjacent structures. Generally speaking the larger a tumor, the greater the risk of malignancy and the greater the risk a given malignancy has already metastasized. The radiologist should be precise in their description of location within a given bone; diaphysis, metaphysis or epiphysis as well as intramedullary, eccentric or cortical. Measuring the lesion's distance from an easily identifiable landmark, such as a joint line, can

aid others in locating the lesion at time of surgery or biopsy or when correlating findings with other imaging modalities. Likewise, the location of a soft tissue tumor in a given compartment and its proximity or invasion of vital structures such as nerve and vessels is crucial for treatment planning. Surgical planning may change depending on the tumor's effect on adjacent structures such as the presence of neural foraminal encroachment or bowel involvement.

The tumor's effect on adjacent structures may reveal its chronicity and aggressiveness. A tumor may show pressure-like 'erosion' of bone where the surface of the cortex remains smooth and intact with minimal or no thinning of the cortex. This absence of invasion suggesting the lesion is long standing and likely benign. A non-aggressive lesion may appear to 'push' or displace adjacent muscle and vessels as opposed to invading or encasing them. Aggressive tumors usually show frank invasion and actual destruction of adjacent soft tissues. However, early in a tumor's course, invasion may occur focally and the radiologist must analyze the entire tumor's margin carefully.

Radiologists often interpret non-enhancing portions of the tumor as necrotic tissue. This is generally true for other tumors, say in the liver or brain, but with sarcomas, the non-enhancing tissue may represent viable hypovascular tissue such as matrix or fibrous tissue. Additionally, sarcomas may have non-enhancing portions due to cystic or gelatinous areas without necrosis, or they may have spontaneous hemorrhage with accumulated blood degradation products. The distinction from necrosis is important because tumors with more necrotic areas tend to be higher grade with more aggressive behavior and poorer prognosis. Unfortunately, correct identification of sarcoma necrosis is difficult with any imaging modality. Dynamic enhancement MR imaging may prove to be useful to distinguish sarcoma necrosis and may be an important field for future research. Furthermore, on follow up imaging, radiologists tend to interpret the development of non-enhancing portions of a tumor as indicative of positive response to radiation or chemotherapy. This conclusion may not be true for sarcoma and the care team must be guarded in their optimism about new areas without enhancement.

A central diagnostic task for the radiologist is the assessment of a tumor's aggressiveness. In general, a homogeneous soft tissue mass without enhancement, destructive features or adjacent reactive changes is less worrisome for malignancy and the radiologist can report the tumor as 'non-aggressive'. Since the imaging appearance cannot render a definitive histologic diagnosis, the radiologist should refrain from reporting such a non-aggressive tumor as 'benign'. Even a non-aggressive appearing tumor could represent an indolent malignancy. Regardless of this fundamental uncertainty, the radiologist's non-aggressive label can reassure the patient and referring doctors that a conservative approach may be reasonable. Conservative management may simply involve monitoring the tumor size over time with physical exam or imaging studies. The interval for surveillance is based on judgment and experience. There are patient factors relevant to this decision. If the patient is a competent individual and an excellent historian, then one might be confident with a long surveillance interval of say, 1 year. On the other hand, many patients in reality are not sure when their mass developed. Often there are associated symptoms

such as pain; however the etiology of the pain is uncertain because there may be an adjacent arthritic joint or recent injury compounding the clinical setting. This common confusing clinical situation may undermine confidence in conservative management pushing the care team to pursue immediate tissue diagnosis or at least a shorter interval for imaging surveillance. The radiologist must avoid allowing imaging intervals less than 3 months as tumors usually won't have changed significantly. Rendering an interpretation that a tumor is stable during a 1 or 2 month interval may be falsely reassuring to the patient and referring team.

Occasionally, we encounter a case that proves to be a cyst on imaging. The radiologist must exercise discipline in diagnosing a cyst which should have no enhancement, no nodularity, minimal if any septation and must show fluid characteristics on the imaging study. Each imaging modality has a distinct strategy for correctly identifying fluid and a fastidious approach is necessary to avoid errantly diagnosing a featureless solid tumor as a cyst. Cysts of the musculoskeletal system are relatively rare and can be seen from remote prior injury with resulting seroma. An adventitial bursa can form de novo from repetitive mechanical irritation of a site. Usually, a referral for possible cyst will actually reveal a lymph node or solid mass that requires further workup or, at least follow up to establish stability. The radiologist must avoid the pitfall of a fluid collection that is actually a cyst dissecting from elsewhere such as a Baker's cyst of the knee extending into the calf, or a paralabral or parameniscal cyst extending away from the joint. As always the radiologist must be wary of an unusual bowel hernia or vascular lesion such as an aneurysm accounting for the clinically suspected 'cyst.'

