Benign soft-tissue lesions outnumber their malignant counterparts by a factor of 100:1,1 but many are small and superficial and do not lead to imaging or biopsy. Soft-tissue sarcomas are estimated to represent 1% of malignant tumors.2,3 The incidence of soft-tissue sarcoma is 8 per 100,000.4 The incidence of soft-tissue sarcoma increases significantly with age, and in patients 80 and older is 8 per 100,000.5 Magnetic resonance (MR) imaging (MRI) is the favored modality for evaluation of soft-tissue tumors and tumor-like conditions. It is valuable for lesion detection, diagnosis, and staging. Although advances in thin-section computed tomography (CT) have recently allowed detailed multiplanar reconstructions, MRI allows superior soft-tissue contrast without radiation exposure.

When planning an MRI study for evaluation of a soft-tissue lesion at least 2 orthogonal planes should be obtained. In our experience lesions are typically best evaluated in the axial plane and this is usually the most familiar to radiologists. The secondary plane of imaging for an anterior or posterior lesion is typically the sagittal plane. Coronal sequences are optimal for evaluation of medial or lateral masses.

T1-weighted (T1W) and T2-weighted (T2W) sequences should be obtain as most soft-tissue lesions have been described with their spin-echo (SE) T1W and T2W signal characteristics. Fast SE sequences in place of SE sequences can reduce scanning time and patient motion artifacts. Gradient-echo sequences can be useful in demonstrating hemosiderin with “blooming,” but also is subject to artifact caused by metal, hemorrhage, and air. Short tau inversion recovery and T2 fat saturation images increase sensitivity to abnormal tissue containing increased water content. However, these techniques also reduce information concerning various tissue consistencies and should be used in the secondary, not the primary plane of imaging. The smallest diagnostic field of view is preferable when evaluating these lesions.

The use of intravenous contrast in lesion evaluation is controversial, but can be useful. Gadolinium contrast agents increase the T1W signal intensity of many soft-tissue tumors, allowing distinction between tumor and muscle or tumor and edema, but the surrounding area of edema may enhance as well. Information about tumor vascularity is also obtained.6,7 Contrast may allow distinction of small tumor nodules in a predominantly cystic lesion or a “spontaneous hematoma.” Malignant lesions may show increased neovascularity at their periphery and high interstitial pressure at their center leading to a high rim-to-center differential enhancement ratio.8 The use of intravenous contrast also increases the cost and length of time of the examination. Severe reactions to gadolinium and nephrogenic systemic fibrosis are rare, but they do occur.

Many investigators have evaluated if dynamic enhancement with gadolinium can help differentiate benign from malignant soft-tissue lesions.6,9,10 High soft-tissue vascularity and perfusion demonstrates an increased rate of enhancement. Malignant lesions usually reveal greater enhancement and an increased rate of enhancement.11 One difficulty with dynamic contrast-enhanced imaging is a significant overlap between the rate of enhancement of benign and malignant lesions.12 We do not routinely perform dynamic enhancement sequences, at our institutions.

Although MR imaging is excellent at delineating soft-tissue lesions, a correct histologic diagnosis based on imaging studies alone is seen in only 25%-30% of cases.13-15 However, we believe that this percentage continues to increase and ultimately will approach the 75%-90% range.16 Most cases are nonspecific with intermediate T1 and intermediate to high T2 signal. A specific diagnosis should be obtained by using a combination of lesion signal intensity, location, growth pattern, and other unique characteristics of the lesion. Unless a specific diagnosis can be determined, the lesion should be considered indeterminate and an appropriate biopsy path should be discussed with the orthopedic oncologist or treating surgeon. A poorly selected biopsy path may violate compartments needed for reconstruction and an amputation may result.

Some authors have proposed that criteria such as tumor margins, homogenous vs. heterogeneous signal intensity,
and lesion size can distinguish a benign from malignant lesion in greater than 90% of cases. Other reports note malignant lesions can appear smoothly margined and homogeneous and MR appearance cannot accurately separate benign and malignant processes. Malignancies tend to grow pushing against adjacent structures and form a pseudocapsule as they enlarge. The pseudocapsule consists of compressed fibrous connective tissue, normal tissue, vascularization, and inflammatory reaction. Malignant lesions tend to respect anatomic compartments and fascial borders until late in their course. Heterogeneous signal may represent mixed tissue types, necrosis, or hemorrhage within the lesion. Only a minority (5%) of benign soft-tissue tumors are greater than 5 cm in diameter and about 1% of benign lesions are deep. In general, well-defined, smooth margins, homogeneous signal intensity, and small size are seen with benign lesions and irregular margins, heterogeneous signal and large size are indications of malignant lesions. Unless a specific diagnosis can be determined, a lesion should be considered indeterminate and an appropriate biopsy path should be discussed with the orthopedic oncologist or treating surgeon.

An intracompartmental lesion is one which has not crossed any natural anatomic boundaries, such as cortical bone, articular cartilage, joint capsule, fascial septa, tendon or ligament. Identification of invasion of other compartments is important for tumor staging and is often apparent on MR. More aggressive lesions more readily invade surrounding tissues and cross anatomic boundaries. Vascular channels and poorly planned biopsy paths may assist in invasion of adjacent compartments.

Lesion location is important for restricting the differential diagnosis. MRI with its excellent soft-tissue contrast is the most valuable modality for determining location. Lesion location includes intramuscular, intermuscular, subcutaneous, and intra-articular/periaricular. Multifocal or an extensive lesion also limits diagnostic considerations to include angiomatous lesions, neurofibromatosis, fibromatosis, lipomatosis, myxoma (Mazabraud syndrome), metastases, or lymphoma. The anatomic location may also aid in diagnosis, such as elastofibroma occurring deep to the scapular tip.

