Sonography of soft-tissue masses

The numerous advantages of MRI in imaging soft tissues have shifted clinicians’ interest toward that modality for evaluating the soft-tissue components of the musculoskeletal system. However, the unique real-time capability of sonography (US), which permits examination during movement and allows guidance of biopsy needles, combined with the exquisite resolution of high-frequency transducers and advances in color Doppler imaging makes US a powerful tool for evaluating soft-tissue masses from the skin to the surface of the bones.

Technical considerations

■ Instrumentation

Although broadband transducers of up to 17 MHz have become standard for the evaluation of very superficial masses, probes of lower center frequency (5 MHz or even 3.5 MHz), which offer a wider field of view and greater ultrasound beam penetration, are sometimes needed to visualize a deeply located lesion or to encompass a large mass. The extended-field-of-view scanning technique has proved very beneficial in musculoskeletal ultrasound in particular when evaluating very large masses. Three-dimensional US has not gained wide acceptance yet because of delays in image reconstruction and lack of intuitive software to navigate through the multitude of planes available, although it is expected that these obstacles will be overcome in the future as the power of on-board computers for image processing increases.

Elastography, which provides elasticity mapping of the soft tissues examined as well as conventional B-mode sonographic images, is a promising technique that has recently become commercially available.

Power Doppler imaging should always be performed when evaluating a mass. The flow mapping of a mass provides new insights into the pathophysiology of masses and improves the differentiation between benign and malignant masses. The use of intravenous ultrasound contrast agents remains mostly investigational.

■ Technique of examination

It is good practice to begin the sonographic examination of a mass by taking a careful history and performing a limited physical examination, focusing on the region to be examined. Combining longitudinal and transverse scans allows calculation of the volume of masses. Comparison with the contralateral anatomic region provides a useful reference for normal anatomy. When a standoff pad is used, the operator can slide the fingers of one hand between the pad and the skin while maintaining the transducer over the region of interest; this allows the mass to be palpated under “sonoscopy”, which establishes an accurate correlation between the palpation and sonographic findings [1].

The deformation and movements of the mass during dynamic maneuvers such as flexion or extension of the adjacent muscles may yield critical information about the relationship between the mass and adjacent structures and thereby identify the anatomic structure from which it is derived [2, 3].

■ Ultrasound-guided interventional procedures

Real-time US is ideal for guiding needle biopsies of soft-tissue masses [4]. Fluid collections can be aspirated with fine (20- or 22-gauge) needles, and percutaneous catheter drainage of abscesses is readily performed with ultrasound guidance. Ultrasound-guided aspiration of ganglion cysts with injection of corticosteroids and local anesthetics has been reported.

Tissue diagnosis of solid soft-tissue tumors, particularly soft-tissue sarcomas, is best achieved with the use of large-core needles and automatic biopsy devices [5-7]. To obtain adequate cores, cutting needles of 14 gauge should be used. Ultrasound is used to guide the needle into the most solid-appearing areas of a mass that contains areas of necrosis. Color Doppler imaging helps identify and avoid large vessels in the tumor or in the planned pathway of the biopsy needle. In contrast to the diagnosis of a primary sarcoma, the diagnosis of a local recurrence of a soft-tissue sarcoma is easily achieved through fine-needle aspiration biopsy.

Techniques used for ultrasound-guided preoperative localization of nonpalpable masses (e.g., recurrences of soft-tissue sarcomas) include simple skin marking if the lesion is superficial, injection of methylene blue or carbon particles in the vicinity of the lesion, insertion of a localizing needle or hookwire, and intraoperative scanning. If needed, the successful excision of a small nonpalpable mass can be confirmed by ex vivo sonographic examination of the fresh specimen.
Nontumoral masses

Many soft-tissue masses are not neoplasms but result from trauma, inflammatory processes, or cystic changes.

Masses of traumatic origin

Masses of traumatic origin include hematomas, muscular ruptures, muscular hernias, fibrous scars, myositis ossificans, and inflammatory reactions around retained foreign bodies [8].

The sonographic appearances of soft-tissue hematomas vary considerably depending on the tissue in which the hematoma develops and the hematoma’s age. Recent hematomas in the subcutaneous fat typically appear as echogenic areas, whereas older, organized hematomas may appear as complex or nonhomogeneous masses containing clots (Fig 1).