Finding a tumor with aggressive features such as heterogeneity, hemorrhage, enhancement, invasion or destruction of adjacent tissues, the radiologist can report a worrisome or aggressive tumor and recommend referral to a sarcoma surgeon. However, even an aggressive appearing lesion may be benign as abscess and hematoma can look similar to a sarcoma. If the clinical setting strongly supports the diagnosis of hematoma or abscess, then appropriate conservative management can be initiated. At our institution we recommend follow up to document complete resolution. Depending on the specific case, adequate follow up may simply entail physical exam alone or may require imaging if the lesion is deep seated. The underlying concern is a sarcoma can have hemorrhage and/or hematoma which may obscure the underlying true pathology. Furthermore, the hematoma could conceivably become secondarily infected and develop an abscess. It is important to perform the follow up imaging after complete clinical resolution has occurred or else the imaging study will simply show a resolving process and an underlying occult neoplasm will not yet be excludable without another follow up imaging exam.

When faced with the numerous tumors that have non-specific and overlapping appearances, the radiologist may become inured to their diagnostic task. But we must not surrender our efforts to find the subtle or unique features that may enable a more specific diagnosis. Patient age and tumor location alone can often generate a useful differential diagnosis for bone tumors. Occasionally, we can discern a specific tumor matrix such as cartilage, fibrous or bone tissue that can narrow the differential diagnosis significantly. Soft tissue tumors are generally more difficult to diagnose specifically. However, there may be identifiable tissues such as fat, calcification or hemorrhage that can help narrow the diagnosis. Likewise, there may be an association with a nerve or vessel that can aid in diagnosis.

In the follow up phase of sarcoma patient care, the radiologist must image the location of tumor origin for recurrence and search for distant metastasis. Generally, the lung is the most common site

for sarcoma metastasis, with marrow and liver being less common and regional adenopathy being an unusual site of metastasis. The typical imaging surveillance interval is 6 months. However, if there is greater clinical concern due to high tumor grade or tumor involvement of surgical margins, a 3-month interval is sometimes employed. Generally, the chest is imaged with contrast enhanced CT to assess for lung metastasis. The bone or soft tissue compartment of origin is imaged with contrast enhanced MRI. The radiologist must assure that the entire bone or soft tissue compartment is included in the exam. Recurrences usually occur at the original tumor site, but can occur anywhere within the surgical bed or compartment. To facilitate adequate imaging coverage and interpretation, we have surface imaging markers placed on any palpable lesion, as well as, at the proximal and distal ends of the surgical scar. Ideally, the MR exams should be performed with the identical imaging sequences, slice thickness and field of view to minimize inter-exam variation and foster accuracy in assessing the stability of a lesion or evolution of post-operative change. PET imaging is rarely utilized for sarcoma imaging due to the variable and unreliable uptake by these tumors and their metastasis. Overall, patient care is best optimized by a thoughtful and dedicated radiologist who can work well with the sarcoma team of care givers.

■ FUTURE DIRECTIONS OF SARCOMA IMAGING

The future of sarcoma imaging will likely gain in specificity as more sophisticated imaging technology develops. Molecular imaging based on tissue specific or even tumor specific markers may improve diagnostic accuracy and increase the sensitivity and specificity of surveillance imaging.

Dynamic enhanced imaging techniques may better characterize tumor vascularity. This is currently employed with breast MR imaging where a graph showing the speed of contrast wash in and wash out from a tumor has proven to be useful to distinguish benign from malignant breast lesion. A similar graph of dynamic MR enhancement may help distinguish benign from malignant soft tissue tumor, and may allow imaging assessment of tumor grade. Furthermore, changes in a tumor's dynamic enhancement may indicate response to radiation or chemotherapy in the neoadjuvant treatment setting.

Another avenue of future sarcoma imaging research may lie in the mathematical modeling and study of the imaging data set. Cross sectional imaging provides three dimensional imaging data of a tumor which could provide the basis for applying mathematical interrogation techniques of a tumor for specific objective features. Vittorio Cristini has performed mathematical modeling of the surface of brain tumors showing correlation with tumor grade and invasiveness (Bearer 2009). In the setting of sarcoma, there are two potential surfaces of interest. The outer surface of a sarcoma interfaces with normal host tissue and its features may correlate with invasive potential. Additionally, sarcomas often are quite heterogeneous internally and hence, have other tissue interfaces that may be of interest, such as between enhancing and non-enhancing areas. Such an internal interface may represent a boundary between matrix producing portions and cellular portions of the tumor.

A different avenue for mathematical modeling would be to study the voxel to voxel (VTV) heterogeneity of a tumor. MR imaging is capable of demonstrating tissue based on different molecular features (i.e. T1 or T2 relaxation, enhancement, diffusion, etc.). For instance, the study of a tumor's T2 relaxation heterogeneity may prove to correlate with differences in intercellular water or may indicate

differences in cellular density. Presumably, high grade tumors would show greater VTV heterogeneity, say on T2 images, and this may correlate with the presence of multiple cell lines. Or, there may be high VTV on post contrast images which might correlate with high levels of neo-angiogenesis and greater metastatic potential.