Lesions discussed in the following paragraphs are included for their frequency, specific location, or unique imaging characteristics allowing a specific diagnosis or a limited differential diagnosis. For the common but nonspecific lesions, a reasonable differential diagnosis requires knowledge of lesion prevalence, anatomic distribution, and age range. Lesions that predominantly affect pediatric patients are not discussed in this article.

**Fibromatoses**

Fibromatosis refers to a family of benign fibrous proliferations. The soft-tissue fibromatoses may be divided into superficial (fascial) and deep (musculoaponeurotic) lesions. These are benign lesions, but deep-seated lesions can display aggressive local biological behavior with rapid growth and frequent recurrence (19%-77% in the first 2 years), but no metastases. In some cases, amputation may be necessary or patient demise may result from involvement of crucial structures.

**Superficial Fibromatosis—Palmar and Plantar Fibroma**

Palmar fibromatosis (Dupuytren disease) is the most common of the superficial fibromatoses, affecting 1%-2% of the population. These lesions occur 3-4 times more commonly in men and most frequently in patients aged more than 65 years (up to 20%). Bilateral lesions are present in up to 50% of cases. The lesions are painless, slow-growing palmar nodules, which may cause a flexion contracture, affecting the flexor tendons of the fourth and fifth fingers. MR typically shows multiple nodular or cordlike superficial soft-tissue masses, which involve the aponeurosis of the volar aspect of the hand, extending superficially in parallel to the flexor tendons. Lesion signal intensity on T1W and T2W images is low (similar to tendon) reflecting hypocellularity and dense collagen. MR can be helpful for surgical planning as more immature lesions demonstrate intermediate to higher signal on T1W and T2W images, reflecting the high cellularity, and have a higher local recurrence rate after local resection. Mature lesions with low T1W and T2W signal intensity are less likely to locally recur.

Lesions show diffuse enhancement, which is more prominent in lesions with higher cellularity.

Plantar fibromatosis (Ledderhose disease) occurs less frequently than the palmar lesion, with an incidence of 0.23%. In our experience, Ledderhose disease is more frequently imaged in our institutions than Dupuytren disease. It presents most frequently in patients aged 30-50 years. Men are affected twice as often as females, and lesions are bilateral in 20%-50% of cases. Associated palmar fibromatosis may be present in 10%-65% of cases. Patients present with one or more subcutaneous nodules, which most frequently (78%) are found in the medial aspect of the plantar arch and can extend to the skin or deep structures of the foot. The lesions are typically painless, but may have pain with prolonged standing or walking. With MR imaging, superficial lesions along the deep plantar aponeurosis typically blend with the adjacent plantar musculature. Lesions typically show heterogeneous signal (92%), which is isointense to hypointense to skeletal muscle on T1W and T2W sequences (Fig. 1). The degree of enhancement has been reported as marked in approximately 67% and mild in 33% of cases. Linear tails of extension (“fascial tail sign”) along the aponeurosis are frequent and best seen following contrast.

**Deep Fibromatosis**

The World Health Organization in April 2002 designated the term desmoid-type fibromatosis for all deep fibromatoses. Desmoid tumor is a descriptive term from the Greek word desmos meaning “band” or “tendon.” Deep, or musculoaponeurotic, fibromatoses include extra-abdominal fibromatosis or aggressive fibromatosis (49%), abdominal fibromatosis (43%), and intra-abdominal fibromatosis (8%).
Intra-abdominal fibromatosis is the type most commonly associated with Gardner syndrome.\textsuperscript{32,33} Abdominal fibromatosis tends to occur in women during or immediately after pregnancy or with oral contraceptive use. Estrogen appears to be a stimulatory growth factor.\textsuperscript{34} The most common locations of extra-abdominal fibromatosis in a large series by the AFIP are the shoulder/upper arm (28%), chest wall/paraspinal (17%), and thigh (12%). Desmoid-type fibromatosis is most common in the second and third decades with a peak incidence between the ages 25 and 35.\textsuperscript{23,35} Two to 4 people per million are affected with this lesion and less than 5% are seen in the pediatric age group.\textsuperscript{24} There is a female predilection in younger patients, which equalizes in older patients. Desmoid type fibromatosis presents as a deep, firm, and poorly circumscribed soft-tissue mass, which is usually slow growing and painless. Lesions may be multicentric in 10%-15% of cases and may insinuate about vital neurovascular structures.\textsuperscript{23} A skeletal dysplasia has been reported in 19% of patients with multicentric desmoid-type fibromatosis. MR is the optimal modality for evaluation of deep fibromatosis, due to its superior soft-tissue contrast. Lesions are usually centered intermuscularly with a rim of fat (split fat sign). Invasion of the surrounding muscle is frequent. The lesions are equally likely to be well defined or have irregular infiltrative margins.\textsuperscript{36,37} Linear extension along fascial planes (fascial tail sign) is a common manifestation (80% of cases).\textsuperscript{37} The signal intensity of desmoid-type fibromatosis is quite variable reflecting the amount of collagen and degree of cellularity of the lesion. Immature lesions with marked cellularity reveal higher signal intensity on long repetition time (TR) images. In our experience, these lesions are also associated with a higher local recurrence rate after resection. More mature hypocellular lesions with abundant collagen reveal lower signal intensity on T1W and T2W sequences.\textsuperscript{37,38} Large studies of patients have shown the most common appearance of desmoid-type fibromatosis on MR is intermediate signal intensity on both T1W (similar to muscle) (83%-95% of cases) and T2W images (lower than fat but higher than muscle on images without fat suppression) (46%-77% of cases).\textsuperscript{36,37,39-41} T1W and T2W sequences commonly show significant heterogeneity (Fig. 2). Postcontrast images reveal moderate to marked heterogeneous enhancement with less than 10% of lesions lacking significant enhancement.\textsuperscript{42} Although low-signal T2W areas are not specific for desmoid-type fibromatosis (See suggested differential later in the text) the bandlike morphology (low-signal bands are seen in 62%-91% of cases) of low signal intensity suggests the diagnosis. These low-signal bands are best observed on T2W or T1W fat-suppressed images post contrast (the hypocellular collagenized bands do not enhance).

