



Dorothy Fox. *Mt. Porzio Couple*. Watercolor, 28" × 36".

Advances in imaging techniques have markedly improved the diagnostic efficacy of evaluating soft tissue masses.

Diagnostic Imaging Update: Soft Tissue Sarcomas

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Background: No single imaging approach is ideal for every tumor. While radiography can be effective for diagnosis of specific tumors, additional imaging is often required. Soft tissue sarcomas require a multimodality approach.

Methods: The authors discuss the general imaging approaches for patients who present with soft tissue masses, the fundamental principles inherent to tumor imaging, and the specific applications of newer imaging modalities.

Results: Magnetic resonance imaging has emerged as the preferred technique for evaluating soft tissue tumors but is limited in demonstrating the pattern of soft tissue calcification. Computed tomography is the best modality for evaluating osseous architecture and for patients who cannot be evaluated with MRI. PET is helpful in metabolic imaging, and ultrasonography is useful in differentiating cystic from solid masses. Magnetic resonance angiography accurately reveals the arterial and venous supply of vascular tumors.

Conclusions: Current imaging techniques provide numerous noninvasive methods to diagnose and stage suspected soft tissue sarcomas.

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Abbreviations used in this paper: MRI = magnetic resonance imaging, CT = computed tomography, PET = positron emission tomography, US = ultrasonography, MRA = magnetic resonance angiography.

Introduction

Soft tissue sarcomas are rare cancers. The American Cancer Society estimates that in 2004, approximately 8,680 new soft tissue sarcomas will be diagnosed in the United States.¹ Of these, 3,660 Americans are expected to die of their disease. While malignant soft tissue tumors are rare, benign tumors are not; it is estimated that there are 100 benign lesions for each sarcoma.²

The radiologic evaluation of a suspected soft tissue mass has changed dramatically with the advent of computer-assisted imaging. The currently available imaging modalities offer numerous noninvasive methods to diagnose and stage suspected soft tissue sarcomas. This article highlights the general imaging approach to patients presenting with soft tissue masses. It is not intended as a comprehensive review, but rather as an overview,

emphasizing the fundamental principles inherent to tumor imaging and the specific applications of the newer imaging modalities.

Initial Evaluation

Imaging of soft tissue sarcomas requires a multimodality approach, with no single imaging modality being ideal for every tumor. The diagnostic evaluation should begin with radiographs of the mass or region in question. Although radiographs are frequently unrewarding, they can provide invaluable information when positive. Radiographs may reveal skeletal deformity that can masquerade as a soft tissue mass or soft tissue mineralization that may be suggestive, and at times characteristic, of a specific diagnosis. For example, they may reveal the phleboliths within a heman-

gioma, the osteocartilaginous masses of synovial osteochondromatosis, or the peripherally more mature ossification of myositis ossificans. Radiographs can also provide an excellent method for assessment of osseous involvement by a soft tissue tumor, such as remodeling, periosteal reaction, or overt destruction.

Additional Imaging Modalities

While radiographs may be sufficient for diagnosis of specific tumors such as intramuscular cavernous hemangioma or myositis ossificans, additional imaging is often required. Further imaging may be needed for diagnosis in order to determine the true local extent of a lesion, evaluate its relationship to adjacent structures, and stage suspected malignancy. While magnetic resonance imaging (MRI) is usually considered first for further evaluation of a soft tissue mass, additional available modalities include computed tomography (CT), positron emission tomography (PET), ultrasonography (US), and magnetic resonance angiography (MRA).

Magnetic Resonance Imaging

MRI can provide information for both diagnosis and staging and thus has emerged as the preferred modality for evaluating soft tissue tumors. MRI is ideally suited for this given its multiplanar capability and its ability to accurately assess both the bones and soft tissues. Improved gradient strength and speed, coupled with specialized coils that provide increased signal-to-noise ratios, have markedly improved image quality (Figs 1 and 2). These advances are especially notable in cases where a small field of view imaging is required. While MRI accurately elucidates the anatomic location of a lesion and the lesion's relationship to the neurovascular bundle and bone, it remains limited in its ability to accurately detect patterns of soft tissue calcification.³ More importantly, when MRI is nonspecific, it is limited in its ability to reliably differentiate between benign and malignant soft tissue tumors.

There is no universally accepted technique for the MRI evaluation of a soft tissue mass, and specifics of tumor imaging are not addressed in the *American College of Radiology Practice Guidelines and Technical Standards*. In our experience, examination should include enough information to accurately diagnose and stage the lesion, usually with a combination of T1-weighted and fluid-sensitive sequences. Contrast-enhanced imaging is often not required but is especially useful in the evaluation of hematomas and hemorrhagic lesions. In such cases, contrast-enhanced imaging will identify enhancing, and assumed viable, underlying tumor. Gadolinium-enhanced imaging may also be used in some cases to differentiate solid from cystic (or necrotic) lesions or to identify cystic or necrotic areas within solid tumors — a distinction that may be difficult or impossible on conventional imaging.