INFORMATION FOR MEDICAL STUDENTS AND RESIDENTS

Sarcoma imaging is a subspecialty of musculoskeletal diagnostic radiology. Those interested in the field would typically complete a diagnostic radiology residency and then a fellowship in musculoskeletal imaging. As sarcomas are relatively rare, it can take considerable time to acquire relevant experience and large referral centers would offer an educational advantage to an interested student.

RADIOGRAPHS

It may seem surprising that in the age of cross sectional imaging the simple plain radiograph remains the imaging cornerstone of diagnosis in bone tumors. The radiograph is easy and inexpensive to acquire yet usually shows fundamental features such as location, matrix and aggressiveness. The radiograph in fact is often the best overall depiction of a tumor's aggressiveness by showing its zone of transition, periosteal reaction and bone destruction.

As described above, an indolent lesion may cause thinning of the overlying cortex presumably from pressure of the slow growing lesion against the cortex resulting in bone remodeling. A more aggressive lesion would have destroyed the cortex and created frayed lesion margins. Pressure erosion can create a gently scalloped appearance to the thinned cortex. **Figure 2.1** shows an enchondroma of the finger with scalloped thinning of the cortex but no breakthrough and no fraying of bone.

Aggressive lesions cause bone destruction which appears as cortical erosion or trabecular loss. Generally, any loss of cortex is worrisome and may indicate a destructive or aggressive process.



Figure 2.1 Enchondroma. Anteroposterior radiograph of the hand showing a lucent mildly expansile lesion of the 5th metacarpal. There is a non-displaced pathologic fracture. There is no identifiable matrix. Note the endosteal scalloping and smooth cortical thinning. This is a typical appearance of an enchondroma in the hand, these typically do not have calcified matrix.

However, cortical erosion is not specific and can be seen with infection, rheumatologic disease, metabolic disease such as hyperparathyroidism and neoplastic process. Active cortical erosion will have indistinct margins that look frayed or will appear as if the bone is melting. **Figure 2.2** shows active erosive destruction of the plantar calcaneus in a patient with Reiter's (Reactive) arthropathy. Note how the bone appears to be melting away resulting in an indistinct and fuzzy margin. **Figure 2.3** shows a patient with psoriatic arthropathy who has both active and healed appearing erosions of the interphalangeal joints. All of the erosions show loss of bone, however, the active erosions have the indistinct edges while the healed erosions show white cortical bone margin.



Figure 2.2 Reiter's disease erosion. Lateral radiograph of the heel in a 64 year old man with Reiter's (reactive) arthropathy. There is active erosion of bone along the plantar aspect of the calcaneus, arrows. Note how active erosion appears to melt the bone away.



Figure 2.3 Psoriatic arthropathy. Close up of an anteroposterior view of the fingers in a 75 year old woman. There are active erosions shown by the small arrows. The active erosions show indistinct margins. The large arrows indicate healed or quiescent erosions which have corticated, smooth margins.

Cortical erosion can involve the outer surface or the endosteal surface of the cortex. Bone destruction can involve a broad area, as seen in a large osteosarcoma or may be focal as seen with a portion of an enchondroma that has dedifferentiated into a chondrosarcoma, see **Figure 2.4**. Loss of trabeculae can be a subtle finding only visible as decreased density, loss of trabecular crispness or an area with homogeneous, featureless appearance. **Figure 2.5** shows an osteosarcoma causing trabecular destruction and loss of density along the lateral femoral metaphysis. Frank bone destruction can result in a permeative pattern as seen in **Figure 2.6**. This highly aggressive bone destruction gives the appearance that the bone is melting away. **Figure 2.7** shows numerous lytic defects of the skull which has been termed; 'moth-eaten' pattern or the 'pepper pot' pattern of bone destruction classically seen in multiple myeloma.

The zone of transition is a geometric concept that describes the shortest distance between a point that is entirely in normal bone and a point that is entirely inside the lesion. A wide zone of transition indicates invasive margins of an aggressive lesion. **Figure 2.8** shows a metastasis with permeative destruction of the femoral diaphysis and a wide zone of transition. On the other hand, a narrow zone of transition indicates an indolent lesion with normal, healthy bone abutting the surface of the lesion. The extreme example of a narrow zone of

transition is a sclerotic boarder indicating there has been prolonged period of lesion stability allowing normal bone to form a corticated boarder successfully containing the lesion. **Figure 2.9** shows a non-ossifying fibroma with a sclerotic margin of uniform thickness. There is also a pathologic fracture of the medial cortex.

Periosteal reaction is a sign of bone inflammation and healing. Initially, periosteal reaction is lucent and with time ossifies and becomes dense, eventually remodeling into a thickened cortex. Laminated periosteal reaction (**Fig. 2.10**) may form if there is a rapid or stuttering course of disease causing layers of healing, alternating



Figure 2.4 Grade 3 chondrosarcoma.