Differential diagnosis for soft-tissue lesions with areas of low signal intensity on T1W and T2W sequences includes...
Desmoid-type fibromatosis, densely calcified masses, pigmented villonodular synovitis/giant cell tumor of tendon sheath (GCTTS), granular cell tumor, and malignant fibrous histiocytoma (MFH)/fibrosarcoma.

**Elastofibroma**

Elastofibroma dorsi is a slow-growing myofibroblastic pseudotumor and likely represents a reactive rather than neoplastic process.\(^\text{23,43}\) It is found between the inferior scapula tip and the chest wall in 95%-99% of cases.\(^\text{44}\) The etiology is thought to be repetitive mechanical friction between the chest wall and scapular tip. These lesions were found in 24% of women and 11% of men in an autopsy series of patients greater than 55 years of age.\(^\text{15}\) Most patients are older adults with peak incidence in the sixth and seventh decades. Lesions may be bilateral in 10%-66% of cases.\(^\text{23}\) Most patients are asymptomatic. The most common symptom is stiffness, present in 25% of cases. There is a 2:1 female predominance.\(^\text{44}\) A key imaging feature is entrapped fat within the lesion, which is well seen with CT or MR. T1W images show a crescentic, heterogeneous lesion with signal similar to adjacent skeletal muscle and streaks of high signal representing trapped fat (Fig. 3). Intermediate and heterogeneous signal is also present on T2W sequences and heterogeneous enhancement is common. Characteristic location with demonstration of entrapped fat is pathognomonic of elastofibroma. A differential diagnosis for lesions that are relatively hypocellular and contain abundant collagen would include elastofibroma, extra-abdominal desmoid-type fibromatosis, neurofibroma, and MFH/fibrosarcoma.

**Figure 2** Deep Fibromatosis. Deep fibromatosis in a 35-year-old woman with a slowly enlarging shoulder mass for 10 months. (A) Axial T1-weighted (TR/TE; 516.664/14), (B) STIR (TR/TE; 4950/19.872), and (C) T1 postcontrast, fat-suppressed (TR/TE; 11.92/666.664) MR images demonstrate a heterogeneous mass lying deep to the latissimus dorsi muscle with intermediate T1 and high T2 signal, with diffuse enhancement. Fascial linear extension (white arrow) can be seen medially. Areas of bandlike nonenhancing low T1 and T2 signal (white arrowheads) correspond with hypocellular areas of collagen. The bandlike morphology (open arrow) are better depicted on the (D) sagittal T1-weighted postcontrast fat-suppressed (TR/TE, 12.936/566.664) MR image.
Nodular Fasciitis

Nodular fasciitis is a benign soft-tissue lesion of unknown cause composed of proliferating fibroblasts. The lesion may grow rapidly and show high mitotic activity, simulating a more aggressive lesion. It is the most common benign tumor or tumorlike condition of fibrous tissue. It typically affects patients aged 20-40 years with no sex predilection. Lesions typically present as a rapidly growing painless mass, although mild pain or tenderness may be present in approximately 50% of cases. The upper extremity is involved in 46% of cases, particularly the volar forearm. Nodular fasciitis has 3 common locations: subcutaneous, fascial, and intramuscular. Lesions are subcutaneous between 3 and 10 times more frequently than other sites. The fascial form is the second most common and least frequent is the intramuscular type. The deeper intramuscular form is usually larger and is the most likely to be mistaken for sarcoma. Most lesions show a maximal diameter of 2 cm or less. On T1W images, nodular fasciitis has a signal intensity similar to or slightly higher than skeletal muscle (Fig. 4). With T2W sequences it is most often high signal intensity (greater than subcutaneous fat), but may demonstrate intermediate signal intensity. Lesions are frequently homogeneous on T1W sequences and heterogeneous on longer TR acquisitions. These lesions, as well as ancient schwannomas, are one of the few benign lesions that may demonstrate central necrosis, which may contribute to lesion heterogeneity. Contrast enhancement was present in all cases in a series of 8 patients with a diffuse enhancement pattern in 67% of cases and peripheral enhancement in approximately 25%. Linear extension along the fascia (“fascial tail sign”) may suggest the diagnosis, and mild surrounding edema may also be present.

Dermatofibrosarcoma Protuberans

Dermatofibrosarcoma protuberans constitutes approximately 6% of soft-tissue sarcomas. The lesion is an intermediate grade malignancy, but fibrosarcomatous transformation may occur in 17%-27%. Dermatofibrosarcoma protuberans most commonly occurs in the third to fifth decades of life. Males are affected more frequently than females. The lesion presents as a slowly growing reddish brown to bluish superficial skin nodule. Large lesions may become painful. The trunk is affected in up to 50% of cases followed up in frequency by the proximal upper and lower extremities. MR demonstrates a lesion involving the skin and subcutaneous adipose tissue with a nodular or lobular architecture. The signal characteristics of the lesion are nonspecific, with signal similar to skeletal muscle on T1W images and similar to or greater than fat on T2W sequences. Moderate enhancement is seen after gadolinium enhancement. The lesion may show heterogeneous signal if hemorrhage or necrosis are present. Satellite nodules in the adjacent subcutaneous tissue may be present, and linear extensions along the skin are also often detected.

