Radiology

REVIEWS AND COMMENTARY • STATEMENTS AND GUIDELINES

Ultrasonography of Superficial Soft-Tissue Masses: Society of Radiologists in Ultrasound Consensus Conference Statement

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Conflicts of interest are listed at the end of this article.

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The Society of Radiologists in Ultrasound convened a panel of specialists from radiology, orthopedic surgery, and pathology to arrive at a consensus regarding the management of superficial soft-tissue masses imaged with US. The recommendations in this statement are based on analysis of current literature and common practice strategies. This statement reviews and illustrates the US features of common superficial soft-tissue lesions that may manifest as a soft-tissue mass and suggests guidelines for subsequent management.

Ultrasonography is an excellent imaging method in the evaluation of a palpable superficial soft-tissue mass. The advantages of US include high-spatial-resolution capabilities, portability, easy access, low cost, comparison with the contralateral side, Doppler US, and, importantly, the ability to combine physical examination findings and patient history during the US examination. Additionally, real-time imaging allows manual compression, extremity movement, muscle contraction, and direct patient interaction during US scanning. Superficial lesions are ideally imaged with US, especially when they are small. The US diagnosis of a soft-tissue mass is uncommonly changed with subsequent MRI evaluation (1). One disadvantage of US is when disease is in deeper soft tissue. In these situations, image resolution is reduced, and ancillary information concerning the mass, such as physical examination findings and history, may be ambiguous. This article reviews common superficial soft-tissue masses and provides illustrative examples and recommendations for their management based on US findings.

Methods and Conference Preparations

In 2019, the Society of Radiologists in Ultrasound executive board decided to conduct a consensus conference on an issue that confronts physicians in the field of US. US of superficial soft-tissue masses was selected as the topic for the 2020 consensus conference. Our focus was on only the superficial soft tissues, given the importance of US in the evaluation of superficial lesions (1). Deeper lesions most often require MRI for further characterization. Our goal was to categorize superficial soft-tissue lesions into categories that could be used to guide further management. The co-moderators of the committee (J.A.J., W.D.M.) recruited conference members whose primary academic focus was on US, musculoskeletal radiology, oncologic orthopedic surgery, and pathology based on their special expertise in imaging, diagnosis, and treatment of soft-tissue masses. Conference members chose common soft-tissue masses based on their experience. All members performed a literature search of their individual topic and assembled appropriate references that were distributed to the rest of the committee. By using these references and their personal experience, each member developed material that included background information, US findings, differential diagnosis, summary information, and recommendations. All material was anonymized prior to review, and edits were made by the entire committee. A preliminary complete consensus statement was created and edited during virtual conference calls, and additional revisions were made until a final unanimous consensus was achieved.

Imaging Evaluation

When presented with a soft-tissue mass using US, the initial assessment determines if the mass is superficial (cutaneous or subcutaneous) or deep to subcutaneous tissues. If superficial, there is a group of common abnormalities that have pathognomonic or characteristic features enabling a confident diagnosis. If the abnormality is not specific for a benign diagnosis or has atypical or suspicious clinical or US features, particularly if solid and hypoechoic, possible recommendations include interval follow-up US; additional imaging, such as MRI with intravenous contrast material; biopsy; or surgical consultation. Effective communication between the radiologist and clinical services is critical to ensure recommendations are conveyed accurately.

Abbreviations

MPNST = malignant peripheral nerve sheath tumor, PNST = peripheral nerve sheath tumor

Summary

This consensus statement reviews the US features of superficial soft-tissue masses, classified as reliably benign, non-specific neoplastic, lymphadenopathy, or pseudomass, and provides appropriate diagnosis and management recommendations for each category.

Key Results

- This consensus statement reviews US features of soft-tissue masses, providing recommendations for diagnosis and care.
- If a soft-tissue mass is superficial, there is a group of common diseases that have pathognomonic or characteristic features that enable a confident diagnosis.
- If a soft-tissue mass is not specific for a benign diagnosis or has atypical or suspicious clinical or US features, particularly solid and hypoechoic features, possible recommendations include interval follow-up US examination; additional imaging, such as MRI with intravenous contrast material; biopsy; or surgical consultation.

Examination Technique

An important part of the examination is obtaining targeted clinical history. This should include when the mass was first detected, change in mass size, presence of pain or drainage, and history of trauma, surgery, and malignancy. Imaging should be performed with a high-frequency linear-array transducer with a frequency range typically between 12 and 24 MHz. In general, the highest transmit frequency that enables adequate visualization of the entire lesion and the relevant surrounding tissues should be used. When no lesion is detected despite the presence of a clearly palpable abnormality, lower-frequency transducers that can penetrate deeper than the subcutaneous layer are important, since lesions arising from deeper structures can masquerade as superficial masses at palpation. Lower-frequency linear- or curved-array transducers may also be required to image patients with a high body mass index and larger lesions. They may also be needed when sound is attenuated by inflamed or infiltrated fat. Therefore, a variety of transducers should be available to image soft-tissue masses of different sizes, locations, depths, and compositions.

The palpable lesion should be imaged with abundant gel to minimize transducer pressure. This is particularly important when analyzing the interface between the lesion and the dermis. The lesion should be imaged in at least two planes and measured in three orthogonal dimensions. Determining the relationship of the lesion to the dermis, adjacent nerves, vessels, tendons, muscles, and osseous structures should be a standard part of the examination (2). Dynamic scans obtained during joint movement and muscle contraction help in localizing lesions arising from muscles, tendons, and joints. In the abdominal wall, Valsalva maneuvers help distinguish masses from hernias. Dynamic compression of the lesion may help characterize tissue stiffness and may show the internal movement of echoes, indicating a fluid component.