Traumatic muscle hematomas may be complicated by the development of myositis ossificans. Calcified material can usually be demonstrated on radiographs after the fourth week following the trauma. Large typical calcifications appear on sonograms as hyperechoic foci with acoustic shadowing. Early sonographic changes, including sheets of echogenic material representing lamellar calcification, have also been described. Heterotopic ossification may also develop in surgical scars and result in firm palpable masses.

Muscular ruptures can result in palpable masses. However, the diagnosis is usually made on the basis of the clinical history and physical examination, although it may be difficult to differentiate between a chronic “healed” rupture and a muscular tumor.

Muscular hernias bulge through a weakened or ruptured fascia or aponeurosis. Real-time US under contraction of the involved muscle readily demonstrates that the palpable mass is actually made of normal muscle tissue and that no further imaging is needed (Fig 2).

Inflammatory masses

US can readily distinguish between an abscess and cellulitis. In cellulitis, US shows thickening and diffuse hyperechogenicity of the subcutaneous fat with obliteration of the interface between the echogenic fat and the dermis. Color (power) Doppler imaging demonstrates diffuse hypervascularity throughout the inflamed area. In contrast, abscesses appear as anechoic or complex, uni- or multiloculated masses with thick, irregular, and hypervascular walls. When present, a gas collection is easily identified through the associated “ring-down” artifact. Pyomyositis and other muscular abscesses are common in tropical climates, but they also develop in diabetic or immunosuppressed patients, such as leukemic patients receiving chemotherapy [10]. Pyomyositis appears as a rapidly growing, focal hypochoic swelling of a muscle that rapidly transforms into a hypochoic or complex abscess mass with echogenic debris, pus, and occasionally gas. In a patient with a soft-tissue abscess, special attention should be paid to examining the adjacent bones for osteomyelitis [11]. Diagnostic aspiration and drainage of soft-tissue abscesses are easily performed under sonographic guidance.

Other inflammatory soft-tissue masses detectable by US include fat necrosis and panniculitis. Both of these conditions appear as poorly defined areas of increased echogenicity in the subcutaneous fat (“dirty fat”).

In acute tenosynovitis, US demonstrates that the palpable soft-tissue mass is indeed a fluid collection in the tendon.
sheath. Although large amounts of fluid can also be found in chronic tenosynovitis, this condition is most often associated with a prominent, hypoechoic thickening of the synovium, with little or even no fluid. In rheumatoid tenosynovitis, the pannus is well seen as a markedly hypoechoic thickening of the synovium with marked hypervascularity on power Doppler imaging [12].

The diagnosis of bursitis is facilitated by the fact that synovial bursae are located at specific sites (Fig 3). In chronic bursitis, the echogenicity of the enlarged bursa often becomes mixed, with echogenic debris and occasionally calcifications. Subdeltoid, olecranal, patellar, and calcaneal bursae are most frequently affected.

**Cysts**

US is essential in diagnosing cysts that manifest as soft-tissue masses.

**POPLITEAL CYSTS**

A popliteal cyst typically appears as a well-defined anechoic, fluid-filled collection wrapping around the origin of the gastrocnemius medialis muscle. Internal echoes representing fibrinous strands or debris and synovial thickening can be seen in inflamed or infected cysts [13]. In patients with rheumatoid arthritis, popliteal cysts may be completely filled with pannus, thus mimicking a solid mass.

In the case of a recently ruptured cyst, US can demonstrate the leak as a subcutaneous fluid collection extending distally into the lower calf, often with subcutaneous fluid being detected as low as the ankle (Fig 4).

**GANGLION CYSTS**

Ganglion cysts usually arise from the wrist joint, with which they communicate; they also are found adjacent to tendon sheaths in the hand and foot. Ganglion cysts are generally sonolucent, but thin internal septation is a common finding, and internal low-level echoes can be found in chronic or inflamed cysts.

**MENISCAL CYSTS**

Meniscal cysts arise from the menisci (more often from the lateral one) and are seen in the periarticular soft tissues of the knee. US demonstrates a loculated fluid-filled collection or a complex mass that connects to a meniscus. However, MRI is by far superior to US in demonstrating the frequently associated meniscal lesions, which are not depicted with sufficient reliability with US.