A differential diagnosis for a subcutaneous lesion would include cutaneous MFH/fibrosarcoma, dermatofibrosarcoma protuberans, skin adnexal/appendage tumor, and metastasis.

MFH/Fibrosarcoma

The World Health Organization significantly reorganized the nomenclature of malignant fibrous lesions of the soft tissue in April 2002. The term MFH has been replaced by undifferentiated high-grade pleomorphic sarcoma. Giant cell MFH and inflammatory MFH are now called undifferentiated high-grade pleomorphic sarcoma with giant cells and undifferentiated high-grade pleomorphic sarcoma with prominent inflammation. Malignant fibrous histiocytoma (MFH) is now called myxofibrosarcoma. Having said this, most of our colleagues continue to use the term MFH either out of familiarity or because of the cumbersome new designations.

Fibrosarcoma is a low-to-intermediate grade malignant tumor of fibroblasts composing 5% of soft-tissue sarcomas. It occurs primarily in adults with 60% of patients aged 40-70
There is a male predilection (61% of cases). It most commonly involves the deep soft tissues of the trunk. Patients usually present with a painless mass slowly enlarging over several months duration and 30% of patients may have dull aching pain or tenderness.

MFH/undifferentiated high-grade pleomorphic sarcoma is a high-grade lesion of fibroblasts, myofibroblasts, or undifferentiated mesenchymal cells. Subtypes include storiform and/or pleomorphic (50%-60%), myxoid (25%), giant cell (5%-10%), and inflammatory (<5%) types. MFH is the most common soft-tissue sarcoma of adults accounting for 20%-30% of soft-tissue sarcomas and is the most frequent post radiation sarcoma. Peak incidence is in the fifth decade. There is a male predilection (70% of lesions). Patients usually present with an enlarging, painless soft-tissue mass with an average size of 5-10 cm. Most common locations are the lower extremity (50%), upper extremity (25%), and retroperitoneum (15%). Lesions are most commonly in a deep intramuscular location (70%) with 5%-10% being subcutaneous.

Imaging features of adult fibrosarcoma and MFH are indistinguishable and described together. Lesions are typically seen as an intramuscular mass with intermediate intensity on T1W and intermediate-to-high (greater than fat) signal on T2W images (Fig. 6). The lesions are heterogeneous on all pulse sequences reflecting variable amounts of collagen, myxoid tissue, necrosis, and hemorrhage. Low signal regions on T2W sequences presumably represent areas of high collagen content. The lesion margin is usually well defined because of a fibrous pseudocapsule. MFH and/or fibrosarcoma typically show enhancement, which may be heterogeneous if areas of necrosis or hemorrhage are present. Destruction of adjacent cortical bone may be present, similar to synovial sarcoma. When there is history of a spontaneous hematoma, be suspicious of an underlying neoplasm (particularly MFH or synovial sarcoma) and look for solid or nodular enhancing components, usually in the periphery. Hematomas reveal thick non-nodular walls often containing hemosiderin. Edema is often seen surrounding a hematoma secondary to irritation from the blood, but a tumor that hemorrhages typically retains the blood within the pseudocapsule and edema is not a prominent feature.

Lipoma

Lipoma is the most common soft-tissue neoplasm and represents about 50% of all soft-tissue tumors. The incidence is approximately 2.1 per 100 people. Lipoma is more common than liposarcoma by a ratio of 100:1. Most lipomas are discrete masses categorized by anatomic location as superficial (subcutaneous) or deep. Deep lipomas are much less common and account for approximately 1% of lipomas. Lipomas are typically small with less than 5 cm. Superficial lipomas are most commonly located in the trunk, shoulders, upper arm, and neck. Superficial lipoma
is often difficult to distinguish from the surrounding cutaneous tissue, particularly if the lesion is “nonencapsulated.” Therefore, we prefer to place a fiducial marker over superficial lesions, position the patient so the lesion is not compressed, and compare the area to the contralateral side.

Deep lipomas (including the intramuscular and intermuscular lipomatous tumors) occur most commonly in patients aged 20-60 years. Men are affected more frequently than women, and lesions commonly affect the large muscles of the lower extremity (45%), trunk (17%), and shoulder (12%). Lipomas of the retroperitoneum are rare and a lipomatous lesion in this location should be treated as a liposarcoma. Lipomas most commonly demonstrate signal characteristics identical to subcutaneous fat on all pulse sequences with high signal on T1W and T2W sequences with minimal (<2 mm) septations, however 28%-30% may have thick septa or nodularity similar to liposarcoma. Intramuscular lipomas may have irregular margins, which interdigitate with the adjacent skeletal muscle referred to as “infiltrating lipoma.” There should be no significant enhancement of the lesion after contrast administration.

Differential diagnosis for a lipomatous lesion with mild complexity includes lipoma, angiolipoma, myolipoma, chondroid lipoma, lipoblastoma, spindle cell/pleomorphic lipoma, hibernoma, and well-differentiated liposarcoma.

