Soft-Tissue Tumors and Tumorlike Lesions: A Systematic Imaging Approach[1]

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Soft-tissue lesions are frequently encountered by radiologists in everyday clinical practice. Characterization of these soft-tissue lesions remains problematic, despite advances in imaging. By systematically using clinical history, lesion location, mineralization on radiographs, and signal intensity characteristics on magnetic resonance images, one can *(a)* determine the diagnosis for the subset of determinate lesions that have characteristic clinical and imaging features and *(b)* narrow the differential diagnosis for lesions that demonstrate indeterminate characteristics. If a lesion cannot be characterized as a benign entity, the lesion should be reported as indeterminate, and the patient should undergo biopsy to exclude malignancy.

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Radiology

Patients are commonly referred for imaging to evaluate a soft-tissue mass in the trunk or extremities. These lesions range from nonneoplastic conditions to benign and malignant tumors. Presently, imaging provides a limited ability to reliably distinguish between benign and malignant soft-tissue lesions. Thus, the primary goal for the imaging referral is to confirm the presence of a mass and to assess its extent in preparation for possible treatment. In an important subset of cases, characteristic clinical and imaging information can help to narrow the differential diagnosis. These characteristics include clinical history, lesion location, mineralization on radiographs, and signal intensity (SI) characteristics on magnetic resonance (MR) images. The goals of this review are to *(a)* introduce the etiologic spectrum of soft-tissue masses with emphasis on the most common entities and *(b)* provide the reader with a systematic MR-based approach for the work-up of a suspected soft-tissue mass.

Spectrum of Soft-Tissue Lesions

Soft tissue arises from the mesenchyme, which differentiates during development to become fat, skeletal muscle, peripheral nerves, blood vessels, and fibrous tissue (1). Soft-tissue tumors are histologically classified on the basis of the soft-tissue component that comprises the lesion, but this does not imply that the tumor arises from that tissue (1). For instance, lipomas contain cells that produce fat; however, lipomas do not necessarily arise from fat cells.

The World Health Organization (WHO) classification system for soft-tissue tumors (2) provides uniformity for the reporting and treatment of various tumors and reactive processes and is in common use. The WHO classification includes nine categories of soft-tissue tumors: adipocytic, fibroblastic/myofibroblastic, so-called fibrohistiocytic, smooth muscle, pericytic (perivascular), skeletal muscle, vascular, chondro-osseous, and those of uncertain differentiation (Table 1). The WHO classification was last revised in 2002, and a few important changes deserve mention. Atypical lipomatous tumor and well-differentiated liposarcoma are now considered to be the same entity since they are morphologically identical and do not have the potential for metastasis (2,3). Myositis ossificans is classified as a fibroblastic/myofibroblastic lesion instead of a chondro-osseous lesion (2,3). Lastly, malignant fibrous histocytoma has been replaced with undifferentiated pleomorphic sarcoma as the descriptor for tumors without a clear line of differentiation, since many tumors previously reported to be a malignant fibrous histocytoma have histologic characteristics that overlap with those of other malignant tumors (2,4). Undifferentiated pleomorphic sarcoma is now a diagnosis of exclusion and represents a much smaller group of lesions than did malignant fibrous histocytoma, which was previously considered to be the most common soft-tissue sarcoma in adults (5).

Additional soft-tissue lesions are not included in the WHO classification (Table 2). Tumors of the peripheral nervous system are classified separately by the WHO. This category includes nonneoplastic lesions, such as Morton neuromas and benign and malignant PNSTs (1,6). Additionally, tumorlike lesions (eg, ganglia, hematomas, foreign body granulomas, and anomalous muscles) should be considered in the differential diagnosis of a soft-tissue mass.

Essentials

- Although soft-tissue lesion characterization is not always possible, MR is the best imaging modality for lesion characterization.
- By systematically using clinical history, lesion location, findings on radiographs, and MR imaging features, the radiologist can differentiate between determinate and indeterminate lesions.
- If a lesion cannot be characterized as a benign entity, the lesion should be reported as indeterminate and considered for biopsy to exclude malignancy.

Common Soft-Tissue Lesions with Characteristic Features

A few common and distinctive soft-tissue lesions deserve discussion. They include lipoma, hemangioma, ganglion, PNST, GCT of the tendon sheath, myositis ossificans, hematoma, and Morton neuroma. These lesions often have specific clinical and/or imaging features that help with characterization and guide appropriate evaluation, which often averts biopsy. These are not the only soft-tissue lesions with characteristic features, but they are included here owing to their combination of unique clinical and/or imaging features and their common occurrence.

Lipomas and Other Lipomatous Lesions

Lipomas are the most common soft-tissue tumor and contain tissue histologically identical to adipose fat (7). The incidence of lipomas is up to 2.1 per 100 individuals (7). Lipomas are radiolucent on radiographs and computed tomographic (CT) images and are isointense relative to subcutaneous fat on MR images obtained with all pulse sequences (7). The classic lipoma is composed entirely of fat, without areas of nodularity or thickened septations (8) (Fig 1). Of note, a substantial percentage of benign lipomas demonstrate nonadipose features. In a study by Kransdorf et al

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Abbreviations:
GCT = giant cell tumor
PNST = peripheral nerve sheath tumor
SE = spin echo
SI = signal intensity
SPGR = spoiled gradient-recalled acquisition in the steady state
WHO = World Health Organization

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(8), 31% (11 of 35) of lipomas showed nonadipose content, which the authors attributed to fat necrosis and associated calcification, fibrosis, inflammation, and myxoid change. Lipoma variants, such as angiolipoma and myolipoma, are another group of tumors that are predominantly fat containing but demonstrate nonadipose features that may be difficult to dismiss as a benign lipoma (9,10).

The important differential diagnosis for a benign lipoma includes a well-differentiated liposarcoma, which may also demonstrate a large fat component. It is important to remember that other subtypes of liposarcoma (dedifferentiated, myxoid, and pleomorphic) may contain minimal or no visible fat (11). Features found to favor a diagnosis of well-differentiated liposarcoma include lesion size greater than 10 cm, presence of thick (>2-mm) septae (diffuse or focal), presence of globular and/or nodular nonadipose areas or masses, and lesion composition of less than 75% fat (8). Well-differentiated liposarcomas must also be distinguished from benign inter- and intramuscular lipomas. Intramuscular lipomas vary greatly in size, can have well-defined or infiltrative margins, and can appear to have septae owing to intermingled muscle fibers (12). However, the muscle fibers should be isointense to normal muscle on both T1- and T2-weighted MR images and, when viewed in the longitudinal plane, should maintain their native architecture (12).

In the past, a distinction was made between atypical lipomatous tumors and well-differentiated liposarcomas. Although these tumors are histopathologically identical, they were designated atypical lipomatous tumors when they occurred in the extremities and well-differentiated liposarcomas when they occurred in the retroperitoneum and mediastinum (2,4). This distinction was made to reflect the low morbidity and low incidence of recurrence of tumors in the extremities, since wide excision is achievable, as opposed to that of retroperitoneal and mediastinal tumors, in which com-

Table 1

Abbreviated WHO Classification of Soft-Tissue Tumors

Tumor Type	Tumor
Adipocytic	
Benign	Lipoma, lipomatosis, lipomatosis of nerve, lipoblastoma, lipoblastomatosis, hibernoma
Intermediate (locally aggressive)	Atypical lipoma, well-differentiated liposarcoma
Malignant	Liposarcoma: dedifferentiated, myxoid, round cell, pleomorphic, mixed type, not otherwise specified
Fibroblastic/myofibroblastic	
Benign	Nodular fasciitis, myositis ossificans, elastofibroma, fibromatosis coli, fibroma of tendon sheath, Gardner fibroma
Intermediate	
Locally aggressive	Superficial fibromatosis, desmoid-type fibromatoses, lipofibromatosis
Rarely metastasizing	Solitary fibrous tumor and hemangiopericytoma, infantile fibrosarcoma
Malignant	Adult fibrosarcoma, myxofibrosarcoma
So-called fibrohistiocytic	
Benign	GCT of tendon sheath, diffuse-type giant cell, deep benign fibrous histiocytoma
Intermediate (rarely metastasizing)	GCT of soft tissues
Malignant	Pleomorphic fibrous histiocytoma or undifferentiated pleomorphic sarcoma, giant cell fibrous histiocytoma or undifferentiated pleomorphic sarcoma with giant cells, inflammatory fibrous histiocytoma or undifferentiated pleomorphic sarcoma with prominent inflammation
Smooth muscle	
Benign	Angioleiomyoma, leiomyoma of deep soft tissue
Malignant	Leiomyosarcoma
Pericytic (perivascular)	Glomus tumor, myopericytoma
Skeletal muscle	
Benign	Rhabdomyoma
Malignant	Rhabdomyosarcoma: embryonal, alveolar, pleomorphic
Vascular	
Benign	Hemangioma, epithelioid hemangioma, angiomatosis, lymphangioma
Intermediate	
Locally aggressive	Kaposiform hemangioendothelioma
Rarely metastasizing	Retiform hemangioendothelioma, Kaposi sarcoma
Malignant	Epithelioid hemangioendothelioma, angiosarcoma of soft tissue
Chondro-osseous	Soft-tissue chondroma, mesenchymal chondrosarcoma, extraskeletal osteosarcoma
Uncertain differentiation	
Benign	Intramuscular myxoma, juxtaarticular myxoma, ectopic hamartomatous thymoma
Intermediate (rarely metastasizing)	Angiomatoid fibrous histiocytoma, ossifying fibromyxoid tumor
Malignant	Synovial sarcoma, epithelioid sarcoma, clear cell sarcoma of soft tissue, extraskeletal myxoid chondrosarcoma, extraskeletal Ewing tumor, intimal sarcoma

Source.—Reference 2.

Note.—GCT = giant cell tumor.

plete excision is difficult (2). This distinction was abandoned in the 2002 WHO classification, so both tumors are now considered to be the same entity (2). Some authors still reserve the term *atypical lipomatous tumor* for tumors that occur in the subcutaneous soft tissue (4).

The WHO classification includes additional adipocytic tumors, including lipoblastomas, lipomatoses of nerves (formerly neural fibrolipomas or lipofibromatous hamartomas of nerves), and hibernomas (2). Nevertheless, there are also fat-containing masses that are not classified by the WHO as adipocytic tumors. These masses include hemangiomas, fat-containing hernias, and muscle atrophy with fatty replacement. Ultimately, if a fatty mass cannot be reported as a lipoma or other benign fat-containing mass, a liposarcoma needs to be considered.

Hemangiomas

Hemangiomas are benign vascular lesions composed of various vessels by which they can be further histologically classified (13). They are common tumors in infancy and childhood but can occur in any age group (14–16). Clinically, hemangiomas can manifest with bluish skin discoloration and a history of size fluctuation (17). Occasionally, pain may occur following exercise owing to shunting of blood flow away from the surrounding tissue into the hemangioma (17). On images, hemangiomas can contain serpentine vessels, fat, smooth muscle, hemosiderin, and phleboliths (17). Identifying phleboliths, which are focal dystrophic mineralizations in a thrombus, on radiographs or CT images can be helpful in characterization (13,15). Changes in the bone, including periosteal reaction, cortical and medullary changes, and overgrowth, can be seen (17,18). On MR images, hemangiomas may be well-circumscribed or have poorly defined margins, with varying amounts of hyperintense T1 signal owing to either reactive fat overgrowth or hemorrhage (17,19) (Fig 2). Areas of slow flow typically have high T2 SI, while rapid flow can demonstrate a signal void on images obtained with a non–flow-sensitive sequence (15).

Ganglia

Ganglia are not true tumors; therefore, they are not included in the WHO classification of soft-tissue tumors. However, ganglia are common and should be considered in the work-up of a soft-tissue mass. Ganglia commonly occur in the hand, wrist, and feet (20) and can arise from joint capsules, bursae, ligaments, tendons, and subchondral bone (20,21). Their pathogenesis is controversial: Theories include development from synovial rests deposited at embryogenesis, proliferation and metaplasia of mesenchymal cells, degeneration of connective tissue owing to chronic trauma, and origination from the articular capsule (22).

Ganglia are lined by a capsule composed of flat spindle cells and do not have a synovial lining (23). They are distinguished from synovial cysts, which represent true herniation of the synovial membrane through the joint capsule (20). While McEvedy (24) found attachment of the ganglia to the joint capsule in an overwhelming majority of 150 cases examined at surgery, at arthrography and MR imaging, ganglia are not always seen to communicate with the joint (23). In some instances, it may be hard to distinguish a true ganglion from a paraarticular cystic lesion arising owing to intraarticular derangement (25).

Clinically, ganglia are usually asymptomatic; however, symptoms can develop from mass effect, including nerve compression, on adjacent tissue (26). The lesions can also fluctuate in size. Typically there are no findings on radiographs, but they but may show nonaggressive remodeling of the bone (27). On MR images, the lesions typically appear as round or ovoid masses that are uni- or multiloculated, with smooth or slightly lobulated surfaces, and are in close proximity to a joint or tendon (27). Ganglia are usually isointense or slightly hypointense to muscle on T1-weighted MR images and hyperintense on T2-weighted MR images and have a thin rim of contrast enhancement, with or without thin low-SI enhancing septae (27) (Fig 3). On occasion, they may be hyperintense to muscle on T1-weighted images, reflecting higher proteinaceous content (28). Ganglia may be associated with a track extending toward the joint and may have pericystic edema (27). Moreover, a ganglion can occur far away from a joint (28).