Gray-scale and Doppler imaging are essential in the evaluation of a lesion. Harmonic imaging and real-time spatial compounding improve image quality in most cases, although spatial compounding should be deactivated when attempting to detect subtle shadowing. A panoramic (extended) field of view is often helpful in demonstrating lesion location relative to adjacent structures. Panoramic views also help provide a complete comparison of the lesion morphology and vascularity to surrounding tissues and are required to measure the lesion when it is too large to be fully imaged in one field of view. A side-by-side comparison with the contralateral side of the body can be extremely helpful, particularly when the findings are subtle and unclear.

In regard to Doppler US, primary acquisition modes include spectral Doppler, color Doppler, and power Doppler, with new microvascular techniques based on power Doppler (3). Color Doppler displays the presence of flow, including mean velocity and direction. Traditional power Doppler does not show flow direction or velocity but is less dependent on the Doppler angle and is marginally more sensitive than color Doppler is to low flow. Spectral Doppler shows flow direction and patterns, including pulsatility and waveforms, and can provide some quantitative information, such as velocity and resistive indexes. Doppler US is extremely important, since the detection of vascularity in a discrete lesion indicates that the mass is solid and is likely neoplastic. Perilesional hyperemia is also a helpful sign in the detection of infections in otherwise nonspecific fluid collections, as well as inflammatory changes around masses. Compression of a lesion with the transducer may occlude slow-flowing blood vessels in a tumor and may result in the false impression of an avascular non-neoplastic lesion. This is particularly true with very superficial lesions. Thus, it is critical to avoid compression when evaluating blood flow. With very superficial lesions, a thick layer of gel should be used to separate the transducer from the lesion and minimize pressure. Spectral Doppler US also helps avoid misinterpretation of the color Doppler artifacts. It is also useful in the analysis of primarily vascular lesions, such as arteriovenous malformations. Since red blood cells are smaller than the wavelength of transmitted sound, the strength of Doppler signals is proportional to the fourth power of the transmitted frequency; therefore, for superficial lesions, the sensitivity is generally higher at higher Doppler transmit frequencies. Sensitivity is also higher when the Doppler scale (pulse repetition frequency) is low, when the wall filter is low, when the color threshold is set to minimize Doppler signal suppression, and when the beam is not steered. In all cases, the color Doppler gain should be increased to the point where artifactual Doppler signal is seen and then decreased until the spurious signal is minimized. Minimizing the size of the color region of interest is also helpful to maintain the highest possible frame rate. When necessary, frame rates can be further increased by reducing the color line density, albeit at the expense of lowered resolution.

Examination Report

There are several important features that should be included in the report of superficial soft-tissue masses. These include composition, location, size, relationship to adjacent structures, echogenicity, margins, vascularity, and other miscellaneous findings. The report should also contain a defined recommendation for further care. A suggested dictation template is shown in Figure 1.

Findings:
Location in Body: location is [Nonspecific, Typical for a (bursa, ganglion, lymph node other)]
Location in Tissues: [Subcutaneous, Intramuscular, Subcutaneous and intramuscular]
Composition: [Entirely solid, Predominantly solid, Predominantly cystic, Entirely cystic]
Size: __ cm cranio-caudal, __ cm transverse, and __ cm anterior-posterior.
Involved structures: [No adjacent structures, Dermis, Nerve, Tendon, Bone, Joint, Vessels].
Sound Attenuation: [None, Increased through transmission, Posterior shadowing]
Echogenicity: Anechoic, Hypoechoic, Isoechoic, Hyperechoic, Heterogeneous] compared to surrounding tissues
Margins: [Smooth, Ill-defined, Lobulated, Irregular, Infiltrative].
Vascularity: [No internal vascularity, Barely detectable internal vascularity, Readily detectable internal vascularity, Abundant internal vascularity, Peripheral vascularity but no internal vascularity].
Doppler mode: [Color, Power, Color and Power]
Other Features: [Multilocularity, Compressibility, Mobile low-level internal echoes, Calcifications, other].

Impression:

1. Lesion as described above that is
    a. [typical of a benign (__)]
    b. [consistent with a soft tissue neoplasm but otherwise nonspecific.]
    c. [not a mass. It is consistent with a ( ).]
    d. [consistent with lymphadenopathy.]
        i. It is most likely (reactive), (metastatic disease), (lymphoma).
        ii. It is otherwise nonspecific.
2. Recommend
    a. [no further evaluation other than periodic self-examination.]
    b. [follow-up ultrasound in __ weeks.]
    c. [MRI with contrast.]
    d. [ultrasound guided biopsy.]
    e. [ultrasound guided aspiration.]
    f. [surgical consultation.]

Figure 1: Dictation template.

Reliably Benign Masses

The most common soft-tissue masses referred for US evaluation are benign, and most have a characteristic appearance and can be diagnosed with confidence (Figure 2). When the US appearance is typical and there are no worrisome clinical features, no further evaluation or follow-up other than periodic self-monitoring is necessary.

Lipoma

Background

Lipomas are the most common soft-tissue tumors and typically manifest as slowly enlarging soft mobile masses (2,4–12). Pathologically, they are composed of mature adipocytes with uniform nuclei that are identical to those seen in normal fat. The fat may contain a few small capillaries within thin fibrous septae. A thin fibrous pseudocapsule (when present) separates lipomas from surrounding tissue. Lipomas are benign, with no malignant potential, and usually occur in subcutaneous tissues virtually anywhere in the body; however, lipomas also can be in deeper tissue, can be intra- or intermuscular, and can affect a wide age range.

US Findings

Lipomas may be hyper-, iso-, or hypoechoic when compared with adjacent subcutaneous tissues, with a uniform echotexture. Pure fat is anechoic, so echogenicity depends on the presence of connective tissue and other reflective interfaces in the lipoma. According to Wagner et al (12) 26% are hyperechoic; 59%, isoechoic; and 15%, hypoechoic. Gently curved echogenic lines parallel to the skin surface are a characteristic feature of lipomas seen in up to 89% of cases and represent fibrous septae. There is typically no detectable internal blood flow on Doppler US images. Uncommonly, minimal flow may be identified within a septum. Additionally, lipomas tend to be compressible. In 2004, Inampudi et al (9) reported US accuracy of 49%–64% in the diagnosis of lipomas. More recently, sensitivity of 95%–96% and specificity of 94%–97% have been reported by Wagner et al (12) and Hung et al (6); however, the lipomas in these latter studies were subcutaneous only, whereas Inampudi et al included deeper masses.