**Liposarcoma**

The World Health Organization has reorganized the nomenclature of malignant lipomatous lesions of soft tissue in April 2002. Current subtypes of liposarcoma include well-differentiated liposarcoma, dedifferentiated liposarcoma, myxoid liposarcoma, pleomorphic liposarcoma, and mixed-type liposarcoma. The previous lesion referred to as round cell liposarcoma has been incorporated into the category of myxoid liposarcoma. Liposarcoma is the second most common soft-tissue sarcoma after MFH. The estimated annual incidence is 2.5 per million population.

**Well-Differentiated Liposarcoma**

Well-differentiated liposarcoma is a low-grade malignancy, which recurs locally, but does not metastasize. It is the most common subtype representing about 50% of all liposarcomas. There is an equal sex distribution. This lesion is not seen in patients aged less than 10 years and the peak prevalence is in the sixth and seventh decades. Common lesion locations include the lower extremities (50%), retroperitoneum (20%-33%), upper extremity (14%), and trunk (12%). Retroperitoneal lesions have up to a 91% local recurrence rate after resection. Lesions are most frequently intramuscular, but they can occur in intermuscular and subcutaneous locations. With MR, well-differentiated liposarcoma is a mass composed of greater than 75% adipose tissue, but with significant nonadipose components seen as prominent thick septa and focal nodular regions usually less than 2 cm in size (Fig. 8). Nodular nonlipomatous components of size greater than 3 cm suggest dedifferentiated liposarcoma. The lesion can be difficult to distinguish from lipoma. Statistical factors favoring the diagnosis of well-differentiated liposarcoma as opposed to lipoma include male sex, age...
greater than 66 years, lower percentage of fat in the lesion, mineralization, size greater than 10 cm, greater than 2 mm thick septa, or nonlipomatous nodular or globular foci.86 A differential diagnosis for soft-tissue lesions with components of relatively high signal intensity on T1W images may include lipoma/well-differentiated liposarcoma, clear cell sarcoma, melanotic melanoma, alveolar soft part sarcoma, hemangioma, and subacute hemorrhage.

Myxoid Liposarcoma

Myxoid liposarcoma is an intermediate to high-grade malignancy depending on the percentage of round cell component. It is the second most common type of liposarcoma representing 20%-50% of all liposarcomas.78,87-89 Myxoid liposarcomas account for 10% of all soft-tissue sarcomas.89 Peak prevalence is from the forth to fifth decades of life. These lesions show no gender predilection78 and predominantly affect the lower extremity (75%-80% of cases), particularly the popliteal region and medial thigh. Extremity myxoid liposarcoma are most frequently intermuscular (70%-80% of cases). Intramuscular and subcutaneous lesions are less common.23,79,81,87-89 Clinical presentation of myxoid liposarcoma is that of a painless soft-tissue mass. On MR, these lesions are typically large, well-defined, and multilobulated (Fig. 9). Low signal intensity T1W images and marked high signal T2W sequences reflect the high water content of the lesion and these features may mimic a cyst. Adipose tissue with high T1W signal typically constitutes a small volume of the lesion (<10%) with a lacy or linear pattern. In our experience, approximately 90% of myxoid liposarcomas demonstrate fat on an MR image. Identification of the subtle fat component may require comparison of T1W and T2W images in the same plane.78,91,92 Areas of intermediate T1W and T2W signal may represent foci of a round cell component. Myxoid liposarcoma may demonstrate enhancement in a peripheral nodular (61% of cases), central nodular (44% of cases), or diffuse pattern (17% of cases) allowing differen-
tion from a cystic lesion. Round cell components may reveal more marked diffuse enhancement.93

Differential diagnosis for a predominantly myxoid appearing soft-tissue lesion includes; myxoid liposarcoma, myxofibrosarcoma (or myxoid MFH), myxoid chondrosarcoma, myxoma, ganglion cyst, synovial cyst/bursa, and peripheral nerve sheath tumor.

Benign Peripheral Nerve Sheath Tumor

Benign peripheral nerve sheath tumors (BPNSTs) are typically divided into schwannoma (neurilemoma) and neurofibroma.61 Both lesions contain cells closely related to the normal Schwann cell.

Schwannoma is slightly less common than neurofibroma and comprises approximately 5% of all benign soft-tissue tumors.72 Schwannoma is most commonly seen in patients aged 20-50 years with an equal sex distribution.61,94 Schwannoma is usually a slow growing, nonaggressive lesion that presents as a painless mass of size less than 5 cm. Pain may be associated with larger lesions.73 Common sites of involvement include the cutaneous nerves of the head, neck, and flexor surface of the extremities. Posterior mediastinum and retroperitoneum are frequent locations for deep-seated lesions.61 Schwannoma may be plexiform or multiple in ap-

![Figure 7](image_url)

Lipoma. A 62-year-old man with firm arm nodule for 10 years. (A) Axial T1-weighted (TR/TE; 500/15) image demonstrates a well-encapsulated superficial (subcutaneous) lesion with signal isointense to subcutaneous fat beneath the fiducial marker. A 38-year-old woman with slowly growing thigh mass for 6 years, now with pain on sitting. (B) Axial T1-weighted (TR/TE; 633/11) and (C) T2-weighted fat saturation (TR/TE; 4540/72) images demonstrate an intramuscular lesion (*) with signal identical to subcutaneous fat and thin fibrous septa. (D) Sagittal T1-weighted fat saturation post (TR/TE; 631/11) demonstrates mild peripheral and septal enhancement. Note the similar septations present in the adjacent subcutaneous fat.
Lesions are sporadic in 90% of cases; 3% occur with neurofibromatosis type 2 (NF2) and 2% occur with schwannomatosis. The lesion is typically separable from the adjacent nerve after incising the epineurium and nerve function is thus preserved after resection.