Peripheral Nerve Sheath Tumors

PNSTs are classified separately as neurogenic tumors by the WHO and comprise benign and malignant PNSTs (1,6). Benign PNSTs include both schwannomas (neurilemomas) and neurofibromas, which together account for 10% of benign soft-tissue tumors (14). PNSTs can manifest with both motor and sensory nerve disturbances (29). Schwannomas and neurofibromas can be difficult to distinguish from each other at imaging (3). Either tumor can appear as a well-defined smooth-bordered fusiform mass that is aligned along the nerve (Fig 4). Occasionally on MR images, a schwannoma can be distinguished from a neurofibroma by its location relative to the nerve: The schwannoma can be eccentric to and separable from the nerve, whereas the neurofibroma is intrinsic to it (30). The "split fat sign" can be associated with PNSTs: As the tumor enlarges, a surrounding rim of normal fat is maintained (3). Benign

Table 2

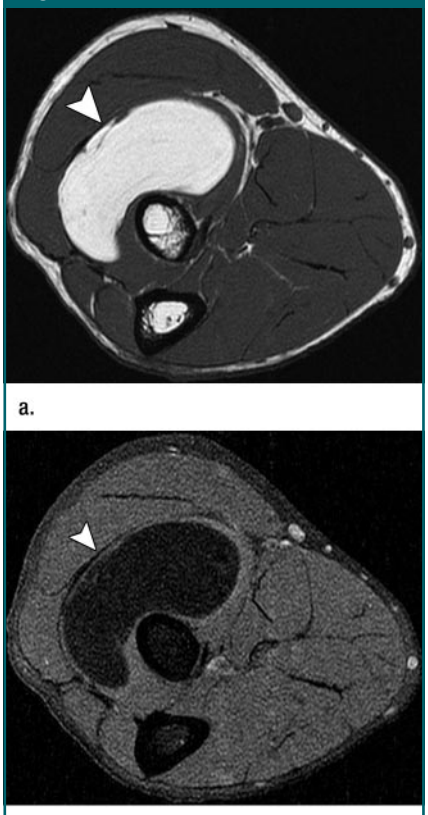
Lesions Not Included in the WHO Classification of Soft-Tissue Tumors

Lesion Type	Lesion
Neurogenic tumors	
Benign	Morton neuroma; traumatic neuroma; PNST: schwannoma (neurilemoma), neurofibroma; perineurioma
Malignant	PNST
Tumorlike	Ganglion; hematoma; seroma; abscess; epidermoid inclusion cyst; foreign body granuloma; anomalous muscle: soleus, palmaris longus, manus brevis

PNST = peripheral nerve sheath tumor.

Radiology

Figure 1

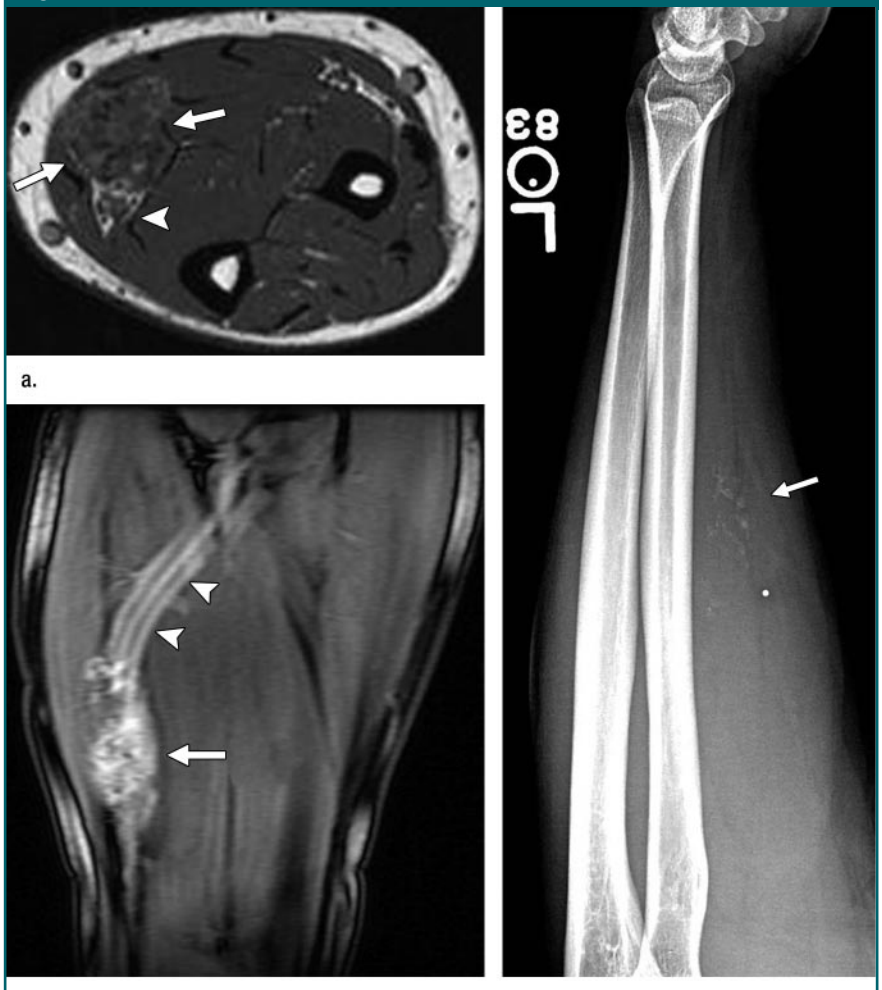


a.

b.

Figure 1: Axial MR images in 49-year-old man show lipoma (arrowhead) in upper forearm. **(a)** Spin-echo (SE) T1-weighted MR image shows uniformly hyperintense lesion with SI identical to that of subcutaneous fat. **(b)** Fat-suppressed spoiled gradient-recalled acquisition in the steady state (SPGR) T1-weighted MR image shows uniform fat suppression of lesion and no thickened septae or nodular areas.

Figure 2



a.

b. c.

Figure 2: Images in 32-year-old woman show hemangioma in forearm. **(a)** Axial SE T1-weighted MR image shows heterogeneous mass (arrows) with focal area of T1 hyperintensity (arrowhead). **(b)** Coronal contrast agent– enhanced fat-suppressed SPGR T1-weighted MR image shows heterogeneous enhancement (arrow) with large entering vessels (arrowheads). **(c)** Lateral radiograph shows phleboliths (arrow).

PNSTs are typically isointense to muscle on T1-weighted MR images and slightly hyperintense to fat on T2-weighted MR images (3,31) but are nonspecific in terms of their SI. Nevertheless, on cross-sectional MR images, a "target sign" appearance may be seen on T2-weighted images in some benign PNSTs, more commonly in neurofibromas than schwannomas (Fig 5) (30,32). The central area of low T2 SI histologically corresponds to fibrocollagenous tissue, whereas the outer area of high T2 SI corresponds to myxomatous tissue (31). Contrast enhancement in benign PNSTs is variable (31).

Malignant PNSTs account for 6% (5) of soft-tissue sarcomas and are associated with type 1 neurofibromatosis in 50% of cases (30). Malignant PNSTs can be difficult to differentiate from benign PNSTs; however, malignant PNSTs are typically larger and have ill-defined margins, rapid growth, and central necrosis (3,26,30).

GCTs of the Tendon Sheath

A GCT of the tendon sheath is a nodular form of pigmented villonodular synovitis, the histologic appearance of which is identical to that of its intraarticular counterpart (33,34). These tumors, as the name suggests, are intimately associated with the tendon sheath, and the most common location is the hand. They typically are adjacent to an interphalangeal joint (34). The lesion usually manifests as a small slow-growing mass, with or without pain. Radiographs usually show no abnormalities, though they may reveal nonaggressive remodeling of the adjoining bone (35). These lesions are typically isointense or hypointense to muscle on T1- and T2-weighted MR images owing to abundant collagen and hemosiderin, often with enhancement (36) (Fig 6). Some lesions may not contain enough hemosiderin to be T1 and T2 hypointense or to

cause a blooming artifact on gradient-echo images (34).

Myositis Ossificans

Myositis ossificans is a benign ossifying soft-tissue mass that occurs in muscle. Lesions are suspected to arise following trauma; however, patients often do not recall any antecedent traumatic episode (37). Patients may be asymptomatic or may present with pain, swelling, and, occasionally, an elevated erythrocyte sedimentation rate (37). Most lesions arise in the large muscles of the extremities (37).

The appearance of myositis ossificans on images varies, depending on its stage of development (37). Calcification is rarely seen on radiographs in the first few weeks but can become apparent 3–8 weeks after onset, starting peripherally and progressing centrally in a zonal pattern (37,38) (Fig 7). It evolves from faint irregular floccular densities to dense calcifications and, ultimately, to a rim of mature lamellar bone with central osteoid matrix (39). The MR appearance also varies, reflecting the histologic changes. Early lesions are poorly defined and isointense on T1-weighted images, heterogeneously T2 hyperintense, and have diffuse surrounding soft-tissue edema (39). As peripheral calcification develops, peripheral low SI may become visible on MR images (39). On both T1- and T2-weighted images, mature lesions are well-defined masses that are isointense to fat centrally and have low SI peripherally, without surrounding soft-tissue edema (39). Low SI also may be seen centrally if fibrosis, mineralization, or hemosiderin is present (39). Early-stage myositis ossificans can enhance (39) and can be mistaken for sarcoma. Moreover, areas of low SI on MR images may not be recognized as calcification or ossification, so it is important to consider myositis ossificans in the differential diagnosis and to assess for the characteristic zonal pattern of mineralization on radiographs or CT images.

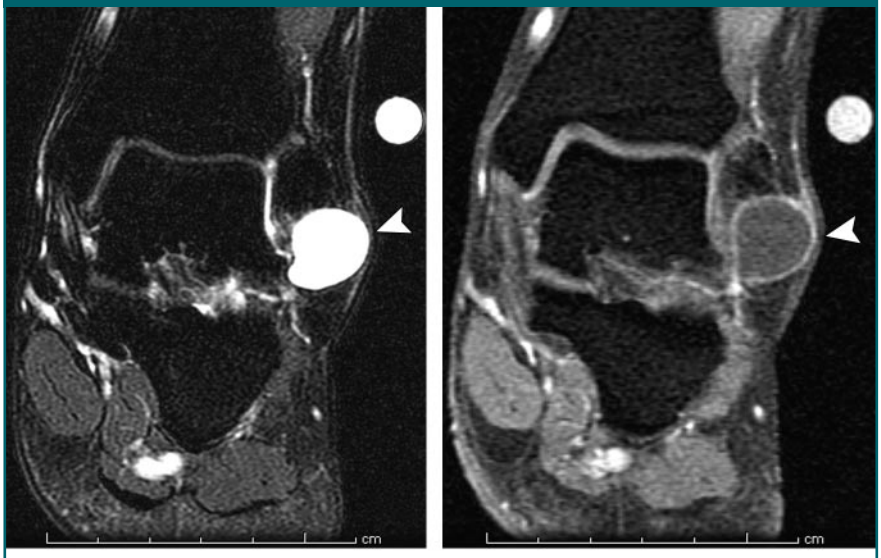
Hematomas

Hematomas can occur following trauma in a patient who has received anticoagulant treatment (20,40) or who has a clotting deficiency (15). Ecchymosis may be present at physical examination, and the appearance of a hematoma varies with its age (37). Acute (a few days old) hematomas are typically iso- or hypointense to muscle on T1- and T2-weighted MR images (37). Subacute (1-week- to 3-month-old) hematomas are usually T1 and T2 hyperintense (37). The high T1 SI, which is attributed to methemoglobin content, may initially appear in the periphery (37). Chronic hematomas are T1 and T2 hyperintense but can have a prominent hypointense rim representing a wall of collagenous fibrous tissue (40) and/or hemosiderin (41). Hematomas can arise in conjunction with underlying tumors; thus, any hematoma with nodular areas of soft-tissue enhancement should be followed to resolution in order to exclude an underlying lesion, especially if no traumatic event has occurred (42). The differential diagnosis for internal enhancement includes enhancing fibrovascular tissue in an organizing hematoma. Hematomas that do not resolve may calcify peripherally (15) or may continue to bleed, forming a chronic expanding hematoma (40).

Morton Neuromas

Morton neuromas are benign nonneoplastic lesions that arise owing to fibrosis and degeneration around the plantar digital nerve (33). Most lesions occur in the second or third interspace at, or just distal to, the level of the transverse metatar-

Figure 3



a. b.

Figure 3: Coronal MR images in 37-year-old woman show ganglion (arrowhead) in lateral ankle soft tissues. **(a)** Fat-suppressed fast SE T2-weighted MR image shows cystlike hyperintense lesion. **(b)** Contrast-enhanced fat-suppressed T1-weighted MR image shows rim enhancement without internal or nodular enhancement.