Differential Diagnoses

Differential diagnoses include asymmetric fat deposition (non-neoplastic), which can be distinguished from lipomas by lack of a pseudocapsule. A variant of a lipoma is an angiolipoma, which tends to be more hyperechoic, heterogeneous, and vascular, and is more likely to be painful. Angiolipomas are also more likely to be multiple (seen in 70% of cases) and commonly occur in a subcutaneous location near the elbow. Differentiation is not critical since angiolipomas also have a benign clinical course. Another differential diagnosis is a slow-flow vascular malformation, which may also contain fat. However, the presence of dilated vascular channels, phleboliths, and Doppler flow allow differentiation from lipoma. Although atypical lipomatous tumors (well-differentiated liposarcomas) are more common in deeper locations, may be more hyperechoic, and may have more detectable flow, they can sometimes simulate a benign lipoma.

Summary

An oval compressible iso- to hyperechoic soft-tissue mass with linear or gently curvilinear reflectors and no or minimal septal vascularity is a characteristic finding of lipoma.

Epidermal Inclusion Cyst

Background

Epidermal inclusion cyst is a superficial lesion that involves the hair-bearing areas of the body, most commonly the head or neck, trunk, and scrotum, and less commonly involves the extremities (6,10,13–19). It is more common in men and is rare prior to puberty. Variable terms have been used for epidermal inclusion cyst, including infundibular cyst and epidermal cyst. An epidermal inclusion cyst histologically has a fibrous capsule with stratified squamous epithelial lining and a lumen filled with keratin debris, with rare reports of malignant transformation. In regard to its origin, a congenital epidermal cyst may be formed by trapping of displaced embryonic epithelial rests, commonly occurring in the head and neck. Acquired epidermal inclusion cysts can result from obstruction of hair follicles (pilosebaceous unit) or implanted fragments of epidermis in the dermis after a penetrating injury or an injection. Multiple epidermal cysts can occur in patients with Gardner syndrome, particularly on the face and scalp.

RELIABLY BENIGN MASSES—Recommendation when typical: No further evaluation other than periodic self-monitoring

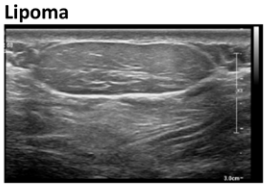
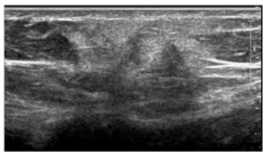
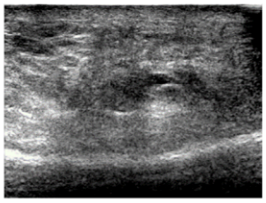
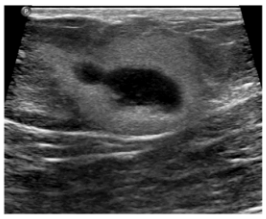
Pathology	Typical Findings	Atypical Findings	Recommendations When Atypical	Comments
Lipoma 	• Isoechoic to hyperechoic • Linear internal reflectors • Oval • Compressible • No or minimal septal vascularity	• Focal hyperechoic areas • Abundant or focal vascularity • Deep location • Accelerated growth	• Contrast-enhanced MRI • Surgical consultation	
Fat Necrosis   	• Hyperechoic • Often poorly marginated • Avascular • History of trauma or injection	• Hypoechoic • Calcifications • Liquified components • Well marginated	• Follow-up US • Contrast-enhanced MRI • Biopsy • Surgical consultation	Fat necrosis has a variable appearance. Consider fat necrosis when lesions have a sonographic appearance that is not typical of any other condition.

Figure 2: Chart shows lesion images, description of typical and atypical findings, recommendations when typical and atypical findings are present, and additional commentary *(Fig 2 continues)*.

US Findings

When an epidermal inclusion cyst is not ruptured, it most commonly appears ovoid and mildly hyperechoic, with increased posterior through-transmission. Internal heterogeneity is characteristic with linear low-echogenic areas and scattered areas of bright linear echoes and anechoic clefts representing keratin debris. Calcification is rare in epidermal inclusion cysts. They usually have well-defined borders and a hypoechoic halo without internal flow on Doppler US images. They may have a gray-scale appearance simulating the echogenicity of a testicle. Other features of an epidermal inclusion cyst include involvement of more than 50% of the dermal layer and the presence of a focal hypoechoic region extending toward the epidermis (the submarine sign). When ruptured or infected, an epidermal inclusion cyst may appear lobular, with increased flow on Doppler US images, and many of the characteristic features will be absent (18). Sensitivities and specificities in the US diagnosis of epidermal inclusion cysts range from 66% to 93% and from 77% to 99%, respectively.

Differential Diagnosis

The characteristic US features of an epidermal inclusion cyst aid in differentiation from complex cysts or cystic masses. A ruptured epidermal inclusion cyst has a more nonspecific appearance and may simulate the appearance of other diseases. A trichilemmal (pilar) cyst may be differentiated from an epidermoid cyst by its location (the vast majority arising from the scalp), the absence of a connecting tract to the epidermis, and a higher prevalence of calcifications, hair fragments, or both.

Summary

A round or ovoid mildly hyperechoic lesion with a hypoechoic halo, increased through-transmission, internal linear echogenic and anechoic debris, and no internal Doppler flow is characteristic for an epidermal inclusion cyst.