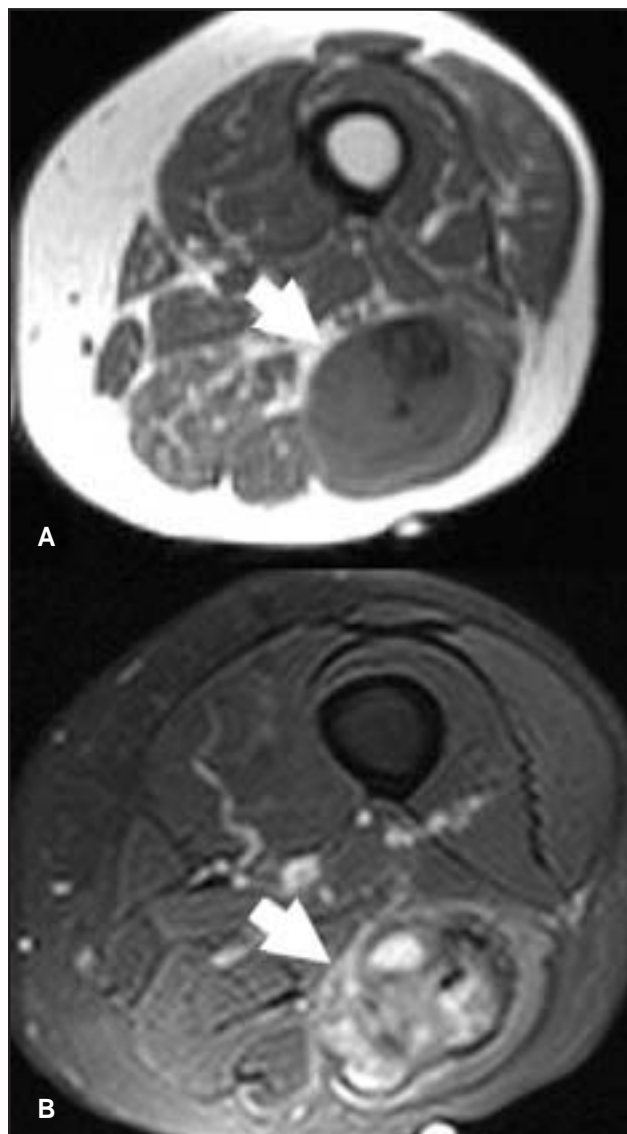


Fig 1 A-B. — (A) Axial T1-weighted sequence and (B) T1-fat-suppressed post-contrast demonstrate a posterior compartment malignant fibrous histiocytoma (arrows) of the thigh.

Enhanced imaging is also useful in identifying a suitable biopsy site in certain instances.

Computed Tomography

CT remains the most effective modality for the detailed evaluation of osseous architecture. It is ideally suited for evaluation of lesions in areas in which the osseous anatomy is complex. CT is able to assess osseous remodeling, periosteal reaction, and matrix when these are not adequately delineated on initial radiographs. It is also useful in identifying extrinsic osseous erosions, subtle areas of mineralization, or soft tissue gas that may not be apparent on MRI.

Image quality has been markedly improved due to the introduction of multidetector scanners and high-quality multiplanar reformatted images. Multidetector scanners allow acquisition of 2, 4, 8, or even 16 images during each tube rotation. Faster gantry rotation speed (up to 0.5 seconds per rotation) allows more volume coverage with better detail. The combination of faster gantry speeds with multidetector technology results in up to 8 times faster



Fig 2. — Coronal T1-weighted sequence, benign lipoma (asterisk) of the thigh. The diagnosis of lipoma is made when the lesion shows a signal identical to that of subcutaneous fat on all imaging sequences.

scanning time than single slice, 1-second spiral scanners. Improved temporal resolution decreases motion artifact, allows more efficient x-ray tube usage, and provides larger volumes of coverage. Thin section scanning produces high-quality reformatted images and 3-dimensional reconstructions (Fig 3). Newer scanners permit imaging to be done with 0.5-mm collimation that allows for isotropic viewing. Isotropic imaging enables the creation of reformatted images in any plane, with the same spatial resolution as the original sections. With more efficient use of the x-ray tube, technique can be manipulated to minimize beam-hardening artifact in patients with metallic orthopedic hardware. This increases visualization of the surrounding soft tissues and generates diagnostic information in postoperative patients who cannot be evaluated with MRI.