Figure 4

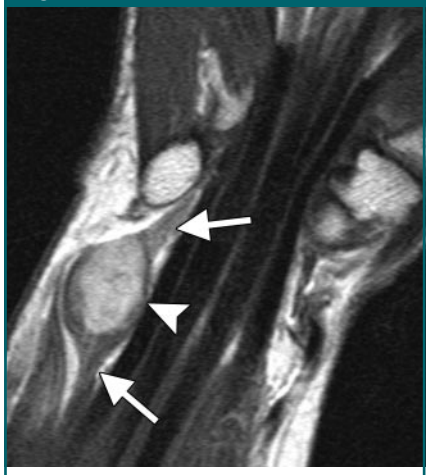


Figure 4: Coronal fast SE T2-weighted MR image of wrist in 36-year-old man shows ulnar nerve (arrows) entering and exiting a hyperintense schwannoma (arrowhead) slightly eccentrically to the mass.

sal ligament and plantar to the plane of the transverse ligament (29,33). Identifying a lesion in this location with characteristic burning pain can suggest this specific diagnosis without the need for biopsy (29). There is a high predominance for symptomatic lesions in female patients (33). Radiographs are often negative but may, with large lesions, show splaying of the metatarsal heads. On MR images, a Morton neuroma typically appears as a well-defined teardrop-shaped mass that is isointense to muscle on T1-weighted images and hypointense to fat on T2-weighted images, with low SI attributed to fibrotic tissue (43) (Fig 8). Lesions can show variable enhancement (33). Asymptomatic lesions that are visible on MR images are often smaller than their symptomatic counterparts (43,44).

A Systematic Approach for Characterization of Soft-Tissue Masses

Given the wide variety of masses and the overlap that exists between the imaging characteristics of benign and malignant masses, it is impossible to arrive at a single diagnosis for many of the lesions encountered. Early studies (45–49) found that lesions could only be characterized as benign or malignant in one-quarter to one-third of cases on the basis of features such as margin definition, T1 and T2 SI, SI homogeneity, perilesional edema, and involvement of adjacent bone or neurovascular structures. However, by applying a systematic approach, one *(a)* can arrive at a diagnosis for the subset of lesions that have characteristic appearances and *(b)* can narrow the differential diagnosis for lesions that demonstrate indeterminate characteristics. In the appropriate clinical setting, excluding a benign diagnosis (eg, lipoma or ganglion) can aid in clinical decision making. Ultimately, if a lesion cannot be characterized as a benign entity, the lesion should be reported as indeterminate and the patient should undergo biopsy to exclude malignancy (2,15). The final decision regarding biopsy will, of course, be made by patients and their treating physicians and will take into consideration factors such as lesion accessibility and patient comorbidities. The remainder of this review offers a systematic approach for the analysis of soft-tissue masses, with an emphasis on MR imaging SI characteristics.

Figure 5

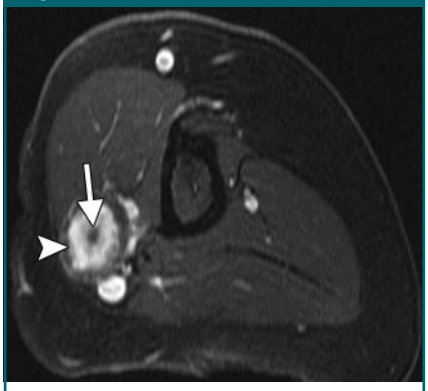
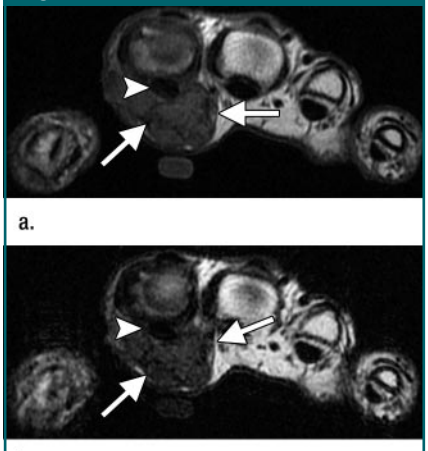


Figure 5: Axial fat-suppressed fast SE T2-weighted MR image in 56-year-old man shows schwannoma arising from radial nerve in upper arm. Lesion has a target appearance, with central hypointensity (arrow) and peripheral hyperintensity (arrowhead).

Figure 6



a.

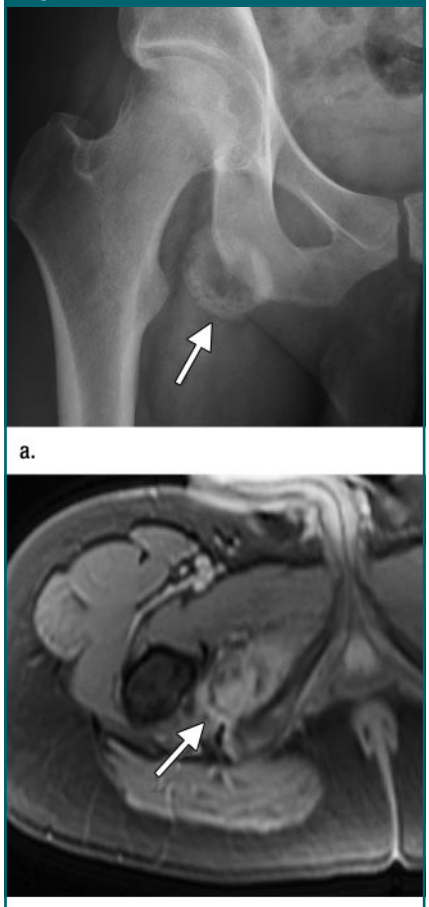
b.

Figure 6: Axial **(a)** SE T1-weighted and **(b)** fast SE T2-weighted MR images of the hand in 34-year-old woman with GCT of the tendon sheath show an isointense lobulated mass (arrows) arising from the flexor tendon (arrowhead) of the index finger.

Clinical History and Physical Examination

Evaluation of a soft-tissue mass begins with the clinical history and physical examination. Information regarding age, re-

Figure 7



a.

b.

Figure 7: Images in 25-year-old man show myositis ossificans in right groin. **(a)** Anteroposterior radiograph shows mass (arrow) with peripheral mineralization. **(b)** Axial contrast-enhanced fat-suppressed T1-weighted SPGR MR image shows central and perilesional enhancement (arrow).

Figure 8

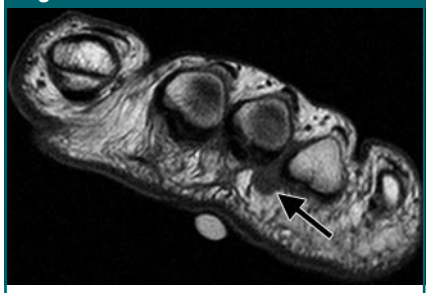


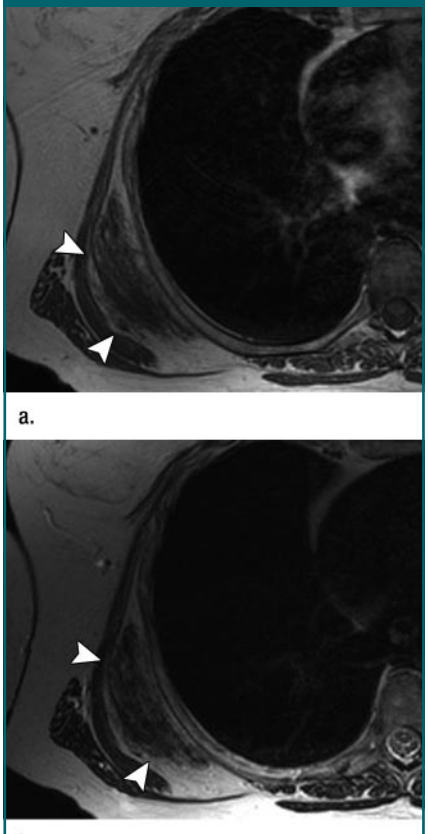
Figure 8: Coronal SE T1-weighted MR image in 37-year-old woman with forefoot pain shows teardrop-shaped hypointense lesion (arrow) in third interspace; location is typical for a Morton neuroma.

cent trauma, fluctuating mass size, history of malignant cancer and familial syndromes, and physical examination can help with lesion characterization. For instance, although liposarcoma is a common malignant soft-tissue mass in adults, it is rare in early childhood. In a review of 2500 cases of liposarcoma at the Armed Forces Institute of Pathology, only two cases occurred in children younger than 10 years (50). Similarly, epitheliod sarcoma is a relatively rare malignant tumor, accounting for only 1.4% of malignant tumors in a large study performed at the Armed Forces Institute of Pathology; however, this tumor accounts for 21%–29% of all soft-tissue malignancies in the hand and wrist of patients aged 6–25 years (5). A history of trauma can support the diagnosis of a hematoma or myositis ossificans; however, many patients do not recall a history of trauma, even when it may have occurred (20,37).

Changes in the size of the mass can help with diagnosis. While rapid growth is certainly a concern for malignancy, a benign mass may grow rapidly owing to hemorrhage. Decrease in lesion size is unlikely to occur in an untreated malignancy, unless there is an associated hematoma that is resolving (51). Fluctuation in lesion size can be seen with ganglia or hemangiomas, as they may become engorged with fluid or blood, respectively (15,17). In patients with malignancies, soft-tissue metastases and radiation-induced sarcomas can be considered (52,53). If multiple lesions are seen, metastatic disease and certain syndromes, including type 1 neurofibromatosis and hereditary multiple lipomas, can be considered (54).

At physical examination, determining whether the mass is mobile or fixed can be helpful. In general, masses that are mobile are more suggestive of a benign diagnosis, while masses that are fixed to surrounding tissues are more suggestive of malignancy (26). Skin changes, such as ecchymosis related to trauma or inflammatory changes from cellulitis and soft-tissue abscess, can aid in establishing an appropriate differential diagnosis.

Figure 9



a.

b.

Figure 9: Axial **(a)** SE T1-weighted and **(b)** fast SE T2-weighted MR images in 48-year-old woman show elastofibroma (arrowheads) in right posterolateral chest wall that is isointense to muscle on both images.

Location

Certain masses occur in specific locations in the body, aiding in lesion characterization. For example, elastofibroma is a benign fibroelastic tumor that occurs almost exclusively along the inferomedial border of the scapula, deep to the latissimus dorsi and rhomboid major muscles (55) (Fig 9). When a lesion is found in this location, a benign elastofibroma should be suspected, especially if there are bilateral lesions (55,56). Similarly, a teardrop-shaped mass found along the plantar aspect of the second or third interspace of the foot in the region of the plantar digital nerve, with appropriate SI characteristics, has a high likelihood of being a Morton neuroma (29,33). Additional site-specific lesions include plantar fibromas, glomus tumors, and popliteal or Baker cysts (Table 3). While location can be used to favor a given diagnosis, other lesions must be considered if the imaging findings are indeterminate. Thus, correlation with the clinical history and additional follow-up or biopsy may be indicated.

In a similar fashion, recognizing that a lesion arises from a specific structure (eg, nerves, vessels, or tendons) can help in lesion characterization. Tumors arising from nerves are typically benign PNSTs, which include schwannomas and neurofibromas. If there is a history of type 1 neurofibromatosis, a malignant PNST should be considered (30). Occasionally, fat-containing tumors can also arise from nerve. This type of lesion, previously known as a fibrolipomatous hamartoma, has been designated as lipomatosis of the nerve by the WHO in the 2002 classification (7). Vascular neoplasms typically have dilated tortuous vessels entering and/or exiting the lesion and include hemangiomas, lymphangiomas, and angiosarcomas (57). Hemangiomas are the most common of the vascular lesions and contain serpentine vessels, areas of fat, and phleboliths (15). Besides true vascular tumors, several additional vascular lesions should be included in the differential di-

Table 3

Location-specific Soft-Tissue Lesions

Lesion	Location
Elastofibroma	Inferior tip of scapula
Glomus tumor	Tufts of finger at nail bed
Baker cyst	Posterior medial aspect of knee, between gastrocnemius and semimembranosus tendons
Plantar fibroma	Associated with plantar fascia
Morton neuroma	Second and third metatarsal interspace

agnosis of a soft-tissue mass arising from vessels. Pseudoaneurysms can occur in the setting of trauma, such as femoral vessel injury from cardiac catheterization. In these cases, it is important to make the diagnosis prospectively and to avoid biopsy. Another group of masses characteristically arise from tendon sheaths. Lesions arising from tendons are most commonly GCTs of the tendon sheath (35); however, ganglia, lipomas, and fibromas are all masses that may arise from a tendon sheath.

Radiographs

Although the utility of radiographs in evaluating soft-tissue lesions is limited, some important information may be present on these images. Radiographs should be assessed for distortion of tissue planes, radiolucent fatty areas (Fig 10), indolent or aggressive remodeling of the bone, radiolucent foreign bodies, and soft-tissue calcifications or ossification. If there is a clustered group of phleboliths, one should consider the presence of a soft-tissue hemangioma (18). Remodeling of the bone in response to changes in local vascular flow may also be present. If there are juxtaarticular calcifications or ossific foci, with or without bone erosion, one should consider the possibility of a synovial sarcoma (Fig 11) or synovial osteochondromatosis (34). Mature ossification in soft tissues suggests the presence of heterotopic ossification or myositis ossificans, which can mimic an aggressive sarcoma when evaluated by using MR imaging appearance alone (20,38). Hazy calcification, with or without well-circumscribed paraarticular erosion, can indicate the presence of a gouty tophus (26), which is another lesion that could be misleading on the basis of its MR imaging appearance. Radiographs are an important adjunct in the assessment of soft-tissue masses with MR images and, if not obtained prior to MR imaging, can be performed afterwards to evaluate soft-tissue mineralization and changes in the bone.

MR Images

MR imaging is well-suited for the evaluation of soft-tissue tumors and tumorlike lesions because of its intrinsically high soft-tissue contrast and its capability to aid in imaging superficial and deep soft tissues over both large and small fields of view (20,45,46,48,49,54,58). Evaluation with MR images allows tumor staging, detection of neurovascular involvement, identification of tumor necrosis, and preoperative planning (54,58). Although tissue characterization is not always possible, MR imaging is, overall, more effective for tissue characterization than are CT and ultrasonography (54,58). The utility of MR imaging in the assessment of soft-tissue masses is predicated on the generation of diagnostic images of good quality. A brief discussion of technical considerations as they relate to MR imaging of soft-tissue masses is therefore presented after the section on newer techniques.