**HYDATID CYSTS**

In countries where hydatid cysts are endemic, such cysts may be seen in the soft tissues of the extremities. They have the same wide spectrum of sonographic appearances as do visceral lesions, ranging from the classic multivesicular pattern to the misleading predominantly solid pattern, which can mimic a soft-tissue tumor.

**Synovial proliferations**

Proliferative diseases of the synovium, including osteochondromatosis, pigmented villonodular synovitis, rheumatoid arthritis, and changes associated with hemophilic arthritis, can present clinically as soft-tissue masses. On sonograms, these lesions appear as hypoechogenic masses. The possibility of a synovial mass should be included in the differential diagnosis whenever a soft-tissue mass abuts a joint space.

**Miscellaneous masses**

✓ Subcutaneous rheumatoid nodules occur in 20% of patients with rheumatoid arthritis. They appear as elongated hypoechogenic masses. They can also be found within the tendons, especially in the distal extremities.
In patients with hypercholesterolemia, US demonstrates the intratendinous xanthomas as hypoechoic masses; US is an ideal modality with which to monitor the effect of therapy on the Achilles tendon’s thickness and echotexture.

Giant cell tumors of tendon sheaths (or xanthomas) represent a circumscribed form of tenosynovitis related to pigmented villonodular synovitis. They involve preferentially the flexor surfaces of the fingers in middle-aged women. Sonographically, these tumors appear as hypoechoic, sometimes lobulated masses.

In palmar fibromatosis (Dupuytren’s contracture), US shows a hypoechoic mass in the subcutaneous tissues of the palm, associated with skin retraction and usually located immediately over the course of the flexor tendons of the fourth and/or fifth fingers. Real-time examination shows that the tendons slide smoothly in their sheath, at least in the early stages of the disease.

Plantar fibromatosis, the counterpart of palmar fibromatosis in the foot, also appears as an ill-defined, elongated, hypoechoic mass in the subcutaneous tissues, superficial to the echogenic plantar fascia [14]. Power Doppler imaging may show considerable vascularity (Fig 5).

**Tumors**

Soft-tissue tumors must be evaluated for their number, location, shape, size, margin regularity, echogenicity, echotexture, presence of diagnostic artifacts (e.g., shadowing or sound-through transmission), vascularity on color Doppler mapping, and deformability during contraction and/or relaxation of the muscle(s) involved and application of pressure with the transducer. US is accurate in the detection of soft-tissue tumors, with a very high negative predictive value, but a multimodality approach involving conventional radiography, CT, and MRI is generally needed for further characterization of most masses [15].

**Benign tumors**

Lipomas and hemangiomas are the most common benign tumors found in the superficial soft tissues.

**Lipomas**

Superficial lipomas are usually diagnosed by palpation of a well-delineated, oblong, mobile, and soft superficial mass. When palpation of a superficial soft-tissue mass is inconclusive, US can be used to further characterize the mass. On sonograms, lipomas are elongated, with their greatest diameter parallel to the skin and an average length/anteroposterior diameter ratio of about 3:1. In a study of subcutaneous lipomas, two thirds showed a homogeneous echotexture. Sixty

**Fig 5** • Plantar fibromatosis. A: Coronal MR image shows a lobulated soft-tissue mass. Based on the MR appearance, a soft-tissue sarcoma was included in the differential diagnosis. B: Longitudinal power Doppler sonogram of the distal sole of the foot shows an elongated hypoechoic solid mass with considerable vascularity located anterior to the tendon of the flexor hallucis longus muscle. C: Transverse sonogram of the sole of the foot shows two more minute oval hypoechoic masses (calipers) immediately anterior to the echogenic plantar fascia that were not visualized on MRI. At this point, the diagnosis of soft-tissue sarcoma is unlikely because primary soft-tissue sarcomas are rarely multifocal, and the presumptive diagnosis based on the sonographic examination was that of plantar fibromatosis, which was subsequently confirmed by ultrasound-guided core biopsy.
percent were well defined, with the remainder showing ill-defined margins blending into the surrounding tissues. Twenty-nine percent of the lipomas were hyperechoic, 22% were isoechoic, 29% were hypoechoic, and 20% showed a mixed pattern [16]. Not rarely, lipomas demonstrate internal linear echoes oriented along the lesion’s longest axis, giving a striated appearance. An elongated isoechoic or hyperechoic mass in the subcutaneous tissues should suggest a lipoma. Low-kilovoltage radiographs or CT scans can be used to confirm the radiolucent fatty tumor (Fig 6).