Close up of an anteroposterior radiograph of the proximal femur. The arrows indicate a focus of endosteal erosion. The chondrosarcoma was very large involving the entire proximal femur yet only this small focus of tumor was destroying cortex.



Figure 2.5 Osteosarcoma.

Anteroposterior radiograph of the distal femur shows subtle loss of bone density in the lateral aspect of the metaphysis indicating a lesion destroying trabeculae. The cortex appears intact and no soft tissue mass is yet evident.



Figure 2.6 Metastasis.

Anteroposterior radiograph of the humerus in a patient with small cell cancer of unknown primary. There is permeative destruction of bone with frayed erosion of the endosteal surface. This is a highly aggressive lesion and pathologic fracture is likely imminent. The lesion margins are indistinct and it is difficult to discern where the lesion ends and normal bone resumes. This indicates a wide zone of transition, another hallmark of an aggressive lesion.



Figure 2.7 Multiple myeloma. Lateral radiograph of the skull shows numerous lytic lesions. This has been termed 'moth-eaten' or 'pepper pot' appearance indicating aggressive bone destruction. Although this is classic appearance for multiple myeloma, conceivably metastatic disease could look similar.



Figure 2.8 Metastasis. Anteroposterior radiograph of the femur shows a metastasis with permeative destruction with a pathologic fracture. There is a wide zone of transition which spans between the arrows.



Figure 2.9 Non-ossifying fibroma. Anteroposterior radiograph of the distal femur shows a lucent lesion with uniform thickness undulating sclerotic margins. There is a medial pathologic fracture. The sclerotic margin indicates a non-aggressive lesion with a stable margin.

with overlying layers of new periosteal reaction. In general, continuous smooth periosteal reaction is seen with benign processes such as infection and fracture healing. Discontinuous periosteal reaction is worrisome for underlying neoplasm where the tumor has destroyed both the bone cortex and its overlying periosteum and then spread into the soft tissues. The discontinuous periosteal reaction can result in the Codman triangle sign **Figure 2.11**. The triangle represents the remaining periosteal reaction that is not destroyed by the tumor. Highly aggressive periosteal reaction will have a sunburst or 'hair on end' appearance due to tumor streaming through the periosteal reaction resulting in thin columns of mineralized tissue that are oriented perpendicular to the bone surface. **Figure 2.12** and **2.13** are radiographs of osteosarcomas and a Ewing sarcoma, respectively, showing highly aggressive periosteal reaction with the hair-on-end or starburst appearance. There are three types of bone tumor matrix including fibrous, cartilaginous and osteoid. A radiograph can usually demonstrate the matrix type. **Figure 2.14** shows the ground glass appearance of fibrous matrix as seen in an 11 year old boy with fibrous



Figure 2.10 Ewing sarcoma. Lateral radiograph of the forearm in a 3 year old boy. There is laminated periosteal reaction along several areas of the radial diaphysis. The laminated periosteal reaction probably results from a stuttering disease course with alternating layers of healing. Although this is malignant periosteal reaction, it is not as aggressive as the sunburst or hair-on-end pattern of periosteal reaction.

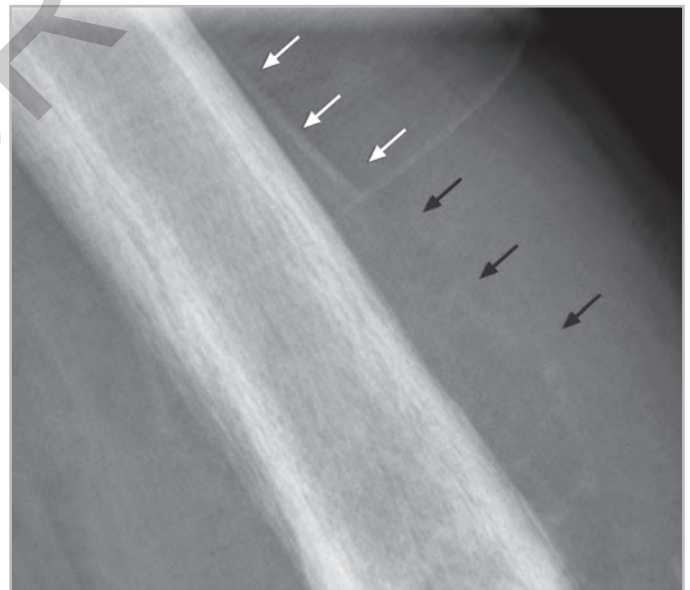


Figure 2.11 Osteosarcoma. Lateral radiograph of the distal femur shows a Codman triangle, white arrows, of preserved periosteal reaction. The black arrows indicate where the tumor has destroyed the periosteal reaction. The Codman triangle indicates a highly aggressive lesion.

dysplasia. Note the homogeneous, featureless appearance of fibrous matrix. A cystic lesion can have a similar featureless appearance due to the absence of trabeculae. **Figure 2.15** shows the arc and ring pattern of calcification seen in an enchondroma of the proximal humerus in a young adult. The arcs represent a partially calcified ring or a partially visualized ring. Note the rings tend to be 2-4 mm in diameter. **Figure 2.16a** is another case of an enchondroma with arc and ring calcification pattern involving the distal femur. **Figures 2.16b** and **2.16c** are



Figure 2.12 Osteosarcoma. Lateral radiograph of the distal femur shows the sunburst or hair-on-end pattern of periosteal reaction. This indicates a highly aggressive lesion with soft tissue extension of tumor. There are areas of calcified osteoid projecting within the marrow of the distal metaphysis.