Fat Necrosis

Background

Fat necrosis is a non-neoplastic self-limited entity, which is caused by vascular impairment or trauma, with resultant organized hemorrhage, necrosis, fibrosis, and—in some cases—calcification (saponification) (20–25). Patient history may include a compressive soft-tissue trauma, although often there is no recognized history of trauma. Fat necrosis can

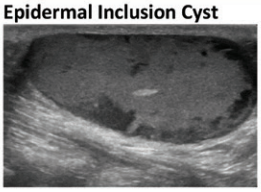
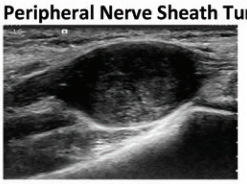
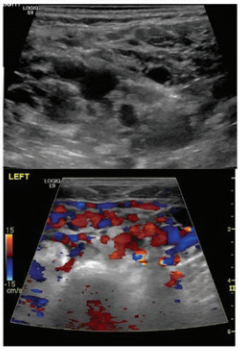
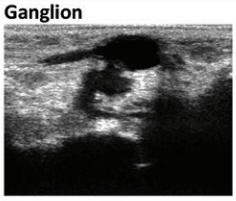
Epidermal Inclusion Cyst 	• Minimally hyperechoic • Internal linear echogenic and anechoic debris • Broad contact with dermis • Extension to dermis • Round to oval • Increased through transmission • No internal blood flow • "Pseudotestis"	• Detectable internal blood flow • Ill-defined margins • Lobular margins • Perilesional soft-tissue inflammation	• Contrast-enhanced MRI • Biopsy	Suspect rupture if margins are ill-defined and adjacent fat is focally hyperechoic or hyperemic.
Peripheral Nerve Sheath Tumor  Schwannoma with eccentric entering and exiting nerve	• Hypoechoic • Round or ovoid hypoechoic mass • Nerve continuity • Increased posterior through-transmission • Internal vascularity • Severe pain with biopsy	• No detectable nerve continuity • Heterogeneous echogenicity • Large • Ill-defined margins • Central necrosis • Rapid growth	• Contrast-enhanced MRI • Surgical consultation	
Vascular Malformation 	• Heterogeneous hypoechoic and hyperechoic areas • Variable vascularity • Possible hyperechoic foci with shadowing	• Associated mass • Deep extension • Increase in size • Change in symptoms • Possible hyperechoic foci with shadowing • If associated mass, the US findings are not specific	• Contrast-enhanced MRI	
Ganglion 	• Hypoechoic or anechoic • Multilocular or unilocular • Non-compressible • Possible septal vascularity • No associated mass • Characteristic location	• Solid components • Nonseptal vascularity • Unusual location	• Contrast-enhanced MRI	

Figure 2: (*continued*) Chart shows lesion images, description of typical and atypical findings, recommendations when typical and atypical findings are present, and additional commentary.

also be due to a variety of other causes, including surgery, injections, autoimmune disorders, vasculitis, and sickle cell disease.

US Findings

Reports in the US literature (excluding the breast) are primarily case reports and small case series, likely because fat necrosis rarely requires biopsy confirmation. The typical appearance of fat necrosis is hyperechoic and poorly marginated. Fat necrosis has a varied and usually nonspecific appearance, described as hyper-, hypo-, or isoechoic, with a hypoechoic halo. Descriptions also include a poorly defined mixed echogenicity heterogeneous region and a well-defined and encapsulated hyperechoic mass with cystic degeneration.

Differential Diagnosis

Given a nonspecific US appearance, there are numerous diagnostic considerations. Cellulitis may have a similar appearance, although clinical findings and more diffuse subcutaneous hyperechogenicity in a cobblestone pattern are common. Subcutaneous panniculitis-like T-cell lymphoma may appear as hyperechoic infiltration or nodules and may simulate fat necrosis, although interspersed linear hypoechoic areas are also described.

Summary

Fat necrosis can be diagnosed when subcutaneous lesions are ill defined, hyperechoic, and avascular, particularly in the setting of trauma. Unfortunately, fat necrosis has a variable US appearance that is often atypical and nonspecific.

PSEUDOMASSES—Recommendation when typical: Depends on the diagnosis. Follow-up US, aspiration, biopsy, or MRI may be required to help determine clinical management.

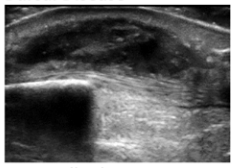
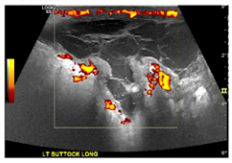
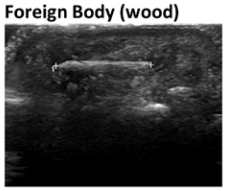
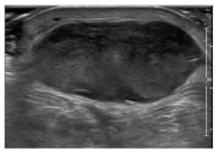
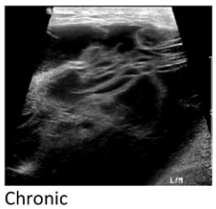
Pathology	Typical Findings	Atypical Findings	Recommendations when Atypical	Comments
Bursal Disease  Prepatellar bursitis	• Variable but commonly hypoechoic • Well circumscribed • Variable vascularity • Location of an anatomic bursa or at site of extrinsic pressure (adventitious bursa)	• Substantial solid components • Vascularity in solid components	• Contrast-enhanced MRI	Management is guided by clinical history given possible causes of trauma, inflammatory, and proliferative synovial processes; MRI may be considered to further characterize if proliferative; if concern for infection, then aspiration or synovial biopsy is recommended.
Abscess 	• Variable heterogeneous echogenicity; commonly hypoechoic • Increased through-transmission • Mobile internal echoes with sonopalpation • Adjacent edema or cellulitis • No internal vascularity, possible peripheral hyperemia	• Nonsupportive clinical history • Internal vascularity • Normal adjacent fat • Deep location	• Contrast-enhanced MRI biopsy or aspiration	Aspiration is usually required for cultures and cell count even when findings are typical, or to differentiate between an abscess and hematoma when the diagnosis is in doubt.
Foreign Body (wood) 	• Echogenic foreign body (between cursors) • Variable posterior acoustic shadowing • Variable surrounding halo of fluid or hypoechoic inflammation • Variable vascularity	• Nonsupportive clinical history	• Radiographic correlation • CT or MRI	Surgical consultation
Hematoma  Subacute  Chronic	• Variable echogenicity ranging from hyperechoic (if acute) to anechoic (if chronic) • Variable internal heterogeneity • No associated mass • Avascular • History of trauma or anticoagulation	• Nonsupportive clinical history • Internal vascularity • Deep location	• US follow-up • Contrast-enhanced MRI • Biopsy or aspiration	Aspiration may be required to exclude superimposed infection, even when findings are typical.