Figure 10

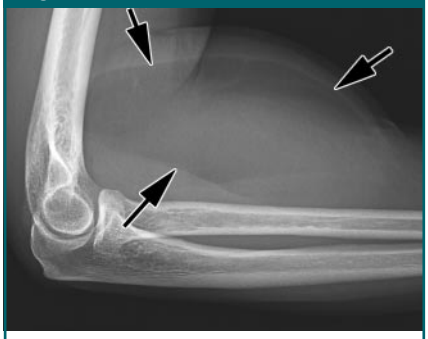
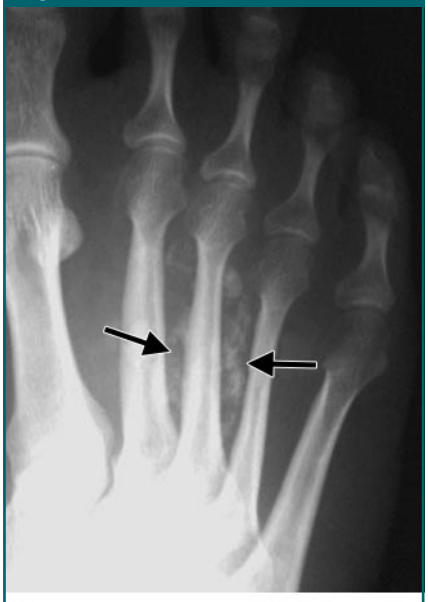
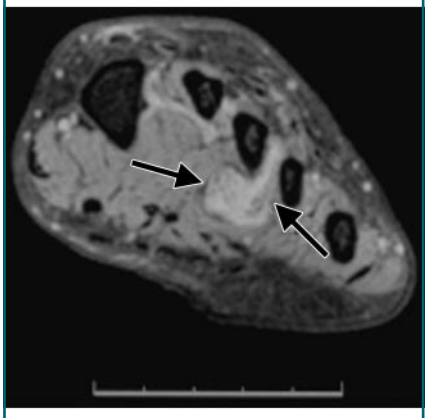


Figure 10: Lateral radiograph of the elbow in 46-year-old man shows large painless lipoma as a large radiolucent mass (arrows).

Figure 11



a.



b.

Figure 11: Images in 37-year-old woman show synovial sarcoma in the forefoot. **(a)** Anteroposterior radiograph shows irregular soft-tissue calcifications (arrows) surrounding third metatarsal shaft. **(b)** Coronal contrast-enhanced fat-suppressed T1-weighted SPGR MR image shows a heterogeneous enhancing mass (arrows) between the third and fourth metatarsal shafts.

Newer Techniques

The use of techniques such as MR spectroscopy and diffusion imaging has been reported for the evaluation of soft-tissue masses and, in particular, for assessing response to therapy (59–61). These techniques offer intriguing potential for interrogation of soft-tissue masses but are not yet in routine clinical use.

Technical Considerations for MR Imaging of Soft-Tissue Masses

Given the variety of sizes and locations of soft-tissue masses, it is difficult to prescribe a single imaging protocol. Nonetheless, a number of general principles apply. The lesion should be demarcated prior to imaging, but care should be taken not to compress or distort the mass, either with the skin markers or by imaging the mass dependently against the table. Images should be of sufficiently high spatial

resolution to demonstrate relevant morphologic features and local anatomic detail. T1- and T2-weighted images should be obtained for lesion characterization. Images should be obtained in the axial plane for compartmental anatomy and in a relevant longitudinal plane to assess the mass in relation to key anatomic landmarks. The protocols used at our institution are given in Table 4.

Imaging Strategy

In cases where the goal is to establish the presence of a mass, a large field of view that includes the contralateral side should be considered. In these cases, symmetry can help to highlight the presence of a mass. This is particularly applicable in the thighs, calves, and, occasionally, upper thorax and shoulder girdle. However, use of a large field of view generally translates into sacrificing spatial resolution. In cases where detailed assessment of the mass is needed to delineate its features and assess its proximity to surrounding structures, a smaller field of view that is targeted to the lesion itself is strongly indicated. In most cases, these two strategies are not mutually compatible. Therefore, it is important to assess the case ahead of time to decide which strategy will best serve the case at hand.

Imaging Sequences

Masses are classically described in terms of their T1 and T2 SI. As a result, the basic sequences employed to evaluate a soft-tissue mass are T1- and T2-weighted sequences. We include a fat-suppressed T1-weighted sequence, obtained with frequency-selective (also known as chemically specific) fat suppression, to evaluate masses that have high T1 SI. Masses that contain fat will lose SI on fat-suppressed T1-weighted images. This form of fat saturation only works effectively at field strengths of 1.5 T or above because it is dependent on sufficient separation between water and fat peaks, which depends on field strength. We also include a fat-suppressed T2-weighted sequence in order to highlight areas of increased edema both within and around the mass. Fat-suppressed T2-weighted images are particularly helpful when the non–T2-weighted images are obtained with fast SE techniques. On T2-weighted fast SE images, fat remains relatively bright, and it can be difficult to detect high-T2-SI masses or edema situated within fat unless fat suppression is employed. It is important to realize that the SI of a mass can appear quite different on a fat-suppressed image, as compared with the corresponding non–fat-suppressed T1- or T2-weighted image, because of changes in the dynamic range of the image (Fig 12). As a result, fat-suppressed sequences cannot be used to reliably describe the SI characteristics of a mass. These anatomic imaging sequences should all be obtained prior to contrast agent administration.

Describing Masses

The SI of masses should be described in relation to an internal standard. Most often, a mass is described as being hypo-, iso-, or hyperintense to muscle on both T1- and T2-weighted images. Some authors describe the SI of a mass on T2-weighted images in relation to subcutaneous fat; however, the relative SI of fat differs between SE and fast SE techniques (62).

Additional Sequences

A T2*-weighted gradient-echo sequence is a useful adjunct sequence for assessing the presence of hemosiderin. T2* weighting is achieved by using a relatively long echo time in conjunction with a gradient-echo sequence. Hemosiderin causes local magnetic susceptibility effects that create accentuated low SI on T2*-weighted im-

Table 4

MR Protocols for Soft-Tissue Lesions

Sequence	Repetition Time (msec)	Echo Time (msec)	Echo Train Length	Flip Angle (degrees)	Matrix	No. of Signals Acquired
Axial T1-weighted SE	600	15	. . .	. . .	256 × 256	1
Axial T2-weighted fast SE	2500	80	17	. . .	256 × 192	2
Axial STIR	4000	60	12	. . .	256 × 192	2
Coronal, sagittal, or oblique longitudinal T1-weighted SE	600	15	. . .	. . .	256 × 192	1
Coronal, sagittal, or oblique longitudinal STIR	4000	60	8	. . .	256 × 192	2
Axial nonenhanced fat-suppressed T1-weighted SE	700	15	. . .	. . .	256 × 192	1
Axial contrast-enhanced fat-suppressed T1-weighted SE	700	15	. . .	. . .	256 × 192	1
Coronal, sagittal, or oblique longitudinal contrast-enhanced fat-suppressed T1-weighted SE	700	15	. . .	. . .	256 × 256	1
T2*-weighted gradient-echo*	600	20	. . .	15	256 × 192	1
Dynamic contrast-enhanced fat-suppressed three-dimensional T1-weighted SPGR*	8	4	. . .	10	320 × 192	1

Note.—Generally, a coil that is close in field of view to the area of interest is selected. Surface coils offer the advantage of a relatively high signal-to-noise ratio, while volume coils offer more homogeneous signal over the volume of tissue imaged. Field of view and section thickness are selected to maximize spatial resolution but vary depending on the anatomic area, mass size, coil quality, and field strength. STIR = short inversion time inversion recovery.

* Optional sequences.

Figure 12

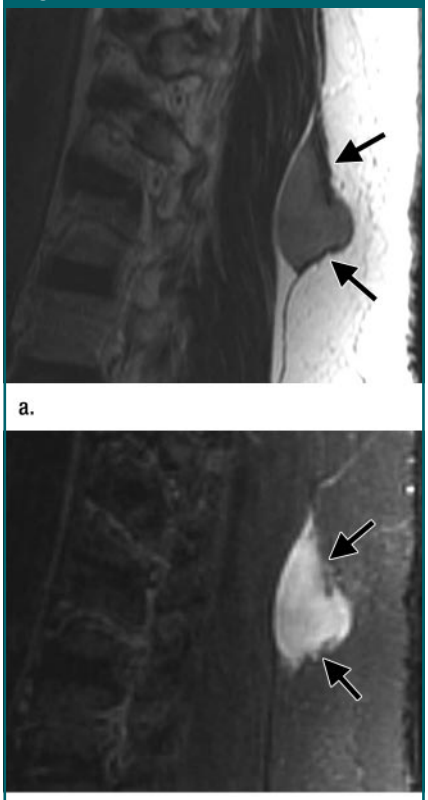


Figure 12: Sagittal T2-weighted fast SE MR images in 45-year-old woman show posterior chest desmoid tumor. **(a)** MR image without fat suppression shows mass (arrows) in subcutaneous soft tissues that is only slightly hyperintense to muscle. **(b)** Fat-suppressed MR image shows same mass (arrows) as much more hyperintense than muscle owing to changes in dynamic range.

Table 5

Lesion Characterization on the Basis of SI on MR Images

Appearance	Lesion
T1 hyperintense	
Lesion containing fat	Lipoma, lipoma variant, well-differentiated liposarcoma, hemangioma, myositis ossificans (mature)
Lesion containing methemoglobin	Hematoma
Lesion containing proteinaceous material	Ganglion, abscess
Lesion containing melanin	Melanoma
T2 hypointense	
Lesion containing fibrosis	Scar tissue, plantar fibroma, elastofibroma, desmoid, fibrosarcoma, GCT of tendon sheath, lymphoma (occasionally)
Lesion containing dense calcification	Gouty tophi, dystrophic calcification
Lesion containing hemosiderin	GCT of tendon sheath
T2 hyperintense (cystlike)	
Fluid-filled lesion	Ganglia, seroma, abscess, epidermoid inclusion cyst
Solid tumor	Myxoid lesion: intramuscular myxoma, myxoid liposarcoma; PNST; synovial sarcoma

ages as compared with that on standard T2-weighted images, an effect referred to as blooming. This effect can be observed in pigmented villonodular synovitis, some hemangiomas, and late-phase hematomas (15).

Imaging Plane

Axial images are important for demonstrating relevant anatomy and helping to determine whether the mass is confined to a single compartment and whether it is invading or encasing surrounding structures. As indicated above, images with high in-plane spatial resolution are most helpful in this regard. Images obtained in a longitudinal plane—coronal, sagittal, or oblique—help demonstrate the extent of the mass and its relationship to anatomic landmarks. If axial images are obtained first, they can be used to select the longitudinal plane that best demonstrates the relationship of the mass to bone, vessels, or other structures of interest.

Intravenous Gadolinium-based Contrast Agents

Because of the high intrinsic soft-tissue contrast of MR images, soft-tissue masses are almost invariably visible on MR images without the use of intravenous gadolinium-based contrast agents. In the evaluation of soft-tissue masses on MR images, intravenous contrast agent is used to distinguish cystic from solid structures, to demonstrate the relative vascularity of the masses, and, occasionally, to help highlight tissue planes to aid in assessing the degree of invasion of a mass into vessels and other structures (58). Contrast enhancement can also play an important role in helping to target tumor nodules in cystic or hemorrhagic masses during biopsy (58). For this application, intravenous gadolinium-based contrast agent is generally administered in a nondynamic fashion; that is, the contrast agent is injected, and a relatively longer acquisition of a high-spatial-resolution image is then obtained. Contrast-enhanced images are often obtained with fat suppression to suppress fat and highlight the presence of the gadolinium-based contrast agent. In choosing to use fat-suppressed T1-weighted MR sequences for this purpose, several considerations apply:

1. Images obtained before and those obtained after contrast agent administration must be obtained with identical imaging parameters to allow adequate assessment of enhancement. For instance, a contrast-enhanced fat-suppressed image cannot be compared with a nonenhanced non–fat-suppressed image. Some masses will appear to be T1 hyperintense simply because fat suppression has been applied, and this imaging effect could be mistaken for gadolinium enhancement.

2. For similar reasons, transmit gain cannot be allowed to change between nonenhanced and contrast-enhanced images. To maintain the same transmit gain, no preliminary imaging should take place between nonenhanced and contrast-enhanced imaging.

3. If, on nonenhanced images, fat suppression proves to be inhomogeneous, consideration should be given to acquiring the nonenhanced and contrast-enhanced images without fat suppression.

Unfortunately, inhomogeneous fat suppression can make it difficult to determine whether structures are enhancing.

4. Image subtraction can help to address the problem of inhomogeneous fat suppression, but this technique depends on the absence of patient motion between the nonenhanced and contrast-enhanced sequences.

Lesion Characterization on the Basis of MR Images

T1 Hypo- or Isointense Lesions

Most soft-tissue masses are iso- or hypointense to muscle on T1-weighted images; therefore, there is limited ability to distinguish or characterize lesions on the basis of low T1 SI alone (63). The differential diagnosis for these masses is extensive and includes both benign and malignant lesions. For example, ganglia, fibrosarcomas, and pleomorphic sarcomas can all demonstrate T1 hypo- or isointensity. Lesions that are iso- or hypointense to muscle on T1-weighted MR images should be further evaluated on the basis of SI characteristics on T2-weighted MR images.