Figure 2.13 Ewing sarcoma. Anteroposterior radiograph of the proximal tibia in a 7-year-old girl shows the sunburst or hair-on-end pattern of highly aggressive periosteal reaction. There is laminated periosteal reaction along the medial aspect of the tibial diaphysis. The cortex is destroyed along the proximal lateral aspect of the tibial metaphysis.



Figure 2.14 Fibrous dysplasia. Anteroposterior radiograph of the distal radius in an 11-year-old boy shows a mildly expansile lucent lesion with endosteal smooth scalloping. The lesion has ground glass density matrix indicating fibrous tissue.

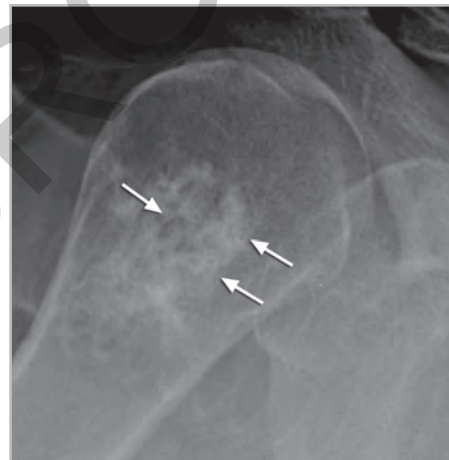


Figure 2.15 Enchondroma. Anteroposterior radiograph of the proximal humerus shows calcified arc and ring matrix pattern, arrows, characteristic of a cartilage lesion. Note the individual rings are approximately 2-4 mm in diameter.

the accompanying MR images. Note the spherical lobules of cartilage tissue which again are about 2-4 mm in size. Some have described these as popcorn in appearance. The MR appearance is quite variable in signal as some lobules are calcified resulting in low signal on all MR sequences. **Figure 2.17** shows osteoid matrix from a healing fracture that is 2 months status post open reduction and internal fixation (ORIF). Note the fluffy yet homogeneously calcified appearance of this new bone. **Figure 2.18** shows the osteoid formation from calcifying heterotopic ossification 23 days after ORIF. **Figure 2.19a** and **2.19b** are radiographs from an osteosarcoma in the proximal tibia of a 13-year-old boy. Note the extensive periosteal reaction and the abundant calcifying osteoid. The diagnosis of osteosarcoma is straight forward when there is a clearly destructive malignancy producing osteoid.

ULTRASOUND

Although ultrasound plays a dominant role in clinical areas such as obstetrics, it has only a limited role in the imaging of soft tissue tumors

of the musculoskeletal system. Ultrasound can definitively diagnose fluid and hence can be used to correctly identify a cyst. However, in our experience, a cyst is rarely the cause of a patient's soft tissue mass. Many of the palpable lesions felt by patients are tumors of the skin and likely are lipomas or prominent lobules of subcutaneous adipose tissue. Ultrasound is not specific for diagnosing fat tissue and no imaging modality can definitively exclude malignant histology. At our institution we find ultrasound is of little value in the initial workup of soft tissue tumor, except when hernia or aneurysm is suspected.

COMPUTED TOMOGRAPHY

CT scanning is a fast and robust imaging modality that uses a rotating beam of radiation to create two dimensional image 'slices' of a patient. Helical (spiral) scanning entails continuous movement of the patient through the scanner with simultaneous continuous rotation of the radiation beam around the patient. This allows for faster scanning and better reconstruction of images into other planes (coronal and