Figure 3: Chart shows lesion images, description of typical and atypical findings, recommendations when typical and atypical findings are present, and additional commentary.

Peripheral Nerve Sheath Tumor

Background

Peripheral nerve sheath tumors (PNSTs) are true neoplasms that can be divided into schwannomas, neurofibromas, and malignant peripheral nerve sheath tumors (MPNSTs) (26–34). Schwannomas and neurofibromas are the two most common PNSTs. Schwannomas are characterized by Antoni A and B areas and are strongly S-100 positive with immunohistochemistry. Schwannomas may contain calcifications, cystic foci, or both and may undergo marked degenerative changes (termed *ancient schwannomas*) with bleeding, fibrosis, hemorrhage, or calcification. Schwannomas and neurofibromas may be solitary, or they can present as multiple soft-tissue masses (schwannomatosis and neurofibromatosis type 1). Neurofibromas can be classified as localized, plexiform, or diffuse. MPNSTs mostly

LYMPHADENOPATHY—Recommendation when typical for a reactive node: Clinical follow-up

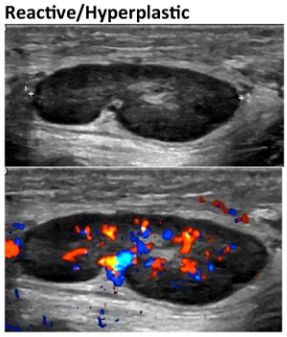
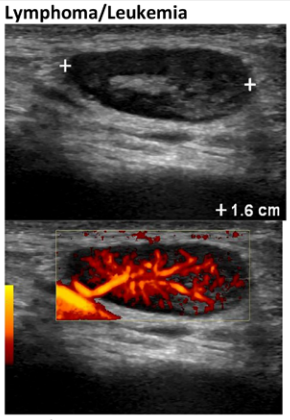
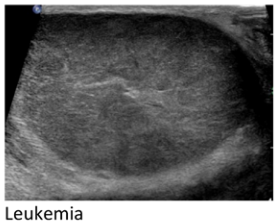
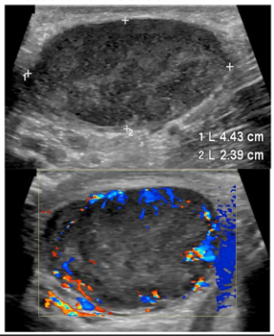
Pathology	Typical Findings	Atypical Findings	Recommendations when Atypical	Comments
Reactive/Hyperplastic 	• Mild to moderate enlargement • Oval shape • Echogenic hilum • Uniform hypoechoic cortex • Hilar vascularity (if present) • Supportive clinical history	• Marked enlargement • Adenopathy at multiple sites • Peripheral or disorganized vascularity • Cystic areas • Calcifications • History of lymphoma or extranodal malignancy • Lack of improvement on follow-up	• Biopsy	Overlap in appearance of reactive and lymphomatous nodes makes distinction difficult. History, physical examination findings, and evolution on follow-up guides decision to recommend biopsy.
Lymphoma/Leukemia  Lymphoma  Leukemia	• Mild to marked enlargement • Oval or round shape • With or without echogenic hilum • Uniform hypoechoic cortex • Hilar vascularity • Supportive additional imaging and clinical history	• Hyperechoic or heterogeneous cortex • One site of adenopathy • Peripheral or disorganized vascularity • Cystic areas • Calcifications • Nonsupportive clinical history	• Biopsy	Overlap in appearance of reactive and lymphomatous nodes makes distinction difficult. History, physical examination findings, and evolution on follow-up guides decision to recommend biopsy.
Metastatic Disease 	• Mild to marked enlargement • Oval or round shape • With or without echogenic hilum • Eccentric cortical thickening • Heterogeneous cortex • Calcification • Cystic areas • Variable vascularity • Supportive additional imaging and clinical history	• Nonsupportive clinical history • Contradictory results on other imaging	• Clinical and US follow-up	Recommendation for nodes with typical findings of metastatic disease depends on the clinical scenario. Options primarily include biopsy or further imaging and staging examinations.

Figure 4: Chart shows lesion images, description of typical and atypical findings, recommendations when typical and atypical findings are present, and additional commentary .

are high-grade sarcomas comprising 5%–10% of all soft-tissue tumors. MPNSTs are associated with neurofibromatosis type 1 in 20%–70% of cases. In general, patients with neurofibromatosis have a prevalence for malignant transformation of a neurofibroma to MPNST of 2%–29% (5% average).

US Findings

PNSTs are most commonly homogenous and hypoechoic (67%), with increased posterior through-transmission (75%). In most cases, the mass is in direct continuity with a peripheral nerve, particularly when involving large nerves, a

NONSPECIFIC NEOPLASTIC MASSES—Recommendation when typical: Contrast-enhanced MRI or biopsy, with surgical consultation depending on MRI or biopsy results

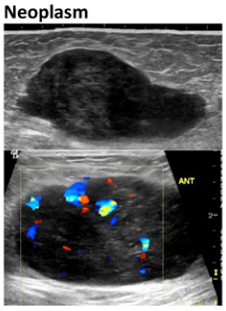
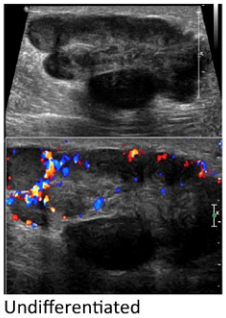
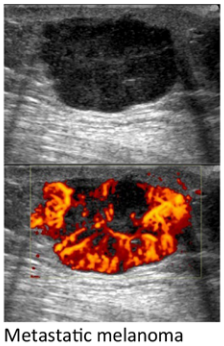
Pathology	Typical Findings	Atypical Findings	Recommendations when Atypical	Comments
Neoplasm  Leiomyoma  Undifferentiated pleomorphic sarcoma  Metastatic melanoma	• Solid or mixed solid and cystic • Predominantly hypoechoic • Variable heterogeneity • Detectable but variable internal vascularity	• Mostly cystic • Avascular • Documented prolonged lack of growth • Clinical history strongly supportive of alternative diagnosis	• Contrast-enhanced MRI • Biopsy	Recommendations are similar whenever a neoplasm is in the differential diagnosis. Biopsy preferred over MRI if lesion is likely to be metastatic or lymphoma.