T1 Hyperintense Lesions

A mass that is higher in SI than is skeletal muscle on T1-weighted images is considered to be hyperintense. As noted above, SI should be determined on images that are obtained without fat suppression because some masses may be isointense to muscle on T1-weighted images without fat suppression but relatively hyperintense to muscle on fat-suppressed T1-weighted images.

Substances that are associated with T1 shortening include fat, methemoglobin, proteinaceous fluid, and melanin (7,28,37,64,65) (Table 5). In the absence of gadolinium enhancement, the differential diagnosis for a mass characterized by T1 hyperintensity would include a fat-containing mass, a hemorrhagic mass that contains methemoglobin, various fluid collections that contain an appropriate concentration of proteinaceous fluid, and mel-

Figure 13

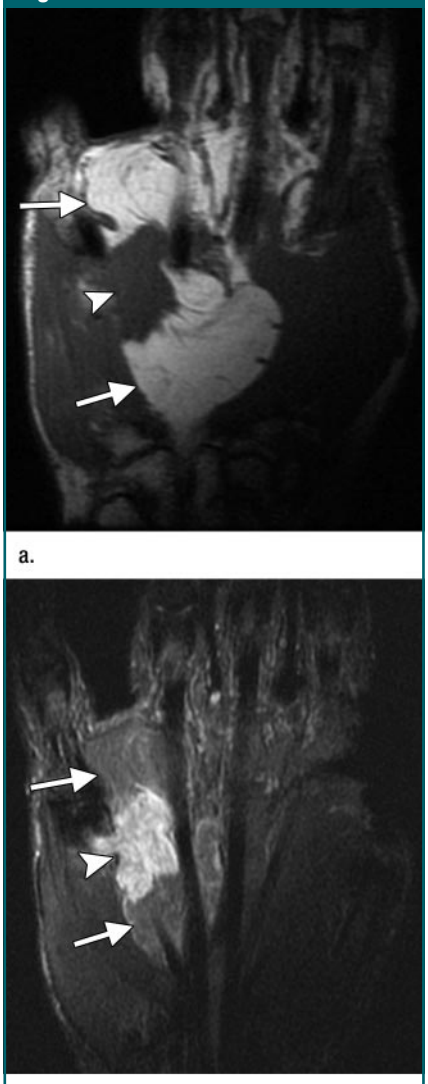


Figure 13: Coronal T1-weighted MR images in 53-year-old woman show well-differentiated liposarcoma in the hand. **(a)** SE MR image shows areas of hyperintensity (arrows) and a central area of hypointensity (arrowhead). **(b)** Contrast-enhanced fat-suppressed SPGR MR image shows enhanced central area (arrowhead) and hypointense fatty areas (arrows) that are not enhanced.

Figure 14

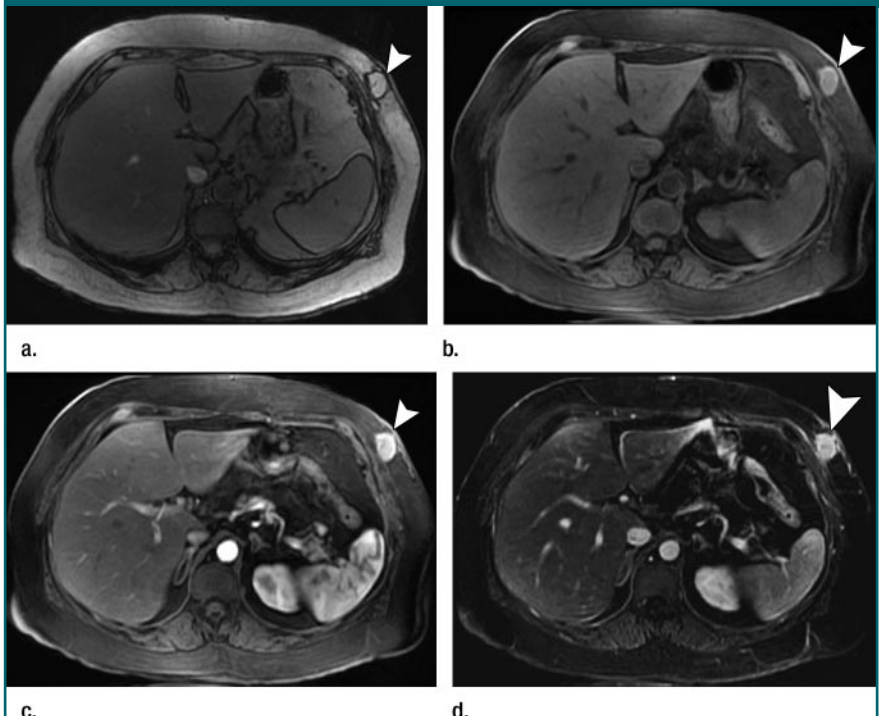


Figure 14: Axial MR images in 69-year-old woman show melanoma metastasis (arrowhead) in anterior abdominal subcutaneous soft tissues. T1-weighted **(a)** opposed phase and **(b)** fat-suppressed SPGR MR images show hyperintense lesion in subcutaneous fat. **(c)** Contrast-enhanced fat-suppressed T1-weighted SPGR MR image shows equivocal enhancement. **(d)** Subtraction MR image confirms solid internal enhancement.

Figure 15

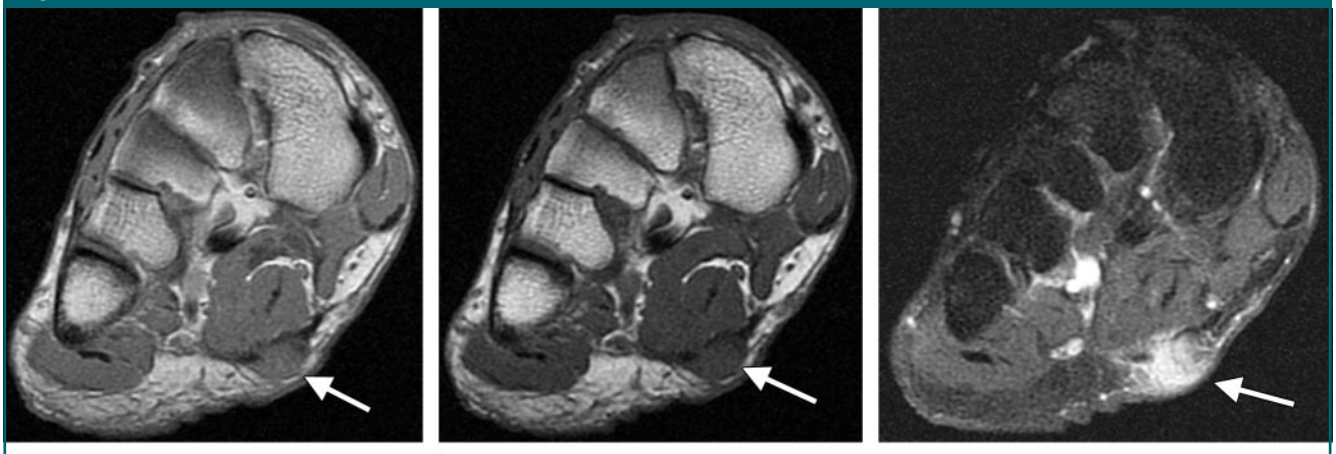


Figure 15: Axial MR images in 34-year-old woman with plantar fibroma (arrow). **(a)** T1-weighted SE and **(b)** T2-weighted fast SE MR images show lesion to be isointense to muscle. **(c)** Contrast-enhanced fat-suppressed T1-weighted MR image shows heterogeneous solid enhancement.

anoma or melanoma metastasis (7,28,37,64,65). Fat has intrinsically short T1 relaxation times due to its molecular structure. Methemoglobin causes shortening of T1 relaxation times due to a paramagnetic effect (66). Proteinaceous fluid is characterized by relative T1 shortening due to accelerated relaxation of water molecules bound to proteins (67,68). Although one report (65) of T1 shortening in melanomas ascribed the effect directly to paramagnetic radicals associated with melanin itself, a later report (64) theorized that it was owing to other sources, such as biological paramagnetic metals that become bound by the melanin.

If the mass has areas of hyperintense T1 signal, the next step is to evaluate suppression on fat-suppressed T1-weighted images. If the hyperintense area is suppressed, then the lesion contains fat, and the most likely diagnoses include lipoma, lipoma variant, well-differentiated liposarcoma, hemangioma, and mature ossification. It is important to perform the sequence with frequency-selective (also known as chemically specific) fat suppression. Inversion-recovery fat suppression is nonspecific and can cause loss of signal of not only fat but also of other short-T1 substances. If the mass is composed entirely of fat, with only minimal thin septations and without nonfatty nodular components, then a diagnosis of lipoma can be made (8). If the lesion is greater than 10 cm in diameter, contains septa greater than 2 mm thick and/or globular or nodular nonfatty components, or is comprised of less than 75% fat, then a diagnosis of well-differentiated liposarcoma is likely (8) (Fig 13).

Some lipomatous masses, including some lipomas and lipoma variants, have a complex appearance because they contain benign soft-tissue constituents; thus, it may be difficult to distinguish these entities from well-differentiated liposarcomas (8). Hemangiomas with fatty components will have suppressed SI on fat-suppressed MR images but should have a distinct appearance from lipomas. Hemangiomas tend to be lobulated and to have high-SI vascular channels on T2-weighted MR images (due to slow intravascular flow), may contain rounded low-SI phleboliths on T1- and T2-weighted MR images, and may cause fatty atrophy in surrounding muscles or reactive sclerosis in abutting bones (17). Phleboliths can be more apparent on radiographs than on MR images.

Ossification, seen with mature myositis ossificans or heterotopic ossification, can appear to be T1 hyperintense owing to fatty marrow (39). Again, reviewing the radiographs for evidence of mature ossification is helpful; however, ossification may not be apparent on radiographs, especially in the early stage of myositis ossificans (38,39). In these cases, CT images may be helpful for identifying early mineralization (58).

If the lesion does not lose SI on the fat-suppressed T1-weighted MR images, then it is composed of another substance that causes T1 shortening, such as methemoglobin, proteinaceous fluid, or melanin. A history of trauma may account for a hematoma with methemoglobin. However, a hematoma might also occur secondary to bleeding from a tumor, so a hematoma should be followed up with imaging to resolution to exclude an underlying sarcoma or other malignant lesion as the source of the hematoma (26). Any mass containing sufficient fluid with an appropriate concentration of protein can have high T1 SI (67). These masses include ganglia, abscesses, and epidermoid inclusion cysts with high protein content (28). If the patient has a history of melanoma and a mass with high T1 SI, the possibility of a melanoma metastasis should be considered (Fig 14). It should be noted, however, that not all melanotic lesions are characterized by substantial T1 shortening (69).

T2 Hypointense Lesions

A mass that is lower in SI than skeletal muscle on T2-weighted MR images is considered to be hypointense (Table 5) (70). Substances that appear hypointense on

T2-weighted images include fibrosis, hemosiderin, and calcification (distinct from ossification). Lesions with fibrotic components tend to have low T2 SI because of a relative lack of mobile protons associated with their hypocellular densely collagenous matrix (47,70). Hemosiderin, a nonspecific end-product from the breakdown of hemorrhage, is T2 hypointense due to magnetic susceptibility. When present in sufficient quantities, hemosiderin can appear more prominent (blooming) on T2*-weighted MR images than on T2-weighted MR images (41). Calcifications are typically T2 hypointense because the protons are immobilized within a crystalline structure and cannot contribute to the signal (71). Paradoxically, calcifications may appear as higher SI when calcium crystals are surrounded by a hydration shell, which provides a source of mobile protons (72,73). Substances that have intrinsic low proton density, such as air and some foreign bodies, also can appear to be T2 hypointense (47,74). Foreign bodies can be deceptive, as small foreign bodies may be surrounded by a hyperintense area from reactive fluid or inflammatory tissue, which can obscure the underlying foreign body and mimic a neoplasm.

Figure 16

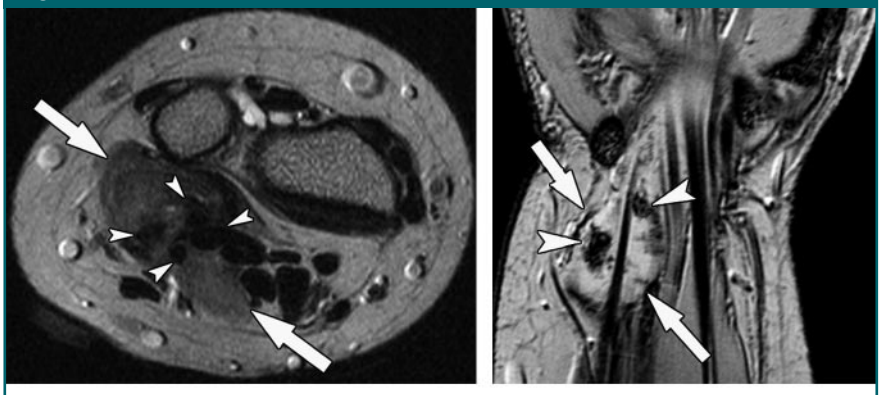


Figure 16: MR images in 36-year-old woman with GCT arising from flexor tendons to long, ring, and small fingers at level of the radiocarpal joint. **(a)** Axial T2-weighted fast SE MR image shows lobulated hypointense mass (arrows) encasing several flexor tendons (arrowheads). **(b)** Coronal T2*-weighted gradient-echo MR image shows blooming artifact (arrowheads) that highlights areas of hemosiderin deposition in the tumor (arrows).