HEMANGIOMAS

Hemangiomas are common benign tumors of soft tissues. Sonographically, hemangiomas range from markedly hypoechoic to hyperechoic and from homogeneous to multiloculated [17, 18]. A clue to the diagnosis is the demonstration of phleboliths, which typically appear as echogenic foci with acoustic shadowing. A notable finding in favor of a hemangioma is the marked compressibility of the lesion (Fig 7). MRI is superior to US in demonstrating the extent of infiltrating hemangiomas, especially intramuscular ones. The vascularity of hemangiomas as seen on color Doppler scans also varies greatly and, not uncommonly, no Doppler signals are detectable.

NERVE SHEATH TUMORS

Using high-resolution probes, the major peripheral nerve trunks in the extremities appear sonographically as echogenic tubular structures. When a hypoechoic mass is seen to connect to a normal nerve, a diagnosis of nerve sheath tumor can be established with confidence (Fig 8) [19, 20]. Schwannomas are better circumscribed than neurofibromas, tend to be eccentric in relation to the nerve axis, may contain characteristic internal cystic cavities, show good sound-through transmission and some central anechoic areas, and are often well vascularized on power Doppler imaging.

Dynamic examination during active or passive flexion and/or extension maneuvers confirms the lack of longitudinal mobility of a nerve sheath tumor relative to the adjacent

**Fig 7 • Hemangioma of the tip of the third finger.** A: Longitudinal sonogram of the fingertip without compression shows a nonhomogeneous, primarily hypoechoic mass (calipers) anterior to the distal phalanx (P). B: Sonogram obtained during compression with the transducer shows the marked compressibility of the mass.

**Fig 6 • Lipoma of the abdominal wall.** A: Sonogram shows a well-circumscribed, homogeneous solid mass (calipers) that is mildly echogenic in relation to the surrounding subcutaneous fat lipoma. B: CT scan confirms the radioluency of the mass (arrows) which is barely identified from the surrounding fat.
muscles and tendons. The only mobility of these tumors is in the transverse direction.

Ultrasound-guided needle biopsy of nerve sheath tumors is sometimes attempted. The insertion of the needle into the tumor may trigger a sharp, excruciating pain, which forces interruption of the procedure but indirectly confirms the neural origin of the tumor.

Other benign masses that arise from nerves and can be visualized on US include traumatic neuromas (including stump neuromas), neurilemmitis and perineural abscesses in leprosy, intraneural ganglia, and Morton’s neuromas.

**OTHER BENIGN SOFT-TISSUE TUMORS**

✔ Intramuscular myxomas are rare benign mesenchymal neoplasms that arise in skeletal muscle. They appear on sonograms as well-demarcated, markedly hypoechoic, intramuscular masses with distal sound enhancement; the tumors contain multiple fluid-filled clefts or cystic areas of various sizes.

✔ Desmoid tumors are fibromatous lesions arising from muscular aponeuroses, usually in young adults. Muscles of the shoulder, chest and abdominal walls, thigh, popliteal fossa, and calf are most often involved. Desmoid tumors appear on sonograms as irregular, ill-defined hypoechoic masses. MRI is usually a better modality for imaging these lesions. Local recurrences after excision are not rare.

✔ Lymphangiomomas are often poorly defined on sonograms, and MRI should be used instead of US, especially for follow-up after excision.

✔ Granular cell tumors are firm, small, benign tumors that can be found virtually anywhere in the soft tissues. On US, they are hypoechoic and grossly round, with irregular margins; some are associated with marked acoustic shadowing. They tend to recur locally if incompletely excised.

✔ Glomus tumors are usually located in the fingers, more specifically in the subungual spaces, although they have been reported in various locations in the body. On sonograms, glomus tumors appear round and markedly hypoechoic [21]. US has proved to be very helpful in the diagnosis and preoperative localization of glomus tumors.

## Malignant tumors

### SOFT-TISSUE SARCOMAS

The vast majority of primary malignant tumors that develop in soft tissues are soft-tissue sarcomas (STS). They can develop in any anatomic area, but most develop in the extremities, usually the lower ones. The two most frequent subtypes of STS in adults are malignant fibrous histiocytoma and liposarcoma. STS most commonly metastasize hematogeneously to the lungs; regional lymph nodes are very rarely involved.