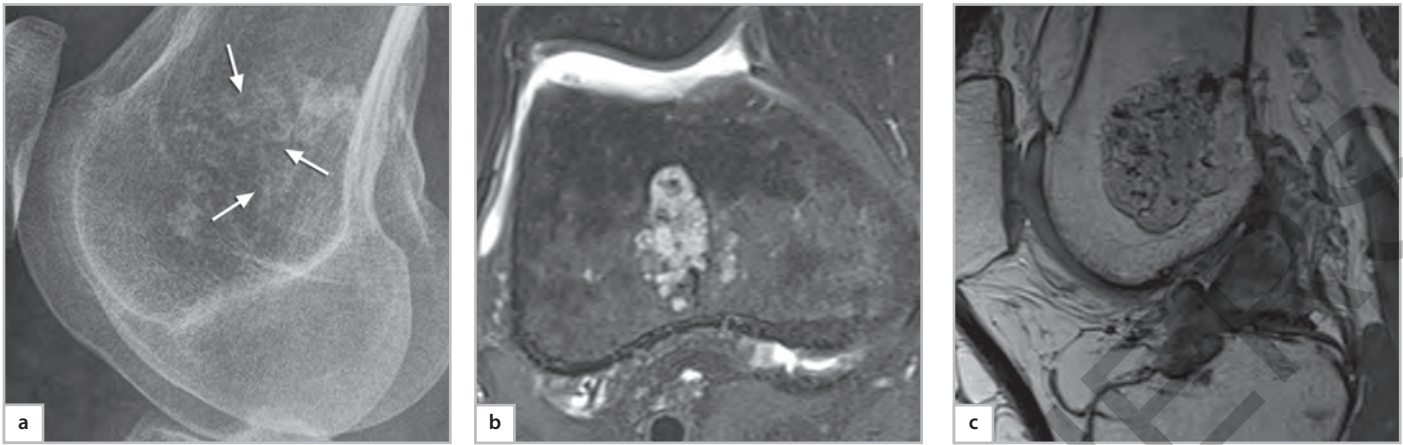


Figure 2.16 Enchondroma. 2.16a is a lateral radiograph of the distal femur shows calcified arc and ring matrix pattern, arrows, indicating a cartilage lesion. MR Figures are presented of the same lesion including; 2.16b axial proton density fat saturated and 2.16c sagittal proton density Figures. Cartilage matrix has a lobulated appearance some have described as emulating popcorn. The signal of cartilage lesions is highly variable depending on the extent of calcification. Uncalcified cartilage will appear T1 isointense and high signal on T2 and STIR Figures similar to the appearance of water on MRI. The calcified portions will be low signal on all sequences and may show blooming on T2 Figures, especially T2* gradient echo Figures. Note again the individual lobules are about 2-4 mm in size correlating with the size of the arcs and rings as seen by radiographs.



Figure 2.17 Healing fracture.

Anteroposterior radiograph of the leg after open reduction and internal fixation (ORIF) of the tibial fracture 2 months prior shows healing osteoid bridging the fractures. Calcifying osteoid has a homogeneous, cloud like appearance.

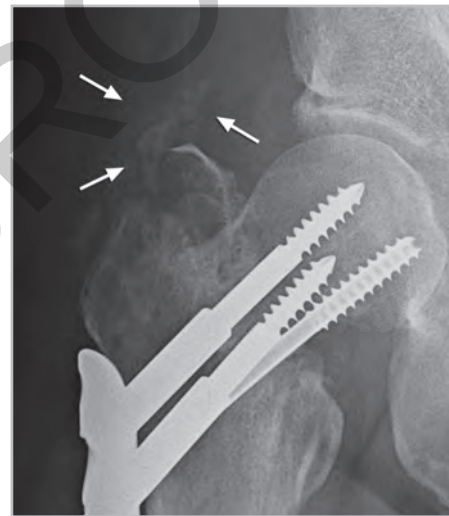


Figure 2.18 Heterotopic ossification.

Anteroposterior radiograph of the hip in a patient with ORIF 23 days prior. There is calcifying osteoid developing in the soft tissues adjacent to the fracture and surgery, arrows. Note the cloud like appearance of this mildly calcified, immature osteoid. With time, the osteoid will ossify developing internal trabeculae of cancellous bone and a corticated surface.

sagittal). Also, modern scanners have multiple detectors (16 slice, 64 slice, etc.) which enable both thinner slices and greater speed of coverage. A standard CT scanning technique (1-3 mm slice thickness) with reformations in the sagittal and coronal planes is a sufficient exam protocol for most cases. CT contrast contains iodine and is rapidly excreted into the urine. Because iodine contrast agents are potentially nephrotoxic, renal insufficiency is a relative contraindication. There is an occasional patient who is allergic to iodine contrast, rarely is the reaction severe or fatal. Patients with prior reaction must be premedicated with steroid and anti-histamine. At our institution, IV contrast is not usually given for CT scan of an extremity tumor because

we typically already have an MRI with contrast to assess vascularity and tumor enhancement. Occasionally, high resolution CT scanning is needed (sub 1 mm slices) to assess a lesion, for example, a small suspected enchondroma in the finger, and the radiologist may protocol especially thin slices with higher beam strength (higher mA setting) to decrease imaging noise.

CT can play an important role in the initial diagnosis of a bone tumor in certain situations. If radiography is equivocal regarding cortical erosion or breakthrough, CT can provide definitive visualization of cortical integrity and the fine detail that allows determination if an erosion is active or healing. Additionally, CT can offer improved visualization of matrix type when radiographs do not definitively demonstrate the presence or the type of matrix.