CT is also useful in patients with contraindications to MRI. In a multi-institutional study by the National Institute of Health, the Radiology Diagnostic Oncology Group found no statistically significant difference between CT and MRI in determining tumor involvement of muscle, bone, joint, or neurovascular structures.⁴ CT is the preferred modality for the identification of pulmonary metastases.

Positron Emission Tomography

PET has proven to be the “gold standard” in metabolic imaging. PET utilizes radioisotopes that undergo positron emission decay. A sophisticated ring detector surrounding the patient then detects the paired gamma photons released as a consequence of decay and registers the interaction in the form of an image. The radionuclide most commonly utilized for PET is [¹⁸F]-fluoro-2-deoxy-D-glu-



Fig 3. — Reformatted 3-dimensional CT image of the proximal tibia shows osseous remodeling (arrows) from juxtacortical cartilage tumor.

cose (FDG). In vivo, FDG behaves like glucose and provides a means of quantifying glucose metabolism. Unlike glucose, the metabolite of FDG is not a substrate for glycolytic enzymes. Therefore, the radioactive tracer is trapped in the cell, allowing subsequent imaging. The amount of tracer accumulation reflects the tissue's glucose metabolism. The use of PET in the diagnosis of sarcoma is still being defined.⁵ However, many types of tumors have higher rates of glycolysis than uninvolved normal tissue. High-grade malignancies tend to have higher rates of glycolysis and FDG uptake than low-grade malignancies and benign lesions (Fig 4).

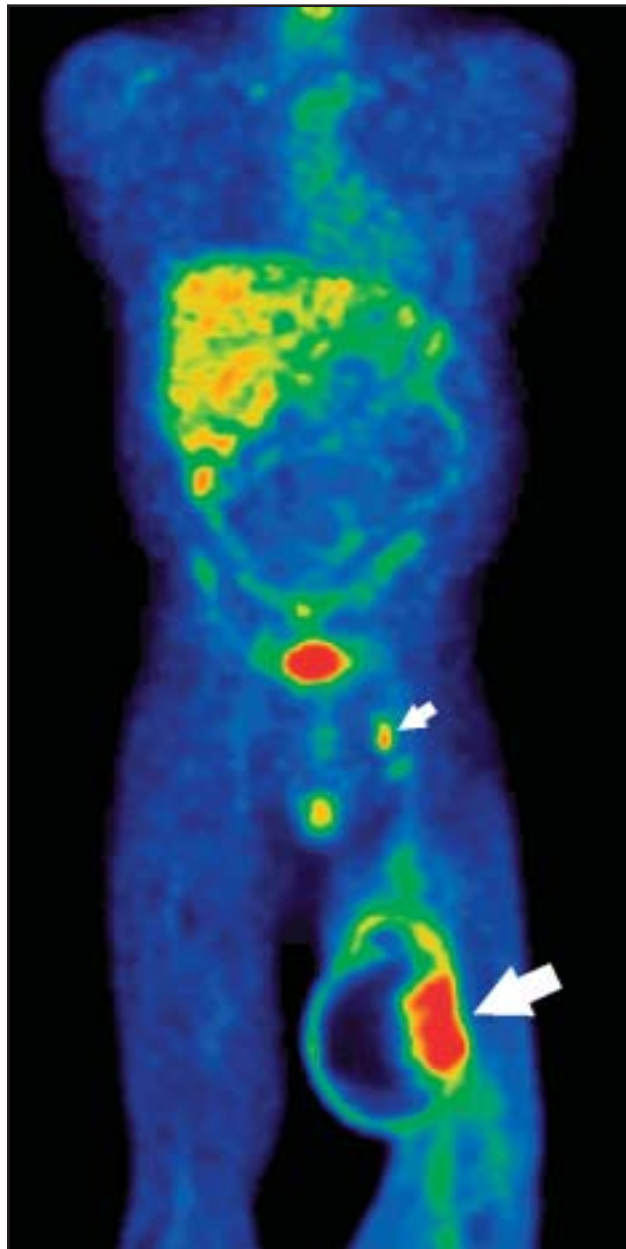


Fig 4. — Coronal reformatted PET image obtained from 3-dimensional data shows high-grade malignant fibrous histiocytoma in the thigh (large arrow). Absence of central activity in the mass reflects necrosis and hemorrhage. Note small hypermetabolic regional lymph node in the groin (small arrow).

A recent surge in interest in this modality has led to a proliferation of PET scanners and has dramatically decreased the cost and increased availability. A typical whole-body scan takes approximately 40 to 60 minutes and is considered positive when uptake is greater than that of the contralateral side or than in adjacent tissues. PET demonstrates several advantages over other conventional nuclear medicine techniques, including rapid imaging and interpretation, with results available in as little as 2 hours, and multiplanar imaging with higher resolution than with other nuclear medicine techniques. Another benefit is that PET is an inherently quantitative imaging method that allows treatment monitoring.