Neurofibroma constitutes slightly more than 5% of benign soft-tissue tumors. Neurofibroma is most commonly seen in patients aged between 20 and 30 years and demonstrates no sex predilection. Three types of neurofibroma are classically described, including localized (90%), diffuse, and plexiform. Superficial cutaneous or deep-seated nerves may be involved. Localized neurofibromas are usually a slow-growing, painless masses measuring less than 5 cm. The diffuse type primarily affects children and young adults and most frequently involves the subcutaneous tissue of the head and neck and only 10% are associated with neurofibromatosis type 1 (NF1). Neurofibroma, unlike schwannoma, cannot be separated from the nerve and complete excision of the neoplasm requires sacrifice of the nerve.

NF1 is seen in 1 of every 2500-3000 births. Males are more commonly affected. NF1 demonstrates multiple local neurofibromas and frequently plexiform lesions. These lesions occur anywhere in the body, both superficial and deep. Plexiform neurofibroma represents diffuse involvement of a

Figure 8  Well-differentiated Liposarcoma. A 31-year-old woman with thigh pain status post fall. (A) Axial T1-weighted (TR/TE; 500/12), (B) short tau inversion recovery (STIR) (TR/TE; 7688/18), (C) T1-weighted fat saturation postcontrast (TR/TE; 468/12), and (D) sagittal T2-weighted (TR/TE; 4303/120) images demonstrate a high-signal intensity intramuscular lipomatous lesion with predominantly fatty signal, but thickened septa (arrows) and mild nodularity (arrowheads).
long segment of nerve giving a “ropelike” or “bag of worms” appearance and is pathognomonic of NF1. The incidence of malignant transformation to malignant peripheral nerve sheath tumor (MPNST) is between 2% and 29% in patients with NF1.

On MR, the signal intensity of localized lesions is nonspecific and will be similar to or lower than muscle on T1-weighted images and higher than fat on T2-weighted images (Fig. 10). Recognition of the well-defined, fusiform shape of the lesion can be very helpful to identify the lesion as BPNST, which is caused by the tubular entering and exiting nerve. With schwannoma, the entering and exiting nerve may be eccentric to the soft-tissue mass. Diffuse neurofibroma may show predominant low T2W signal, which may be related to the high collagen content. Heterogeneity of BPNST is variable, particularly with hemorrhage, necrosis, and areas of degeneration seen in the ancient schwannomas. The “target sign” is almost pathognomonic for neurofibroma (70% of cases), but can be seen with schwannoma. It refers to low-to-intermediate T2W signal centrally secondary to more fibrous tissue and high T2W signal peripherally likely related to myxoid tissue (Fig. 10D). The central fibrous areas have marked contrast enhancement. The “fascicular sign” manifests as multiple ringlike structures seen on T2W or proton density–weighted images and is seen in superficial and deep-seated lesions. MPNST accounts for 5%-10% of soft-tissue sarcomas. It usually affects patients aged 20-50 years, with a slight female predilection. It is associated with NF1 in 25%-70% of cases, where it presents about a decade earlier with a male predilection (80%). Patients present with pain and neurologic symptoms of motor weakness more frequently than those with BPNST. A sudden increase in size of a previously stable lesion should also raise suspicion for MPNST. MPNST usually affects medium to large deep-seated nerves with the sciatic nerve, brachial plexus, and sacral plexus most commonly involved. These lesions are typically greater than 5 cm in size, whereas BPNSTs are frequently less than 5 cm. Distinguishing MPNST and BPNST by imaging can be challenging as the lesions can appear very similar. There are some imaging features that may be helpful. The “target sign” and “fascicular sign” are uncommon in MPNST (Fig. 11). Margins of MPNST may be ill-defined. Central necrosis is more common in the malignant lesion, but can be seen with ancient schwannoma. One study suggests that MPNST and PNST cannot be adequately separated by evaluation of lesion heterogeneity. Enhancement of the benign lesion is variable and prominent enhancement is noted in the malignant lesion. More recently PET imaging, including the use of 11C methionine has been suggested as useful in this distinction as well.
Synovial Sarcoma

Synovial sarcoma is an intermediate to high-grade neoplasm with extensive metastatic potential. This lesion accounts for about 5%-10% of soft-tissue sarcomas. It is typically seen in young adults aged between 15 and 35 years with the mean patient age of 32, although there is a wide age range, including newborns. Males and females are affected equally. Patients with synovial sarcoma may initially present with a palpable slow-growing mass, which can simulate a benign process. In contrast to most other soft-tissue malignancies, pain is often present. The duration of symptom may vary from days to as long as 20 years before initial diagnosis. Synovial sarcomas are most commonly located in the lower extremities (60%-70%) and 80%-95% are in the extremities (often occurring near a joint). The popliteal fossa is the most frequent location. Most synovial sarcomas are centered in an intermuscular location. It is the most common malignancy of the foot and ankle in patients aged 6-45 years. Despite the name, the tumor does not arise from the synovium, and fewer than 10% of cases are intra-articular. Lesions demonstrate calcification, often in the periphery of the tumor, on radiographs in up to 30% of cases. These calcifications are difficult to appreciate on MR. Other soft-tissue lesions, which commonly demonstrate calcification include soft-tissue osteosarcoma/chondrosarcoma, chondroma, myositis ossificans, and leiomyosarcoma. Synovial sarcomas are typically heterogeneous, with signal similar to skeletal muscle on T1W images and equal to or greater than subcutaneous fat on T2W images. The heterogeneity of these lesions is depicted as the “triple sign” in 30%-50% of cases, with areas that are hyperintense, isointense, and hypointense to fat on T2W sequences. This finding is presumably the result of a mixture of solid cellular elements, hemorrhage or necrosis, and calcified or fibrotic collagenized areas. A multiloculated appearance with internal septations may also be present. Hemorrhage is present in more than 40% of patients with fluid levels in...
10%-25% of lesions on MR imaging. A combination of hemorrhage, fluid levels and septa may also cause the “bowl of grapes” sign. Cortical erosion or marrow invasion may be seen on MR in up to 21% of cases. Contrast enhancement is usually prominent and heterogeneous, and can be very important to demonstrate small areas of nodular enhancement in a predominantly cystic lesion that may otherwise be mistaken for a benign cyst. Serpentine vascular channels can be noted in approximately 30% of cases.