Figure 5: Chart shows lesion images, description of typical and atypical findings, recommendations when typical and atypical findings are present, and additional commentary..

pathognomonic finding when seen on US images. Transducer pressure over a PNST often elicits pain or other nerve-related symptoms. Although it can be difficult to differentiate neurofibromas from schwannomas with US alone, neurofibromas tend to be more fusiform, lobulated, and hypovascular, while schwannomas are more round, smooth, and vascular. In addition, the involved nerve is characteristically eccentric to a schwannoma as opposed to a central location with a neurofibroma. Furthermore, the transition of nerve to tumor is better delineated with a schwannoma, whereas neurofibromas show a more infiltrative transition. Typically, neurofibromas demonstrate a target appearance (hyperechoic center, hypoechoic periphery), representing central fibrocollagenous tissue and peripheral myxoid region; however, this finding can also be seen with schwannomas. Ancient schwannomas often show echogenic shadowing foci, consistent with calcifications. A suspected PNST that is large with ill-defined margins, central necrosis, and rapid growth along the axis of the nerve should raise the possibility of MPNST.

Differential Diagnosis

The sonographic finding of peripheral nerve continuity, with the nerve directly entering and exiting the mass, can be considered pathognomonic for both benign and malignant PNST. If peripheral nerve continuity is not identified, the differential diagnosis includes other benign and malig-

nant masses. A hypoechoic and homogeneous PNST may also simulate a complex cystic lesion because of their shared common feature of increased posterior through-transmission; however, the presence of color or power Doppler flow on US images should help differentiate these two lesions, as a complex cyst should not exhibit flow. Severe pain during needle biopsies is also a sign of a PNST.

Summary

A PNST characteristically appears as a round or ovoid hypoechoic mass with peripheral nerve continuity, increased posterior through-transmission, and flow on Doppler US images.

Vascular Tumors and Malformations

Background

Vascular lesions can be categorized as tumors and malformations based on behavior, histologic findings, and genetics (35–38). Vascular tumors are further subcategorized as benign (infantile hemangioma among others), locally aggressive or borderline (Kaposi sarcoma among others), or malignant (angiosarcoma and epithelioid hemangioendothelioma among others). Vascular malformations are subcategorized as simple, combined, those of a major named vessel, and those associated with anomalies. They are often associated with a blue discoloration of the skin. This discussion focuses on vascular tumors and malformations. Other vascular-related abnormalities, such as aneurysms, pseudoaneurysms, and thrombosed veins, are rarely a diagnostic dilemma and are not discussed.

US Findings

Superficial vascular lesions have a heterogeneous appearance, with both hyper- and hypoechoic regions. With flow on Doppler US images, hypo- or anechoic serpentine vessels often appear as a tangle of vessels and can be characterized as low flow or high (arterial) flow. Areas of shadowing may be due to phleboliths related to thrombosis or refractive shadowing at echogenic interfaces. An associated soft-tissue mass has been described with hemangiomas and other vascular tumors. When vascular lesions are located deep to the superficial fascia, characterization and delineation with US become extremely difficult.

Differential Diagnosis

A vascular malformation in the superficial soft tissue can be a characteristic US finding. Inflammation or panniculitis may appear similar, although clinical findings allow differentiation. Diffuse neurofibromas may appear similar to vascular malformation, although clinical findings and history taking may also assist in differentiation. If an associated soft-tissue mass is present, both benign and malignant vascular tumors should be considered.

Summary

A heterogeneous subcutaneous lesion with mixed hypo- and hyperechoic areas, variable blood flow, and possible hyperechoic foci with shadowing is characteristic of a vascular malformation.

Ganglion

Background

A ganglion is a mucin-filled collection that does not have a synovial lining and therefore cannot be categorized as a true cyst (39–43). They most commonly occur at the volar wrist near the radial artery in 69% of cases and at the dorsal wrist near the scapholunate ligament in 31% of cases. Other superficial locations include the tendons of the hands and feet. One prominent theory is that the fluid originates from a joint recess or tendon sheath with a communicating pedicle or neck.

US Findings

A ganglion appears well-defined, hypo- or anechoic, uni- or multilocular, and either noncompressible or minimally compressible. If ganglions are 10 mm or smaller, they commonly are hypoechoic without increased posterior through-transmission. Intrinsic Doppler flow is typically absent, although a complex appearance with internal vascularity related to a septation is possible. Ganglia have a propensity to occur in specific anatomic locations (described previously), where a communicating neck to its site of origin can sometimes be identified.

Differential Diagnosis

The US appearance and location of a ganglion are characteristic findings. Doppler flow assessment should be used to exclude a vascular origin. A cyst located dorsally between the distal interphalangeal joint of the finger and the adjacent nail represents a mucoid cyst associated with osteoarthritis. An associated solid component would suggest another cause, including both benign and malignant neoplasms.

Summary

A hypo- or anechoic multi- or unilocular noncompressible cyst-like lesion in a typical location is a characteristic finding of a ganglion.