CT plays a central role in the systemic surveillance of the patient for metastatic disease, especially for disease spread to the lung. CT is also valuable for surveillance of retroperitoneal tumors. However, typically, MR is used to image the extremities for follow up, and occasionally,

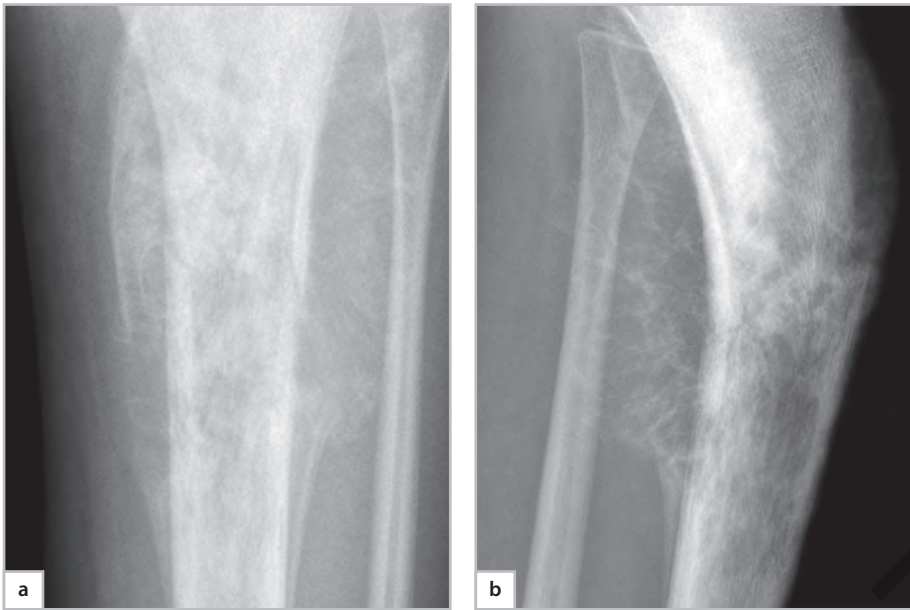


Figure 2.19 Osteosarcoma. 2.19a is an anteroposterior and 2.19b is a lateral radiograph of the proximal tibia in a 13 year old boy. There is soft tissue mass with areas of calcifying osteoid indicating an osteosarcoma. There is a Codman triangle of periosteal reaction along the distal aspect of the tumor as seen on the AP view. There is a pathologic fracture of the tibia. There are areas of densely calcified osteoid projecting within the proximal tibial marrow space best seen on the lateral view.

CT may be employed if there is extensive metallic hardware causing limiting artifact on MR. Any heavy density material, such as metal or barium will attenuate the CT scan beam and may cause spray artifact affecting the slices that go through the dense material. Hence, extensive metallic hardware may render an area uninterpretable on both CT and MR imaging.

MAGNETIC RESONANCE IMAGING

MR imaging is the dominant imaging modality for soft tissue tumors and sarcoma evaluation and follow up. The soft tissue contrast and multiplanar imaging capability make MR an invaluable imaging tool. Medical MRI is based on the imaging of protons whose appearance depends on their molecular environment. Thus MR can identify fat, water and edematous tissue. To a lesser extent, MRI can identify hemorrhage, protein and mineral (calcium). Air and metal will be devoid of signal and actually disturbs the magnetic environment often ruining visualization in the immediate surrounding environment. With the injection of intravenous gadolinium contrast, tissues brighten as demonstrated on T1 weighted images which indicate high vascularity, pooling of blood or leakage of the contrast from the intravascular environment into the interstitial tissue space. The main MR contrast agents use chelated gadolinium which is excreted by the kidneys, but is not nephrotoxic. Allergies to gadolinium contrast are rare. There is a relative contraindication against gadolinium contrast agents in patient with renal insufficiency due to the rare association of nephrogenic systemic fibrosis.

There are a number of technical considerations that effect sarcoma MR imaging. In the US, most scanners are 1.5 tesla field strength and serve well for sarcoma imaging. For the obese or claustrophobic

patient, a so called 'open' MR scanner may need to be utilized. These scanners have a more open architecture to accommodate patients but have lower field strength resulting in generally lesser imaging quality. The radiologist can attempt to design sequences to mitigate this loss of image quality, never the less; the exam will typically take longer and have lesser image quality on a low field scanner.

The proper imaging coil must be chosen to provide adequate coverage of the tumor and its compartment. Generally, the smallest coil to cover the region of clinical interest should be used to optimize signal. Some coils give poor image homogeneity in tissues close to the coil. This can compromise visualization of the skin and superficial structures when using some surface or flex coils. The radiologist must be familiar with their imaging equipment to best optimize studies of sarcoma patients.

The radiologist should carefully design the imaging sequences to obtain maximum tissue information and anatomy in the least possible time. Patient motion related image degradation is a constant problem and the radiologist must design imaging protocols that are time efficient. Each MR sequence typically take 2-5 minutes to perform and requires the patient hold absolutely still for the entire imaging sequence. Any movement during the sequence results in motion blurring of all slices in that sequence. There is no way to repeat a single MR image slice (as one can do with CT scanning). If there is motion, the entire sequence must be redone. Unfortunately, many patients believe they can hold still, perhaps imagining reading a book while sitting on the couch. However, for many patients, lying flat on their back in a noisy scanner, results in back pain, restless legs and pressure points. The technologist plays a crucial role in achieving patient comfort before the exam by thoughtfully placing pillows, towels and sponges to position the patient comfortably and hopefully minimize motion.