Differential diagnosis for soft-tissue lesions with fluid levels includes synovial sarcoma, hemangioma, myositis ossificans, hematoma, and lymphangioma.

**Pigmented Villonodular Synovitis and GCTTS**

Pigmented villonodular synovitis (PVNS) and GCTTS are benign synovial proliferative lesions of the joint and tendon sheath, respectively. These lesions are believed to be neoplas-
tic rather than reactive. They are divided according to their location (intra-articular vs extra-articular) and their pattern of growth (localized or diffuse).

Localized disease, both extraarticular and intraarticular, represents 77% of cases (the tenosynovial form being the most common), compared with diffuse intraarticular involvement, which accounts for 23%. Patients are typically adult, with the peak incidence in the third to fifth decades and there is a slight female predominance. Clinical symptoms include soft-tissue swelling or a slowly enlarging, painless soft-tissue mass, which is freely mobile. Pain may be aggravated by activity. Most of these lesions occur in the hand and wrist (65%-89%). It is one of the most common soft-tissue masses in the hand, second in frequency only to ganglion. In the hand, the lesion more commonly affects the volar aspect of the digits. The foot and ankle location accounts for 5%-15% of lesions. MR frequently demonstrates a nonspecific well-defined soft-tissue mass adjacent to and partially surrounding the tendon. Lesions are approximately equal to or less than skeletal muscle on T1W. On T2W images, lesions are heterogeneous with signal intensity equal to or less than fat. Marked enhancement is noted in most cases. Osseous pressure erosions may be present in 15%-20% of cases.

Pigmented villonodular synovitis is most common in the third and fourth decades. It has equal frequency in men and women, with an annual incidence of approximately 2 per million. Symptoms include mechanical pain aggravated by motion and improves with rest. Swell-

Figure 12 Synovial Sarcoma. A 42-year-old Hispanic female presents with an enlarging extraarticular mass over her superomedial right knee during 6 months. (A) Sagittal proton-density–weighted (TR/TE; 2200/25.6), (B) axial T2-weighted image with fat saturation (TR/TE; 4266.7/105.3), and (C) coronal T2-weighted (TR/TE; 4950/104.1) MR images demonstrate a large, heterogeneous lesion in the superomedial right knee with solid and cystic components. Sagittal MR image demonstrates heterogeneous lesion adjacent to the suprapatellar bursa (arrows). Coronal T2 reveals marked heterogeneity with the “triple sign,” including areas of high (H), intermediate (I) and low (L) signal within the mass.
ing and limited range of motion may also be experienced. \(^1\) PVNS most frequently affects the large joints, with about 75%-80% occurring in the knee. Other joints involved in decreasing order of frequency are the hip, ankle, shoulder, and elbow. \(^2\) Tumor recurrence after surgery is common. Geographic, lytic osseous erosions with sclerotic borders are most common in the hip (93%) and shoulder (75%) because of their smaller capacity. Bone marrow edema may be noted at sites of osseous erosion, but the joint space is usually preserved. \(^3\) MR shows a diffuse, multinodular intra-articular synovial-based mass (Fig. 13). Lesions are approximately equal to or less than skeletal muscle on T1W. There is predominantly decreased signal intensity on T2W images resulting from the hemosiderin with scattered areas of high T2W signal. \(^4\) PVNS reveals susceptibility artifact (“blooming”) on gradient echo sequences, which may help to distinguish the lesion from other causes of diffuse synovial thickening. \(^5\) Intense contrast enhancement is typical, but may vary depending on the amount of fibrosis and hemosiderin in the lesion. \(^6\) There is typically an associated joint effusion, which may be prominent. \(^7\)

**Hemangioma and/or Vascular Malformations**

We tend to combine hemangiomas and vascular malformations into one category for discussion. Hemangiomas and/or vascular malformations are among the most frequent tumors to involve the soft tissue and comprise 7% of all benign tumors. Hemangioma is the most common tu-

![Figure 13](image-url)