Pseudomasses

There are many conditions that can manifest as a palpable abnormality and simulate a superficial soft-tissue mass (Figure 3). For example, tendinosis and gout may cause tendon enlargement and manifest clinically as a superficial mass. A full-thickness retracted tendon tear, such as might occur in the rectus femoris at the thigh, the biceps in the arm, or the tibialis anterior at the ankle, may present as a pseudomass. Association of the pseudomass with the tendon assists in the diagnosis. Similarly, a muscle hernia may also protrude through a fascial defect into the subcutaneous tissues in continuity with the underlying muscle, commonly the tibialis anterior muscle, where the diagnosis is aided by muscle contraction or standing (44). Fibromatosis represents fibroblastic-myofibroblastic proliferation and frequently manifests as a superficial mass in a typical location, such as the palm (Dupuytren contracture) or foot (plantar fibromatosis), with possible increased Doppler flow in the latter

(45). While it is beyond the scope of this article to review all such pseudomasses, in most cases, these lesions can be confidently diagnosed based on a combination of location, anatomic structure of origin, US features, and clinical history. Recommendations vary depending on the diagnosis. Two of the most common pseudomasses are described next.

Bursa-related Abnormalities

Background

A bursa is a sac or cavity found overlying bone surfaces at areas of friction, and its location may be deep or relatively superficial (46–48). There are two types of bursae: anatomic and adventitious. Anatomic bursae are present at birth and have a synovial lining. Adventitious bursae are acquired, forming in response to pressure or friction on superficial subcutaneous tissues in contact with osseous protuberances, and they lack a synovial lining. Both anatomic and adventitious bursae are present at predictable sites. Adventitious bursae are found in the plantar foot, typically plantar to the first and fifth metatarsal heads, as well as at other locations, such as the retro-Achilles (or tendo-Achilles) bursa.

Bursal distention may present as a palpable superficial soft-tissue mass or as areas of swelling. Anatomic bursae that may present as a superficial mass include the olecranon bursa. In regard to anatomic bursae, most abnormalities are related to synovial processes, which may produce fluid or masslike distention. Such synovial processes may be categorized as traumatic (acute or repetitive injury), inflammatory (rheumatoid arthritis, gout, chronic infection, among others), or proliferative (tenosynovial giant cell tumor, synovial chondromatosis, lipoma arborescens, or amyloidosis).

US Findings

Bursal fluid may be composed of anechoic simple fluid or fluid with variable homogeneous or heterogeneous echogenicity, depending on its composition. A complex appearance may be due to crystals, purulent fluid, or blood, which present with echoes floating or layering within the fluid or at times, a solid appearance. If it is due to crystal deposition (such as gout), hyperechoic foci or tophi may be seen. Synovial hypertrophy or proliferation from any cause is typically hypoechoic and minimally compressible or noncompressible. Variable vascularity may be detected with Doppler US. Adventitious bursae are characteristically compressible unless there is prominent fibrous tissue.

Differential Diagnosis

Differential diagnosis includes any synovial process described previously.

Summary

Anechoic, hypoechoic, or mixed echogenicity fluid distention of a bursa, with or without synovial changes (thickening, nodularity, or both) is characteristic of traumatic, inflammatory, and proliferative synovial processes.

Fluid Collections

Background

The cause of a superficial soft-tissue fluid collection includes abscess, hematoma, seroma, or lymphocele (49–54). Infection of the superficial soft tissues often is due to penetrating injury or indwelling catheters. Initially beginning as cellulitis, the infection can spread deeper and form a discrete abscess. A superficial hematoma may be secondary to trauma or recent surgical intervention, or it may be a complication of excess anticoagulation therapy.

US Findings

An abscess most commonly appears as a complex fluid collection with internal echoes and increased posterior through-transmission, although an iso- or hyperechoic appearance is also possible due to the reflective nature of the purulent fluid. Sonopalpation helps confirm the cystic nature of the collection in this latter situation by showing movement of echogenic fluid within the collection. The margins may be discrete or ill defined, and peripheral hyperemia may be seen on Doppler US images. Surrounding hyperechoic cellulitis is typically present. Superficial collections containing hair suggest the diagnosis of hidradenitis suppurativa, especially if they occur in a typical location, such as the intertriginous axillary, groin, or perianal area. A fluid collection containing hair in the intergluteal region is diagnostic of pilonidal cyst. If clinically relevant, a search for a foreign body should be performed. These appear hyperechoic with variable shadowing and reverberation depending on the surface attributes and may be associated with a fluid collection, soft-tissue swelling, or both (53).

The US appearance of a soft-tissue hematoma depends on its chronicity. An acute hematoma is typically solid and iso- or hyperechoic. Over time, the hematoma organizes, becomes hypoechoic, and begins to liquefy with clot lysis. In most instances, the hematoma becomes completely cystic and anechoic (termed *seroma*). Areas of heterogeneity, such as linear fibrin strands, or mural nodules, may be present with chronic hematomas. A hyperechoic wall or interface also may be evident. A hematoma at the interface between subcutaneous fat and muscle fascia, most commonly over the lateral hip and related to a shearing-type injury, has been termed *Morel-Lavallée lesion*.

Differential Diagnosis

Abscess and hematoma may appear similar; therefore, history and clinical findings aid in their differentiation. A hypoechoic mucinous or partially cystic, hemorrhagic, or necrotic soft-tissue tumor (benign or malignant) may simulate a hypoechoic fluid collection as well.

Summary

In the correct clinical setting, a predominantly hypoechoic fluid collection with increased posterior through-transmission and mobile internal echoes with sonopalpation is characteristic of an abscess. A fluid collection ranging from hyperechoic to an-

echoic is consistent with hematoma with history of trauma or anticoagulation.

Lymphadenopathy

Normal lymph nodes rarely present as a palpable mass (Figure 4). Enlarged nodes, on the other hand, are a frequent indication for US. This is most often due to benign reactive or hyperplastic nodes; however, lymphoma and metastatic disease always must be considered. Despite overlap in the appearance of reactive, lymphomatous, and metastatic nodes, reasonable recommendations for management can be made based on a combination of typical and atypical US features, clinical history, and correlative imaging findings (55–57).