For the initial tumor MR imaging study, T1, T2, fluid sensitive, and matching pre and post contrast T1 weighted fat saturated sequences should be performed. Although not specific, tissue enhancement has significant implications. The absence of enhancement is the cornerstone of fluid diagnosis with MR imaging. Without intravenous contrast, the definitive diagnosis of cyst cannot be made with MRI.

NOTE ON MRI TERMINOLOGY

For the sake of brevity, we will omit stating 'weighted' when describing a T1 weighted or T2 weighted sequence. The weighting of an image is an important concept for those wanting to design or understand chemical and physics basis of MR sequences.

In general, enhancing tissue indicates a solid lesion with viable tissue. Whereas, a non-enhancing portion of a tumor may represent hypovascular or avascular tissue such as fibrous tissue, matrix, fluid or necrosis. In the follow up setting, new areas of non-enhancement may indicate ongoing matrix formation or may indicate new necrosis from successful therapy. It is important for pre and post contrast images to be created with identical sequences parameters (same slice, field of view, matrix, TR (repetition time), TE (echo time), shim, bandwidth etc.) so that subtle enhancement can be correctly identified. Ideally, all three imaging planes are obtained on the exam; however, often two imaging planes are sufficient for interpretation.

A fluid sensitive sequence refers to an image where adipose tissues appear low signal (dark or black) and water or edematous tissues appear high signal (bright or white). The radiologist can employ different fluid sensitive sequences including; T2 fat saturated or short T1 inversion recovery (STIR) sequences. STIR has the advantage of providing uniform decrease in fat signal when field homogeneity is compromised. Hence, STIR sequence should generally be used for large fields of view and when there is metallic hardware or a foreign body that limits homogeneity. The STIR sequences requires slightly more time and will have slightly less image quality than a comparable T2 fat saturated sequence but the clinical robustness of STIR sequences is invaluable.

Generally, we use a 10% gap between slices. Only if there is a small tumor do we utilize intercalated slices with no interslice gap. Since soft

tissue tumors tend to be large, thin slice imaging is not emphasized. Instead coverage is paramount so the exam does not miss a skip lesion or area of tumor spread.

Ideally, the initial MR exam would include T1, T2, STIR and enhancement information on a tumor. The radiologist has then performed an 'imaging biopsy' of the lesion (Table 2.2). This full palate of MR sequences can tell the radiologist about the nature of tissue in the tumor. The T2 sequence can be sacrificed on follow up studies when the purpose of imaging shifts to recurrence detection and not tumor diagnosis. Of note, T2 fast spin echo sequences tend to show fat as moderately high signal whereas conventional spin echo T2 sequence will show fat as moderately low signal. In most practices, fast spin echo sequences have virtually replaced conventional spin echo due to the substantially shortened sequence time.

There is extensive overlap in sarcoma appearance on MRI. The majorities of sarcomas have heterogeneous isointense or low signal on T1 with heterogeneous high signal on T2 and STIR sequences. Most sarcomas enhance intensely and heterogeneously. The utility of MR lies in its exquisite ability to show location, spread and adjacent structure involvement. The MR exam can have some tissue specificity, like a biopsy, and can identify fat tissue, viable tissue, water, edema and hemorrhage. There are some imaging appearances of tumors on MR that can be helpful in diagnosis but these are discussed in each tumor subsection but the radiologist is cautioned that specificity is often modest.

Table 2.1 Typical MR protocol for imaging an extremity tumor

	Plane	Weighting	Coverage	Slice
1	Coronal	T1	Joint to joint	5-8 mm
2	Coronal	STIR, T2 fat sat	Joint to joint	5-8 mm
3	Axial	T1 fat sat	Tumor	5-15 mm
4	Axial - optional	T2	Tumor	5-15 mm
5	Axial	STIR, T2 fat sat	Tumor	5-15 mm
6	Axial post	T1 fat sat	Tumor	5-15 mm
7	Sagittal post	T1 fat sat	Joint to joint	5-8 mm

Table 2.2 Imaging biopsy: signal characteristics of various tissues

T1	T2	STIR	Enhances	Tissue type
+	I/-	-	V	Fat
-	-	-	-/V	Fibrous
-	+	+	-	Water, edema
+	+	V	-	Proteinaceous fluid
I	I/+	V/+	+/V	Tumor tissue
-	B	-	-	Hemosiderin, Ca++

+ High signal (White); - Low signal (Black); V Variable; I Isointense signal (grey, similar to normal muscle); B Blooms - a low signal area on T1 becomes larger on T2. This effect is most pronounced on T2* gradient echo sequences.

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