Figure 17

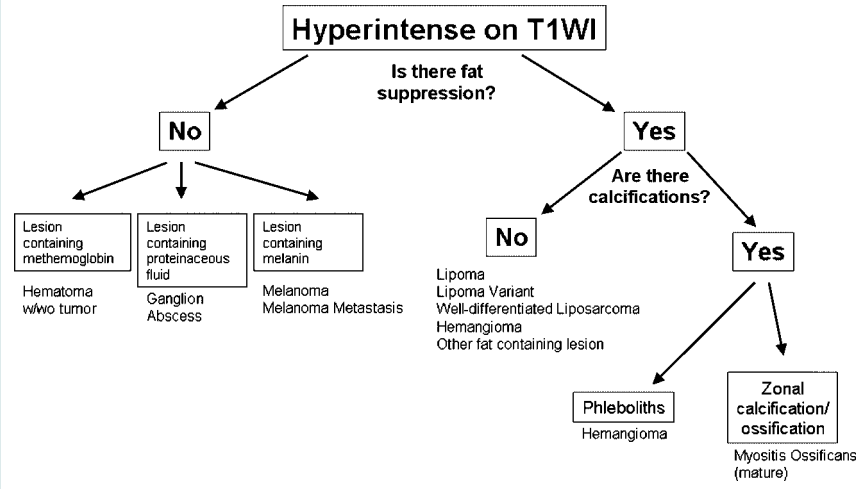


Figure 17: Flowchart of lesions that are hyperintense on T1-weighted MR images *(T1WI). w/wo* = with or without.

Masses that are composed of fibrotic material represent a broad spectrum of benign and malignant lesions, ranging from fibrotic scars to fibromas and some fibrosarcomas (Fig 15). T2 hypointensity in lesions such as GCT of the tendon sheath, amyloid deposits, long-standing rheumatoid pannus, soft-tissue callus, leiomyoma, and lymphoma has been ascribed to the presence of hypocellular fibrosis (35,36,75–77). However, not all fibrous masses have low T2 SI; hypercellular fibrous masses, such as desmoids and leiomyomas, may demonstrate higher T2 SI (55,70).

Masses that contain large amounts of hemosiderin include pigmented villonodular synovitis, GCT of the tendon sheath, and a variety of hemorrhagic masses (35,36,47) (Fig 16). Occasionally, lesions that characteristically contain extensive hemosiderin, such as pigmented villonodular synovitis, may not have bled sufficiently to appear hypointense on T2-weighted MR images or to cause blooming on T2*-weighted MR images (78). Some masses may contain hemosiderin in a portion of the mass because of bleeding but may not contain enough diffuse hemosiderin to have low T2 SI. For example, hematomas may demonstrate a peripheral rim of low-SI hemosiderin, and hemangiomas may contain scattered areas of low-SI hemosiderin because of intermittent bleeding, but neither entity generally manifests as a uniformly low-SI mass on T2-weighted MR images (66,79).

Masses that are diffusely calcified may also appear to have low T2 SI. However, the SI will depend on the extent and distribution of calcification, whether the calcification is hydrated, and whether there is associated edema or inflammatory reaction. For example, Yu et al (80) examined gouty tophi in five patients and found that lesions varied from nearly ho-

mogeneously hypointense to homogeneously T2 hyperintense. Martinez et al (81) reported on five patients with tumoral calcinosis and observed heterogeneous T2 SI, with both hyper- and hypointense components. They speculated that the hyperintense areas seen in tumoral calcinosis reflect an inflammatory component similar to a foreign body reaction.

In evaluating a mass with low T2 SI, the first step is to review the radiographs for the presence of calcifications, which are often difficult to identify on MR images alone. On radiographs, calcifications may have a characteristic pattern, such as the cloudlike paraarticular calcifications seen in gout or the flocculent calcifications seen in tumoral calcinosis.

If there are no calcifications on the radiographs, then a mass with low T2 SI will most likely either be focal fibrosis or a tumor with substantial fibrous content. In these cases, lesion location can be helpful for further characterization. Single or multiple masses within a joint may reflect the presence of pigmented villonodular synovitis. Similarly, if a well-circumscribed noncalcified mass abuts a tendon, it may be a GCT of the tendon sheath. A history of prior surgery at the lesion site could suggest the presence of fibrous scar tissue. A nodular mass that is adjacent to the plantar fascia of the foot most likely is a plantar fibroma (55). Similarly, a mass along the superficial palmar fascia of the hand can suggest Dupuytren disease (55).

T2 Hyperintense (Cystlike) Lesions

Many lesions that are hyperintense on T2-weighted MR images are heterogeneously hyperintense and are difficult to specifically characterize. Nevertheless, there is a subset of lesions that are relatively homogeneously hyperintense and can be further characterized (Table 5).

Water and water-filled masses are T2 hyperintense due to the prolonged T2 relaxation time of water. However, it is important to realize that some solid masses can also appear to be quite T2 hyperintense (82–84). Thus, the differential diagnosis for lesions that are predominantly T2 hyperintense includes not only fluid-filled lesions (eg, ganglia, synovial cysts, and seromas) but also solid lesions (eg, myxomas, myxoid sarcomas, some PNSTs, and small synovial sarcomas) (29,83,85). Because of the relatively homogeneous hyperintensity seen in some of these solid lesions, they can be mistaken for fluid-filled structures and have been termed cystlike lesions by some authors (83). Other tissues that can mimic fluid on T2-weighted MR images are hyperemic synovium (75) and hyaline cartilage (39).

In the subset of cystlike lesions, administering an intravenous gadolinium-based contrast agent is an important step to distinguish between true cysts and solid lesions (58). Cysts and fluid-filled components of masses will not demonstrate internal enhance-

Figure 18

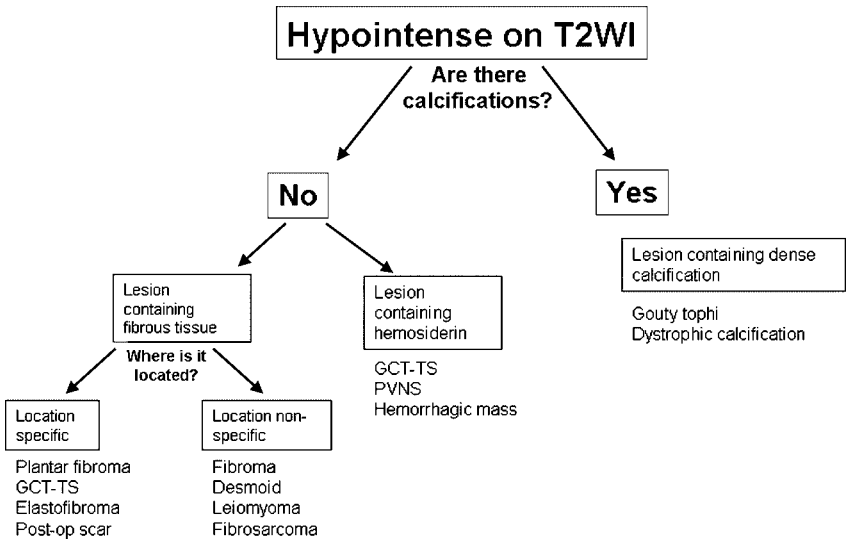


Figure 18: Flowchart of lesions that are hypointense on T2-weighted MR images *(T2WI). GCT-TS* = GCT of tendon sheath, *Post-op* = postoperative, *PVNS* = pigmented villonodular synovitis.

Figure 19

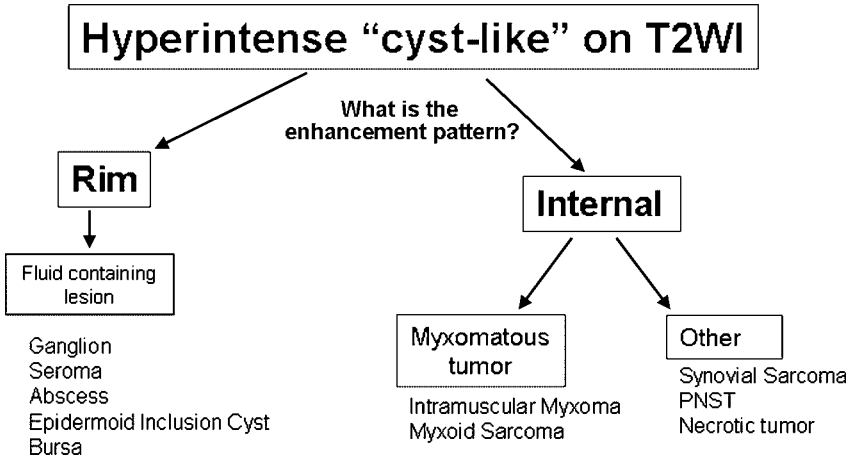


Figure 19: Flowchart of lesions that are hyperintense (cystlike) on T2-weighted MR images *(T2WI).* Administering intravenous contrast agent can help distinguish between fluid-filled lesions and solid tumors.

ment following intravenous contrast agent administration, whereas solid structures will usually demonstrate internal enhancement. An important caveat is that, given sufficient time, gadolinium-based contrast agents can diffuse into the center of a cyst from the periphery. Thus, internal enhancement can be seen in a true cyst if it is imaged late after contrast agent administration (86). Although there are no well-formulated rules for this phenomenon, we typically evaluate enhancement on MR images obtained within 6 minutes after contrast agent administration. If a mass that is T2 hyperintense has a thin even rim of enhancement and no internal enhancement, then it is a cyst of some kind. Ganglia are very common and should be considered whenever a periarticular hyperintense mass is identified on T2-weighted MR images (26). Postoperative seromas, posttraumatic cysts, epidermoid inclusion cysts, lymphoceles, and lymphangiomas are other lesions that may demonstrate a thin rim of peripheral enhancement (86–88). When the peripheral rim of enhancement is thick and/or irregular, other diagnoses must be considered, including inflamed or infected ganglia, abscesses, hematomas, and necrotic tumor masses (86,88).

Figure 20

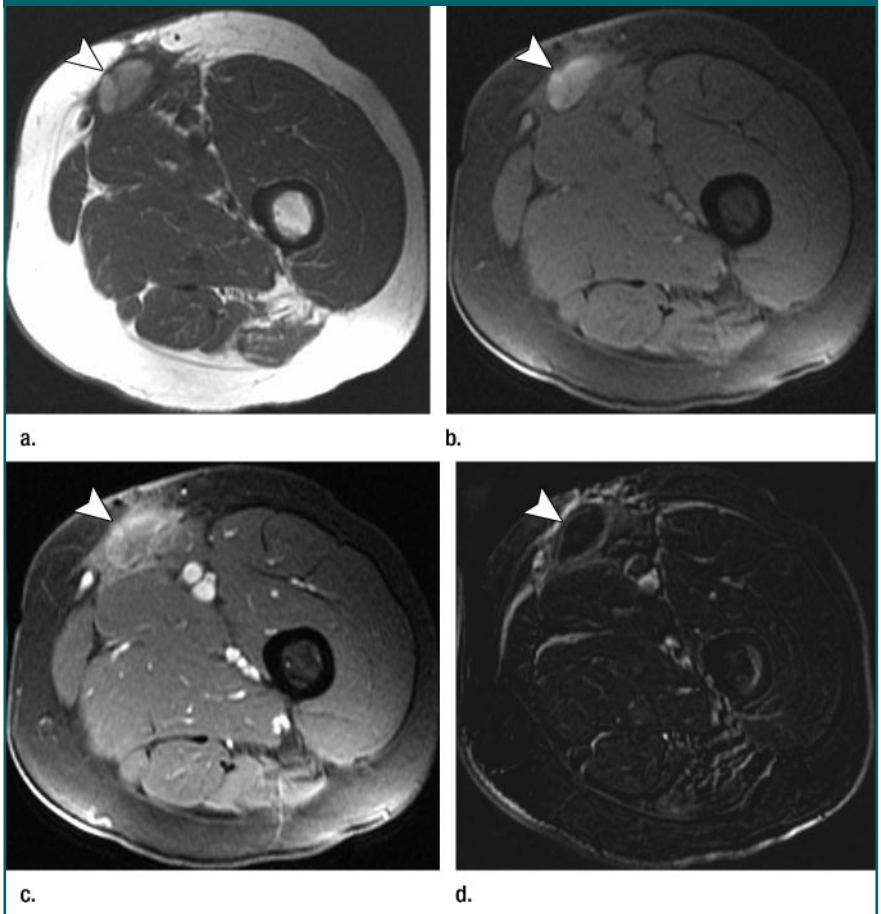


Figure 20: Sample Case 1—Axial MR images in 23-year-old man show palpable mass (arrowhead) in medial upper thigh following trauma. **(a)** SE T1-weighted MR image shows hyperintense lesion in anteromedial subcutaneous fat. Lesion remains hyperintense on **(b)** fat-suppressed T1-weighted MR image, indicating that it does not contain fat and may contain methemoglobin, proteinaceous fluid, or melanin. **(c)** Fat-suppressed contrast-enhanced T1-weighted MR image shows equivocal enhancement. **(d)** Subtraction image shows only rim and no internal enhancement, which is most consistent with hematoma given the clinical history.