**Sonographic appearances and diagnosis**

Except for some liposarcomas, which are echogenic, STS appear as hypoechoic, often relatively well-circumscribed, lobulated masses (Fig 9). Areas of necrosis are often present in large tumors and some subtypes (e.g., 30% of synovial sarcomas) may contain calcifications. The extended-field-of-view technology is useful for encompassing (and measuring) very large lesions. Power Doppler US usually demonstrates increased vascularity.

![Fig 8 • Nerve sheath tumor](image1)

Longitudinal sonogram of the popliteal fossa shows a smoothly marginated, markedly hypoechoic schwannoma and its connection with the normal, echogenic common peroneal nerve (arrows).

![Fig 9 • High-grade unclassified sarcoma of the thigh](image2)

Transverse sonogram shows a lobulated mass with areas of necrosis. F, femur.
Diagnosis of a malignant soft-tissue tumor is rarely achieved with imaging, and a tissue diagnosis is usually required before starting treatment. Such needle biopsy can be performed under sonographic guidance.

**Staging**

The lack of global and reproducible pictures obtained in an operator-independent manner prevents US from playing a role in preoperative staging of STS, which is done with MRI.

**Follow-up after surgical resection**

STS are associated with a high incidence of local recurrence after surgical resection. US is extremely sensitive in the detection of early recurrences after surgical excision [22, 23]. Recurrences of STS usually appear as small round or oval hypoechoic masses. Fine-needle aspiration biopsy can readily document early local recurrences as small as a few millimeters (Fig 10).

**Ultrasound-guided percutaneous ablation of local recurrences of STS**

We have had the opportunity in a few selected cases of multiple local recurrences of STS to use percutaneous radiofrequency ablation or cryoablation. These palliative techniques help control the disease locally.

**OTHER MALIGNANCIES**

✔ **Metastases from non-melanoma primary malignancies are rare.** They usually derive from carcinomas of the lung and the gastrointestinal tract. Soft-tissue metastases appear on US as hypoechoic masses that are grossly round when they are small and exhibit a more irregular shape as they increase in size. Metastases from the gastrointestinal tract often contain calcifications.

✔ **Metastases from cutaneous melanoma** to subcutaneous tissues are not uncommon. Metastases from melanoma are markedly hypoechoic on grayscale imaging and hypervascular on color Doppler imaging. Real-time ultrasound-guided fine-needle aspiration biopsy provides cytologic confirmation (Fig 11) [4].

✔ **Leukemic involvement of soft tissues (e.g., chloromas) and lymphomatous lesions** appear as markedly hypoechoic masses. In a patient with known leukemia or lymphoma, any new focal hypoechoic mass in the soft tissues should undergo fine-needle aspiration. In lymphoma, color Doppler imaging shows hypervascularity (thus confirming the tissular nature of the mass) without distortion of the vessels.

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**Fig 10** • Recurrent osteosarcoma in the soft tissues of the leg. Sonogram obtained during the ultrasound-guided fine-needle aspiration biopsy shows the tip of the needle inside the 1.0- x 0.6-cm recurrence (arrows).

**Fig 11** • Metastasis from melanoma in subcutaneous tissues of the thigh. A: Sonogram shows a markedly hypoechoic lobulated mass. B: Color Doppler sonogram shows the markedly increased vascularity associated with the tumor. C: Sonogram obtained during the ultrasound-guided fine-needle aspiration biopsy, which confirmed the diagnosis of metastatic melanoma within 15 minutes.
Serial volume measurements of metastatic disease by US can be used as an indicator of the response to chemotherapy.

**Conclusions**

Provided the examination is done by a well-trained operator using state-of-the-art equipment, US can yield valuable information in the examination of soft-tissue masses by confirming the presence or absence of a morphologic abnormality with a very high negative predictive value; by determining the cystic or solid nature of a mass; by guiding percutaneous needle biopsy or drainage; by localizing nonpalpable masses before or during surgery; by monitoring lesions that are treated conservatively; and by detecting early recurrences of soft-tissue sarcomas. However, the role of US is limited in the evaluation of joints and areas of complex anatomy, and it cannot be used for preoperative staging of soft-tissue tumors. Other limitations of US include its operator dependence, the restricted field of view of sonograms, and the fact that many clinicians are uncomfortable with viewing sonograms.

**References**