Ultrasonography

While US is rarely used as the primary modality for the evaluation of a soft tissue mass, it is a useful adjunct, especially in differentiating cystic from solid masses.⁶ Combined color and power Doppler ultrasound, as well as spectral wave analysis, may enable assessment of vascular architecture and altered flow in musculoskeletal tumors.⁷ Vascular architecture analysis can be helpful in differentiating benign from malignant tumors and in determining neoplastic involvement or vascular compromise by adjacent masses. Image-guided procedures such as biopsy or aspiration can also be easily performed under US guidance.

Magnetic Resonance Angiography

Recent advances in both hardware and software imaging technology have provided marked improvement in vascu-



Fig 5. — Anteroposterior MRA of the hand obtained from a 3-dimensional data set shows a small vascular spindle cell hemangioma (arrow), with vascular supply from the ulnar artery.

lar imaging. MRA now accurately depicts vascular anatomy, obviating conventional diagnostic angiography in most cases. Imaging can be performed with or without intravenous gadolinium. Newer techniques utilizing bolus administration of gadolinium with fast sequences timed at peak contrast concentration in the affected region can reveal vascular anatomy with remarkable detail.

MRA can accurately reveal the vascular supply of tumors, both arterial and venous. This feature can be helpful in vascular lesions such as arteriovenous malformations and hemangiomas (Fig 5). Vascular lesions such as aneurysm, pseudoaneurysm, and cystic adventitial disease may present as a soft tissue mass, and MRA in conjunction with conventional MRI can be diagnostic in many of these cases.

Tumor Follow-up Imaging

Imaging follow-up is usually dictated by the stage and grade of the initial lesion. Initial base-line postoperative imaging is done at 3 months, which usually allows adequate time for resolution of postoperative changes. High-grade lesions are typically followed initially at 3 to 6 month intervals, while low-grade lesions may be followed annually. Large lesions, or those in which a wide margin could not be obtained, may be followed more frequently. Follow-up imaging is continued for 5 years.

Imaging-Guided Biopsy

Imaging-guided biopsy is usually performed with CT or US guidance. Several principles are important for biopsy of suspected sarcomatous lesions, particularly coordination of the biopsy approach with the surgeon who will perform the definitive resection. An incorrect biopsy violates compartmental anatomy, risks tumor seeding, and may change a wide excision to an amputation.

Ideally, the needle track should be placed in the plane of the future incision. An additional method that may be used to decrease needle seeding is to place a coaxial needle to the edge of the lesion and then perform the biopsies through this coaxial needle. In this manner, the needle traversing the superficial soft tissue is not exposed to the cells from the area of biopsy. Core biopsies typically offer higher yield than fine-needle aspirations.

References

1. American Cancer Society. *Detailed Guide: Sarcoma - Adult Soft Tissue Cancer. What Are the Key Statistics for Sarcoma?* http://www.cancer.org/docroot/CRI/content/CRI_2_4_1X_What_are_the_key_statistics_for_sarcoma_38.asp?nav=cri. Accessed November 12, 2004.
2. Weiss SW, Goldblum JR. General considerations. In: Weiss SW, Goldblum JR. *Enzinger and Weiss's Soft Tissue Tumors*. 4th ed. Philadelphia, Pa: C V Mosby; 2001.
3. Elias DA, White LM, Simpson DJ. Osseous invasion by soft-tissue sarcoma: assessment with MR imaging. *Radiology*. 2003;229:145-152.
4. Panicek DM, Gatsonis C, Rosenthal DI, et al. CT and MR imaging in the local staging of primary malignant musculoskeletal neoplasms: report of the Radiology Diagnostic Oncology Group. *Radiology*. 1997;202:237-246.
5. Bredella MA, Caputo GR, Steinbach LS. Value of FDG positron emission tomography in conjunction with MR imaging for evaluating therapy response in patients with musculoskeletal sarcomas. *AJR Am J Roentgenol*. 2002;179: 1145-1150.

6. Lin J, Fessell DP, Jacobson JA, et al. An illustrated tutorial of musculoskeletal sonography: part 4, musculoskeletal masses, sonographically guided interventions, and miscellaneous topics. *AJR Am J Roentgenol*. 2000;175: 1711-1719.

7. Bodner G, Schocke MF, Rachbauer F, et al. Differentiation of malignant and benign musculoskeletal tumors: combined color and power Doppler US and spectral wave analysis. *Radiology*. 2002;223:410-416.