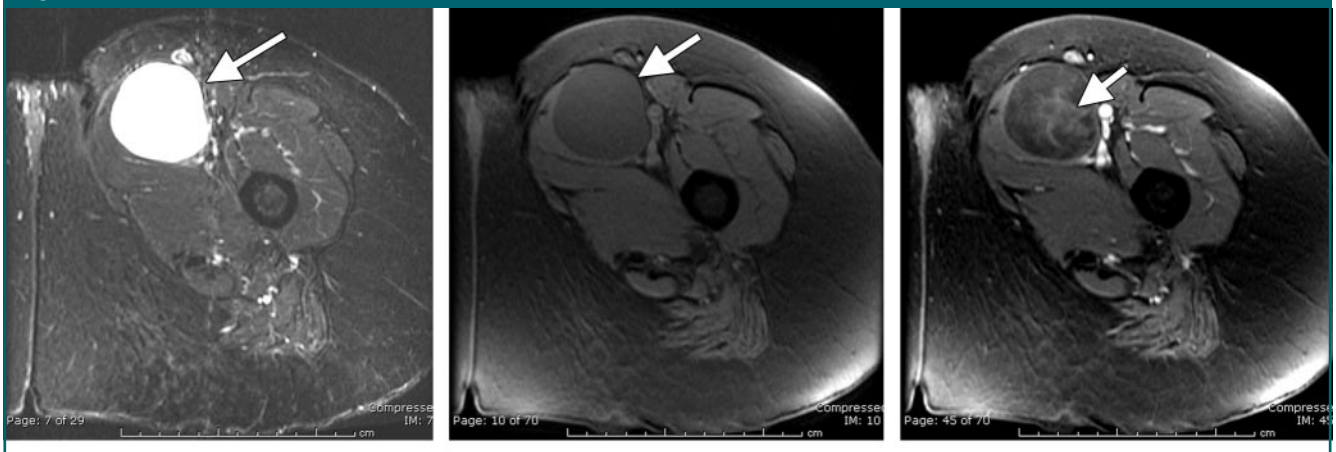
If a mass that is T2 hyperintense demonstrates internal enhancement, either homogeneous or heterogeneous, then soft-tissue masses (eg, intramuscular myxomas, myxoid sarcomas, PNSTs, and synovial sarcomas) should be considered (29,82,83,85,89). Myxoid material comprises a gelatinous matrix stroma that has high levels of hyaluronic acid and immature collagen fibers and can occur in a variety of benign and malignant lesions (83,89,90). Because of its high water content, myxoid material appears hyperintense on T2-weighted MR images. Intramuscular myxomas are benign masses that typically have uniform hyperintensity on nonenhanced T2-weighted MR images but demonstrate internal enhancement on contrast-enhanced MR images (90). Although they often have a thin rim of peripheral enhancement, benign intramuscular myxomas will also demonstrate nodular or more heterogeneous internal enhancement. Myxoid sarcomas can be homogeneously T2 hyperintense but also demonstrate internal contrast enhancement (89). If an enhancing hyperintense lesion is paraarticular, synovial sarcoma should be considered. Irregular calcifications, erosion of the bone, and cystic components may be associated (34,91). If the lesion is fusiform and is associated with a nerve, then the appearance is highly suggestive of a PNST (30,32).

In an effort to distinguish benign from malignant cystic lesions, Harish et al (83) examined 40 cystlike soft-tissue masses, including 16 myxomas, nine myxoid sarcomas, eight ganglia, two schwannomas, and one bursa. They found that the features most suggestive of malignancy were an average dimension greater than 7 cm (odds ratio, 30.3), a maximum dimension greater than 10 cm (odds ratio, 10.7), and heterogeneity on T1-weighted MR images (odds ratio, 6.7).

Contrast Enhancement

Contrast agent administration is useful for differentiating between cystic and solid lesions and for identifying tumor nodules in cystic lesions. If the

Figure 21



a. b. c.

Figure 21: Sample Case 2—Axial fat-suppressed MR images in 56-year-old woman show palpable lesion in groin. **(a)** T2-weighted MR image shows a hyperintense cystlike lesion (arrow) in the left upper thigh. **(b)** Nonenhanced T1-weighted SPGR MR image at level of lesion (arrow). **(c)** Contrast-enhanced T1-weighted SPGR MR image shows wispy internal enhancement (arrow). Intramuscular myxoma was identified at biopsy.

lesion shows only a thin rim of enhancement and does not enhance centrally, then it is a cystic lesion of some sort. If it shows internal enhancement, then it is at least partially solid. The degree of enhancement can relate to the vascularity of the lesion and is relevant preoperative information (92,93). Malignant lesions tend to show greater enhancement and a greater rate of enhancement (94). However, enhancement cannot be reliably used to distinguish benign from malignant lesions (58).

Other MR Imaging Features

The analysis presented here is based on the evaluation of the predominant SI of the mass on MR images. However, a number of additional imaging features have been described that can aid in developing a more specific diagnosis (eg, lesion size, homogeneity versus heterogeneity of lesion SI, contrast enhancement, lesion shape and margins, presence of necrosis or peritumoral edema, presence of bone and/or neurovascular involvement, and extension of the lesion beyond compartments) (48,49,58). For example, both hemangiomas and lipomas are T1 hyperintense. However, most hemangiomas demonstrate circular, linear, or serpentine high T2 SI caused by slow flow in vascular channels, which is not a feature in lipomas (19). Similarly, both myxomas and synovial sarcomas are T2 hyperintense. Perilesional edema and the presence of superior and inferior caps of fat are features that have been described as characteristic of myxomas (84), while the presence of triple signal (areas of hyper-, iso-, and hypointensity to fat on T2-weighted MR images) is a feature that has been described in synovial sarcomas (84,95). Similarly, plantar fibromas and elastofibromas are lesions that are both T2 hypointense. However, plantar fibromas tend to be nodular, often with a linear tail extending along the plantar aponeurosis, while elastofibromas tend to be lenticular, with a striated pattern of alternating fat and fibrous tissue (96,97). Analysis of these additional features can help to improve lesion characterization; however, the specificity for distinguishing benign from malignant entities remains limited (49,54,58,98).

Applying a Systematic Approach

The concepts described above are summarized in Figures 17–19. Figures 20 and 21 show sample cases. The algorithms are intended to illustrate a systematic approach for evaluating soft-tissue masses encountered at imaging on the basis of their predominant SI on MR images and to highlight some key questions to ask. However, these algorithms are not intended to provide guidelines for the complete work-up of soft-tissue masses. In some cases, the algorithms can lead to a specific tumor. In other cases, the analysis leads to a tissue category that includes both benign and malignant diagnoses. This information must be combined with clinical data, lesion location, relevant additional MR imaging features, and, where appropriate, results of other tests to arrive at a more conclusive diagnosis or differential diagnosis.

The Indeterminate Lesion

At the conclusion of this analysis, the observer may have succeeded in identifying the lesion as a benign determinate lesion. Even if the lesion cannot be definitively characterized in this way, one can provide a succinct differential diagnosis on the basis of the available characteristics. However, if the lesion cannot be confidently characterized as a benign entity, then it is an indeterminate lesion and requires further evaluation. This concern should be discussed with the ordering clinician, and a biopsy should be strongly considered. Indeed, the WHO recommends that "soft tissue

masses that do not demonstrate tumor-specific features on MR images should be considered indeterminate and biopsy should always be obtained to exclude malignancy" (2). In some instances, especially in patients with comorbidities or relative contraindications to biopsy, short-term imaging follow-up may be an alternative.

Conclusion

Soft-tissue tumors and tumorlike lesions are encountered often in daily radiologic practice. The vast array of benign and malignant entities can make lesion diagnosis overwhelming for the radiologist. By systematically using clinical history, lesion location, mineralization on radiographs, and SI characteristics on MR images, the radiologist can develop a short and appropriate differential diagnosis. MR images can be particularly useful for characterizing benign lesions that do not require imaging follow-up or biopsy, such as lipomas and ganglia. In cases where a soft-tissue lesion is indeterminate on the basis of clinical and imaging features, biopsy should be considered.

References

1. Origin and classification of soft tissue tumors. In: Kransdorf MJ, Murphey MD. Imaging of soft tissue tumors. 2nd ed. Philadelphia, Pa: Lippincott Williams & Williams, 2006; 1–5.
2. Fletcher CD, Unni KK, Mertens F, eds. WHO classification of tumours: pathology and genetics of tumours of soft tissue and bone. Lyon, France: IARC, 2002.
3. Vilanova JC, Woertler K, Narvaez JA, et al. Soft-tissue tumors update: MR imaging features according to the WHO classification. Eur Radiol 2007;17:125–138.
4. Murphey MD. World Health Organization classification of bone and soft tissue tumors: modifications and implications for radiologists. Semin Musculoskelet Radiol 2007;11: 201–214.
5. Kransdorf MJ. Malignant soft-tissue tumors in a large referral population: distribution of diagnoses by age, sex, and location. AJR Am J Roentgenol 1995;164:129–134.
6. Kleihues P, Cavenee WK, eds. WHO classification of tumours: pathology and genetics of tumours of the nervous system. Lyon, France: IARC, 2000.
7. Murphey MD, Carroll JF, Flemming DJ, Pope TL, Gannon FH, Kransdorf MJ. From the archives of the AFIP: benign musculoskeletal lipomatous lesions. RadioGraphics 2004;24:1433–1466.
8. Kransdorf MJ, Bancroft LW, Peterson JJ, Murphey MD, Foster WC, Temple HT. Imaging of fatty tumors: distinction of lipoma and well-differentiated liposarcoma. Radiology 2002;224:99–104.
9. Bancroft LW, Kransdorf MJ, Peterson JJ, O'Connor MI. Benign fatty tumors: classification, clinical course, imaging appearance, and treatment. Skeletal Radiol 2006;35: 719–733.
10. Weiss SW, Goldblum JR. Enzinger and Weiss's soft tissue tumors. St Louis, Mo: Mosby, 2001.
11. Jelinek JS, Kransdorf MJ, Shmookler BM, Aboulafia AJ, Malawer MM. Liposarcoma of the extremities: MR and CT findings in the histologic subtypes. Radiology 1993;186: 455–459.
12. Matsumoto K, Hukuda S, Ishizawa M, Chano T, Okabe H. MRI findings in intramuscular lipomas. Skeletal Radiol 1999;28:145–152.
13. Vilanova JC, Barcelo J, Smirniotopoulos JG, et al. Hemangioma from head to toe: MR imaging with pathologic correlation. RadioGraphics 2004;24:367–385.
14. Kransdorf MJ. Benign soft-tissue tumors in a large referral population: distribution of specific diagnoses by age, sex, and location. AJR Am J Roentgenol 1995;164:395–402.
15. Papp DF, Khanna AJ, McCarthy EF, Carrino JA, Farber AJ, Frassica FJ. Magnetic resonance imaging of soft-tissue tumors: determinate and indeterminate lesions. J Bone Joint Surg Am 2007;89(suppl 3):103–115.
16. Goodwin RW, O'Donnell P, Saifuddin A. MRI appearances of common benign soft-tissue tumours. Clin Radiol 2007;62:843–853.
17. Vascular and lymphatic tumors. In: Kransdorf MJ, Murphey MD. Imaging of soft tissue tumors. 2nd ed. Philadelphia, Pa: Lippincott, Williams & Wilkins, 2006; 150–188.
18. Ly JQ, Sanders TG, Mulloy JP, et al. Osseous change adjacent to soft-tissue hemangiomas of the extremities: correlation with lesion size and proximity to bone. AJR Am J Roentgenol 2003;180:1695–1700.
19. Murphey MD, Fairbairn KJ, Parman LM, Baxter KG, Parsa MB, Smith WS. Musculoskeletal angiomatous lesions: radiologic-pathologic correlation. RadioGraphics 1995; 15:893–917.
20. Siegel MJ. Magnetic resonance imaging of musculoskeletal soft tissue masses. Radiol Clin North Am 2001;39:701–720.
21. Janzen DL, Peterfy CG, Forbes JR, Tirman PF, Genant HK. Cystic lesions around the knee joint: MR imaging findings. AJR Am J Roentgenol 1994;163:155–161.
22. Malghem J, Vande berg BC, Lebon C, Lecouvet FE, Maldague BE. Ganglion cysts of the knee: articular communication revealed by delayed radiography and CT after arthrography. AJR Am J Roentgenol 1998;170: 1579–1583.
23. Lee KR, Cox GG, Neff JR, Arnett GR, Murphey MD. Cystic masses of the knee: arthrographic and CT evaluation. AJR Am J Roentgenol 1987;148:329–334.
24. McEvedy BV. Simple ganglia. Br J Surg 1962; 49:585–594.
25. el-Noueam KI, Schweitzer ME, Blasbalg R, et al. Is a subset of wrist ganglia the sequela of internal derangements of the wrist joint? MR imaging findings. Radiology 1999;212:537–540.
26. Frassica FJ, Khanna JA, McCarthy EF. The role of MR imaging in soft tissue tumor evaluation: perspective of the orthopedic oncologist and musculoskeletal pathologist. Magn Reson Imaging Clin N Am 2000;8:915–927.
27. Kim JY, Jung SA, Sung MS, Park YH, Kang YK. Extra-articular soft tissue ganglion cyst around the knee: focus on the associated findings. Eur Radiol 2004;14:106–111.
28. Feldman F, Singson RD, Staron RB. Magnetic resonance imaging of para-articular and ectopic ganglia. Skeletal Radiol 1989;18: 353–358.
29. Beggs I. Pictorial review: imaging of peripheral nerve tumours. Clin Radiol 1997; 52:8–17.
30. Banks KP. The target sign: extremity. Radiology 2005;234:899–900.
31. Murphey MD, Smith WS, Smith SE, Kransdorf MJ, Temple HT. Imaging of musculoskeletal neurogenic tumors: radiologic-pathologic correlation. RadioGraphics 1999; 19:1253–1280.
32. Suh JS, Abenoza P, Galloway HR, Everson LI, Griffiths HJ. Peripheral (extracranial) nerve tumors: correlation of MR imaging and histologic findings. Radiology 1992;183:341–346.
33. Waldt S, Rechl H, Rummeny EJ, Woertler K. Imaging of benign and malignant soft tissue masses of the foot. Eur Radiol 2003;13: 1125–1136.
34. Narvaez JA, Narvaez J, Aguilera C, De Lama E, Portabella F. MR imaging of synovial tu-

mors and tumor-like lesions. Eur Radiol 2001;11:2549–2560.