**Figure 13** Diffuse PVNS. A 68-year-old white female with a history of knee pain and swelling. (A) Sagittal proton density-weighted (TR/TE; 2000/18), (B) T2-weighted image with fat saturation (TR/TE; 3000/70) and (C) T1-weighted fat saturation postcontrast images (TR/TE; 550/18) show a heterogeneous lesion filling the posterior knee joint (arrows) with intermediate to decreased signal. Postcontrast image demonstrates diffuse enhancement of the lesion (small arrow) and synovitis in the suprapatellar bursa (arrowheads). A 36-year-old woman with knee pain and swelling shows (D) a large intra-articular lesion with “blooming” artifact (arrows) on gradient echo sequence (TR/TE; 58.2/05).
mor in infancy and childhood. It is estimated 1%-2% of the general population and 10% of Caucasians are affected. Hemangiomas are more common in women with a 3:1 ratio. Lesions may increase dramatically in size during pregnancy. Soft-tissue hemangiomas may be superficial or deep, with the deep lesions most frequently intramuscular. Clinical presentation is often a painful lesion that intermittently changes in size. Pain associated with intramuscular hemangioma is often vague and related to exercise. Hemangioma are frequently subdivided based on the predominant type of vascular channel (capillary, cavernous, arteriovenous, or venous). Cavernous hemangiomas frequently calcify with dystrophic mineralization and organizing thrombus (phlebolith) best seen on radiographs or CT. On T1W images, intramuscular hemangioma may be defined as a poorly marginated mass of low-to-intermediate signal intensity with areas of high signal intensity related to fat or slow-flowing blood (Fig. 14). These high signal intensity areas vary from fine lacelike strands to thick course bands. The fat may be so extensive as to simulate lipoma. On T2W sequences, the lesion may be a well-margined or infiltrative mass with very high signal intensity owing to slow blood flow in vascular components in most lesions and intermediate signal corresponding to adipose tissue. The circular vessels seen en face and linear vessels seen longitudinally with adjacent fat overgrowth have a characteristic appearance. These lesions tend to be heterogeneous on all pulse sequences and they frequently infiltrate rather than displace adjacent tissues.

Figure 14 Hemangioma. Hemangioma in a 28-year-old man with a history of a palpable triceps mass for the past 4-5 months. (A) Sagittal T1-weighted (TR/TE; 13/550) MR image demonstrates an intramuscular triceps mass with predominately peripheral lacelike strands of fat. (B) Coronal STIR (TR/TE; 14/1400) image demonstrates areas of high signal corresponding to slow flow vascularity. (C) Axial T1-weighted postcontrast image with fat suppression (TR/TE; 17/1371.83) shows diffuse mildly heterogeneous enhancement and peripheral circular vessels seen en face (white arrowheads).
Hemangioendothelioma, Hemangiopericytoma, and Angiosarcoma

Hemangioendothelioma is a vascular neoplasm of intermediate aggressiveness between hemangioma and angiosarcoma. Hemangioendothelioma occurs in young patients and involves soft tissue more often than bone. Soft-tissue hemangioendothelioma usually involves the deep tissues of the extremities, with approximately 50% of the cases being closely related to a vessel from which they may have arisen.144

Hemangiopericytoma is a vascular neoplasm of intermediate aggressiveness with benign and malignant forms. The highest incidence is in middle-aged adults.61 Hemangiopericytoma commonly involves the lower extremity (35% of cases), most often the soft tissue of the thigh. The pelvis and retroperitoneum are involved in 25% of cases. The tumor often demonstrates large vessels, predominantly in the periphery.144

Figure 15  Hemangiopericytoma. Hemangiopericytoma is suggested by the presence of high-flow peripheral vessels depicted by serpentine flow voids (white arrows). (A) Coronal T1-weighted (TR/TE; 500/10), (B) Sagittal T1-weighted postcontrast with fat saturation (TR/TE; 600/10), and (C) axial T2-weighted (TR/TE; 4000/84) MR images demonstrate a mildly heterogeneous T1 intermediate, T2 hyperintense, and diffusely enhancing mass in the posterior compartment of the mid thigh.
Angiosarcoma is an aggressive, vascular malignancy with high local recurrence and distant metastases. Male to female predilection is 2:1. Angiosarcomas involve the skin (33%), soft tissues (24%), and bone (6%). Angiosarcoma is related to chronic lymphedema in 10% of cases. It is usually not possible to differentiate hemangioendothelioma, hemangiopericytoma, and angiosarcoma radiologically. The MR signal characteristics are intermediate signal on T1 and high signal on long TR sequences. These lesions demonstrate aggressive infiltration of the adjacent tissues. Areas of hemorrhage with high T1W signal may be seen. Prominent serpentine vascular channels in the periphery of the lesion can suggest the diagnosis and are seen most frequently with hemangiopericytoma. The signal intensity of these vascular structures may reflect high flow (low signal on all pulse sequences) or low flow (high signal on T2W images).

Differential diagnosis for a soft-tissue mass with prominent vascular channels includes alveolar soft part sarcoma, metastatic renal cell carcinoma, hemangiopericytoma, hemangiioendothelioma, rhabdomyosarcoma, extraskeletal Ewing sarcoma, and synovial sarcoma.

**Leiomyosarcoma**

Leiomyosarcoma is a high-grade malignancy, which represents approximately 9% of all soft-tissue sarcomas. Patients with soft-tissue leiomyosarcoma have a median age in the fifth to sixth decades. Retroperitoneal lesions (20% of cases) are more common in females 2:1 to 7:1, and there is a male predilection for peripheral lesions (12% of cases). Retroperitoneal lesions present clinically as an abdominal mass and swelling with pain in less than 10%. It is the second most common retroperitoneal tumor after liposarcoma. Extremity lesions present with a painless slowly enlarging mass most commonly affecting the thigh. Imaging of leiomyosarcoma is typically nonspecific. Mineralization on radiograph has been reported in 17% of cases. Lesions are typically isointense to muscle on T1-weighted images and
variously hyperintense relative to muscle on T2-weighted images, with prominent contrast enhancement (Fig. 16). Large lesions are usually more heterogeneous secondary to hemorrhage, necrosis, and cystic change.

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