35. Karasick D, Karasick S. Giant cell tumor of tendon sheath: spectrum of radiologic findings. Skeletal Radiol 1992;21:219–224.

36. De Beuckeleer L, De Schepper A, De Belder F, et al. Magnetic resonance imaging of localized giant cell tumour of the tendon sheath (MRI of localized GCTTS). Eur Radiol 1997; 7:198–201.

37. Crundwell N, O'Donnell P, Saifuddin A. Non-neoplastic conditions presenting as soft-tissue tumours. Clin Radiol 2007;62:18–27.

38. Parikh J, Hyare H, Saifuddin A. The imaging features of post-traumatic myositis ossificans, with emphasis on MRI. Clin Radiol 2002;57:1058–1066.

39. Kransdorf MJ, Meis JM. Extraskeletal osseous and cartilaginous tumors of the extremities. RadioGraphics 1993;13:853–884.

40. Sreenivas M, Nihal A, Ettles DF. Chronic haematoma or soft-tissue neoplasm? a diagnostic dilemma. Arch Orthop Trauma Surg 2004;124:495–497.

41. Hardy PA, Kucharczyk W, Henkelman RM. Cause of signal loss in MR images of old hemorrhagic lesions. Radiology 1990;174: 549–555.

42. Stacy GS, Dixon LB. Pitfalls in MR image interpretation prompting referrals to an orthopedic oncology clinic. RadioGraphics 2007;27:805–826.

43. Zanetti M, Strehle JK, Zollinger H, Hodler J. Morton neuroma and fluid in the intermetatarsal bursae on MR images of 70 asymptomatic volunteers. Radiology 1997;203:516–520.

44. Bencardino J, Rosenberg ZS, Beltran J, Liu X, Marty-Delfaut E. Morton's neuroma: is it always symptomatic? AJR Am J Roentgenol 2000;175:649–653.

45. Kransdorf MJ, Jelinek JS, Moser RP Jr, et al. Soft-tissue masses: diagnosis using MR imaging. AJR Am J Roentgenol 1989;153:541–547.

46. Dalinka MK, Zlatkin MB, Chao P, Kricun ME, Kressel HY. The use of magnetic resonance imaging in the evaluation of bone and soft-tissue tumors. Radiol Clin North Am 1990;28:461–470.

47. Sundaram M, McLeod RA. MR imaging of tumor and tumorlike lesions of bone and soft tissue. AJR Am J Roentgenol 1990;155:817–824.

48. Greenfield GB, Arrington JA, Kudryk BT. MRI of soft tissue tumors. Skeletal Radiol 1993;22:77–84.

49. Soler R, Castro JM, Rodriguez E. Value of MR findings in predicting the nature of the soft tissue lesions: benign, malignant or undetermined lesion? Comput Med Imaging Graph 1996;20:163–169.

50. Kransdorf MJ, Moser RP Jr, Meis JM, Meyer CA. Fat-containing soft-tissue masses of the extremities. RadioGraphics 1991;11: 81–106.

51. Simon MA, Finn HA. Diagnostic strategy for bone and soft-tissue tumors. J Bone Joint Surg Am 1993;75:622–631.

52. Sheppard DG, Libshitz HI. Post-radiation sarcomas: a review of the clinical and imaging features in 63 cases. Clin Radiol 2001;56: 22–29.

53. Beaman FD, Kransdorf MJ, Andrews TR, Murphey MD, Arcara LK, Keeling JH. Superficial soft-tissue masses: analysis, diagnosis, and differential considerations. RadioGraphics 2007;27:509–523.

54. De Schepper AM, De Beuckeleer L, Vandevenne J, Somville J. Magnetic resonance imaging of soft tissue tumors. Eur Radiol 2000;10:213–223.

55. Dinauer PA, Brixey CJ, Moncur JT, Fanburg-Smith JC, Murphey MD. Pathologic and MR imaging features of benign fibrous soft-tissue tumors in adults. RadioGraphics 2007;27:173–187.

56. O'Sullivan P, O'Dwyer H, Flint J, Munk PL, Muller N. Soft tissue tumours and mass-like lesions of the chest wall: a pictorial review of CT and MR findings. Br J Radiol 2007;80: 574–580.

57. Cohen JM, Weinreb JC, Redman HC. Arteriovenous malformations of the extremities: MR imaging. Radiology 1986;158:475–479.

58. Kransdorf MJ, Murphey MD. Radiologic evaluation of soft-tissue masses: a current perspective. AJR Am J Roentgenol 2000; 175:575–587.

59. Kettelhack C, Wickede M, Vogl T, Schneider U, Hohenberger P. 31Phosphorus-magnetic resonance spectroscopy to assess histologic tumor response noninvasively after isolated limb perfusion for soft tissue tumors. Cancer 2002;94:1557–1564.

60. Einarsdottir H, Karlsson M, Wejde J, Bauer HC. Diffusion-weighted MRI of soft tissue tumours. Eur Radiol 2004;14:959–963.

61. Dudeck O, Zeile M, Pink D, et al. Diffusion-weighted magnetic resonance imaging allows monitoring of anticancer treatment effects in patients with soft-tissue sarcomas. J Magn Reson Imaging 2008;27:1109–1113.

62. Weatherall PT. Benign and malignant masses: MR imaging differentiation. Magn Reson Imaging Clin N Am 1995;3:669–694.

63. Kalayanarooj S. Benign and malignant soft tissue mass: magnetic resonance imaging criteria for discrimination. J Med Assoc Thai 2008;91:74–81.

64. Enochs WS, Hyslop WB, Bennett HF, Brown RD 3rd, Koenig SH, Swartz HM. Sources of the increased longitudinal relaxation rates observed in melanotic melanoma: an in vitro study of synthetic melanins. Invest Radiol 1989;24:794–804.

65. Gomori JM, Grossman RI, Shields JA, Augsburger JJ, Joseph PM, DeSimeone D. Choroidal melanomas: correlation of NMR spectroscopy and MR imaging. Radiology 1986;158:443–445.

66. Rubin JI, Gomori JM, Grossman RI, Gefter WB, Kressel HY. High-field MR imaging of extracranial hematomas. AJR Am J Roentgenol 1987;148:813–817.

67. Koenig SH, Brown RD 3rd. The importance of the motion of water for magnetic resonance imaging. Invest Radiol 1985;20:297–305.

68. Burk DL Jr, Dalinka MK, Kanal E, et al. Meniscal and ganglion cysts of the knee: MR evaluation. AJR Am J Roentgenol 1988;150: 331–336.

69. Ferris JD, Bloom PA, Goddard PR, Collins C. Quantification of melanin and iron content in uveal malignant melanomas and correlation with magnetic resonance image. Br J Ophthalmol 1993;77:297–301.

70. Sundaram M, McGuire MH, Schajowicz F. Soft-tissue masses: histologic basis for decreased signal (short T2) on T2-weighted MR images. AJR Am J Roentgenol 1987;148: 1247–1250.

71. Holland BA, Kucharcyzk W, Brant-Zawadzki M, Norman D, Haas DK, Harper PS. MR imaging of calcified intracranial lesions. Radiology 1985;157:353–356.

72. Burke BJ, Escobedo EM, Wilson AJ, Hunter JC. Chondrocalcinosis mimicking a meniscal tear on MR imaging. AJR Am J Roentgenol 1998;170:69–70.

73. Henkelman RM, Watts JF, Kucharczyk W. High signal intensity in MR images of calcified brain tissue. Radiology 1991;179:199–206.

74. Monu JU, McManus CM, Ward WG, Haygood TM, Pope TL Jr, Bohrer SP. Soft-tissue masses caused by long-standing foreign bodies in the extremities: MR imaging findings. AJR Am J Roentgenol 1995;165: 395–397.

75. Stiskal MA, Neuhold A, Szolar DH, et al.

Rheumatoid arthritis of the craniocervical region by MR imaging: detection and characterization. AJR Am J Roentgenol 1995;165:585–592.

76. Studler U, Mengiardi B, Bode B, et al. Fibrosis and adventitious bursae in plantar fat pad of forefoot: MR imaging findings in asymptomatic volunteers and MR imaging—histologic comparison. Radiology 2008;246:863–870.

77. White LM, Schweitzer ME, Khalili K, Howarth DJ, Wunder JS, Bell RS. MR imaging of primary lymphoma of bone: variability of T2-weighted signal intensity. AJR Am J Roentgenol 1998;170:1243–1247.

78. Jelinek JS, Kransdorf MJ, Utz JA, et al. Imaging of pigmented villonodular synovitis with emphasis on MR imaging. AJR Am J Roentgenol 1989;152:337–342.

79. Levine E, Wetzel LH, Neff JR. MR imaging and CT of extrahepatic cavernous hemangiomas. AJR Am J Roentgenol 1986;147:1299–1304.

80. Yu JS, Chung C, Recht M, Dailiana T, Jurdi R. MR imaging of tophaceous gout. AJR Am J Roentgenol 1997;168:523–527.

81. Martinez S, Vogler JB 3rd, Harrelson JM, Lyles KW. Imaging of tumoral calcinosis: new observations. Radiology 1990;174:215–222.

82. Nishimura H, Zhang Y, Ohkuma K, Uchida M, Hayabuchi N, Sun S. MR imaging of soft-tissue masses of the extraperitoneal spaces. RadioGraphics 2001;21:1141–1154.

83. Harish S, Lee JC, Ahmad M, Saifuddin A. Soft tissue masses with "cyst-like" appearance on MR imaging: distinction of benign and malignant lesions. Eur Radiol 2006;16:2652–2660.

84. Murphey MD, McRae GA, Fanburg-Smith JC, Temple HT, Levine AM, Aboulafia AJ. Imaging of soft-tissue myxoma with emphasis on CT and MR and comparison of radiologic and pathologic findings. Radiology 2002;225:215–224.

85. Blacksin MF, Siegel JR, Benevenia J, Aisner SC. Synovial sarcoma: frequency of nonaggressive MR characteristics. J Comput Assist Tomogr 1997;21:785–789.

86. Ma LD, McCarthy EF, Bluemke DA, Frassica FJ. Differentiation of benign from malignant musculoskeletal lesions using MR imaging: pitfalls in MR evaluation of lesions with a cystic appearance. AJR Am J Roentgenol 1998;170:1251–1258.

87. Sundaram M, Sharafuddin MJ. MR imaging of benign soft-tissue masses. Magn Reson Imaging Clin N Am 1995;3:609–627.

88. Jelinek J, Kransdorf MJ. MR imaging of soft-tissue masses: mass-like lesions that simulate neoplasms. Magn Reson Imaging Clin N Am 1995;3:727–741.

89. Tateishi U, Hasegawa T, Beppu Y, Kawai A, Satake M, Moriyama N. Prognostic significance of MRI findings in patients with myxoid-round cell liposarcoma. AJR Am J Roentgenol 2004;182:725–731.

90. Tan HM, Peh WC, Shek TW. A distinctive shoulder mass. Br J Radiol 2001;74:1159–1160.

91. Morton MJ, Berquist TH, McLeod RA, Unni KK, Sim FH. MR imaging of synovial sarcoma. AJR Am J Roentgenol 1991;156:337–340.

92. van der Woude HJ, Verstraete KL, Hogendoorn PC, Taminiau AH, Hermans J, Bloem JL. Musculoskeletal tumors: does fast dynamic contrast-enhanced subtraction MR imaging contribute to the characterization? Radiology 1998;208:821–828.

93. Daldrup H, Shames DM, Wendland M, et al. Correlation of dynamic contrast-enhanced MR imaging with histologic tumor grade: comparison of macromolecular and small-molecular contrast media. AJR Am J Roentgenol 1998;171:941–949.

94. Verstraete KL, De Deene Y, Roels H, Dierick A, Uyttendaele D, Kunnen M. Benign and malignant musculoskeletal lesions: dynamic contrast-enhanced MR imaging—parametric "first-pass" images depict tissue vascularization and perfusion. Radiology 1994;192:835–843.

95. Jones BC, Sundaram M, Kransdorf MJ. Synovial sarcoma: MR imaging findings in 34 patients. AJR Am J Roentgenol 1993;161:827–830.

96. Morrison WB, Schweitzer ME, Wapner KL, Lackman RD. Plantar fibromatosis: a benign aggressive neoplasm with a characteristic appearance on MR images. Radiology 1994;193:841–845.

97. Kransdorf MJ, Meis JM, Montgomery E. Elastofibroma: MR and CT appearance with radiologic-pathologic correlation. AJR Am J Roentgenol 1992;159:575–579.

98. De Schepper AM, Ramon FA, Degryse HR. Statistical analysis of MRI parameters predicting malignancy in 141 soft tissue masses. Rofo 1992;156:587–591.