Background

Lymph nodes are the filters of the lymphatic system, interconnecting vessels and lymphatic channels, and are therefore identified at expected nodal locations. Normal lymph nodes have a characteristic US appearance, while enlarged abnormal lymph nodes may appear nonspecific.

US Findings

Normal superficial lymph nodes are oval shaped and usually measure 1–4 mm, but they can be as large as 30 mm depending on their location. The normal architecture is composed of hypoechoic cortical tissue surrounding a hyperechoic hilum. The hyperechogenicity is not due to fat alone but rather is secondary to reflections from interfaces where lymphatic sinuses converge with vessels and fat. The hypoechoic cortex is typically uniform in thickness and echogenicity and normally is thin in the elderly population. Doppler US can often be used to detect the branching vascular pedicle located centrally at the hilum.

Reactive (or hyperplastic) lymph nodes preserve their normal architecture on US images. Cortical echogenicity usually remains homogeneous, and thickening of the cortex is usually concentric and uniform, with maintenance of an oval shape. Hypervascularity, when present, typically maintains a hilar pattern. With malignancy, abnormal lymph nodes tend to have a more rounded shape, and the cortex may be heterogeneous or asymmetrically thickened. Loss of the central hyperechoic hilum is the most common finding in malignant involvement but is nonspecific. Calcifications and cystic areas are also suspicious findings. Vascularity is more disorganized with a peripheral or mixed peripheral and hilar pattern. Although size criteria are used to determine enlargement, size alone is unreliable in predicting malignancy and may be most helpful as a baseline parameter.

Differential Diagnosis

Primary considerations of an enlarged lymph node include reactive or hyperplastic versus malignant causes. Reactive or hyperplastic and lymphomatous lymph nodes can have a similar appearance. Malignant nodes can be mimicked by granulomatous and suppurative nodes. A malignant lymph node (primary or secondary) may eliminate any recognizable nodal architecture and appear as a nonspecific hypoechoic mass. The presence of multiple masses in the expected location of a lymph node chain assists in this differentiation.

Summary

An enlarged lymph node that is oval with an echogenic hilum, uniform hypoechoic cortex, and hilar blood flow is considered reactive or hyperplastic unless there are conflicting clinical considerations, particularly if there is a history of lymphoma or other concurrent evidence of malignancy. An enlarged lymph node that is round with the absence of an echogenic hilum, nonuniform cortex, and peripheral or peripheral and hilar blood flow is considered potentially malignant.

Nonspecific Neoplastic Masses

Soft-tissue neoplasms often have a typical appearance (2,6,10,12,34,58–64). Because it is difficult to distinguish benign from malignant neoplasms, lesions with an appearance typical of neoplasms require contrast-enhanced MRI, usually followed by biopsy, surgical consultation, or both. If the patient has a history of a primary malignancy or lymphoma, biopsy can usually be performed initially without prior MRI (Figure 5).

Background

There are many benign and malignant neoplasms that occur in the superficial soft tissues, and a detailed review of such masses is beyond the scope of this article. These lesions may be an extension of a deeper soft-tissue or osseous mass, or they may arise within the superficial soft tissues. Lymphoma and metastases may also be found in the superficial soft tissues.

US Findings

In general, most tumors are solid and appear predominantly hypoechoic. Necrosis and hemorrhage can produce heterogeneity and cystic areas. Myxoid tumors appear hypoechoic and may simulate a fluid collection. Most neoplasms have detectable intrinsic vascularity, and some are intensely hypervascular.

Differential Diagnosis

Most neoplasms can be distinguished from non-neoplastic lesions. Because there is substantial overlap in the sonographic appearance of various neoplasms and in the absence of a helpful clinical history or typical location, it is usually not possible to distinguish benign from malignant neoplasms or to distinguish different types of malignant tumors.

Summary

Most neoplasms are solid or partially solid and appear predominantly hypoechoic, with variable heterogeneity and detectable internal vascularity.

Other Masses

Other superficial masses that may be identified with US are beyond the scope of this article (65). These include glomus tumor, plantar wart, giant cell tumor of tendon sheath, pilomatricoma,

and many others. While a review of masses deep to the subcutaneous tissues is not the focus of this article, the differential diagnosis of a deep mass can be based on the likely anatomic structure of origin guiding diagnostic considerations and subsequent recommendations. MRI with an intravenous gadolinium-containing contrast agent is often needed to further characterize and fully define the extent of deep masses identified at US.

Future Directions

In addition to gray-scale imaging and conventional Doppler US, several new techniques may have an impact on our approach to soft-tissue masses, including contrast-enhanced US, microvascular imaging, elastography, and artificial intelligence (66–80). Given the importance of blood flow in the diagnosis of superficial soft-tissue masses and the plethora of technical considerations in optimizing Doppler sensitivity, any technique that improves the analysis of perfusion will probably be useful. Contrast-enhanced US is extremely sensitive in the detection of blood flow and is helpful in deep and superficial organs throughout the body. One would expect its impact on US analysis of superficial masses to be similar to the impact contrast material has on MRI analysis, and studies confirm that it can aid in the differentiation of benign and malignant soft-tissue tumors. Microvascular imaging is a Doppler technique that improves the detection of small vessels with low volume and low-velocity flow by using adaptive algorithms to distinguish signals from tissue and transducer motion from real blood flow. Like contrast-enhanced US, it has the potential to improve the diagnosis of masses throughout the body, including superficial masses in many locations. Unlike contrast-enhanced US, microvascular imaging does not require an intravenous injection and thus can be used more readily. Elastography is used to evaluate lesion stiffness and can enable objective assessment of stiffness beyond subjective interpretation of lesion compressibility with relatively high accuracy in distinguishing benign from malignant soft-tissue tumors. Artificial intelligence can help identify complex imaging patterns and reduce operator dependence and interobserver variability in the analysis of US imaging. It has been used in the diagnosis of many superficial organs and has recently shown promise in superficial soft-tissue masses.

Conclusion

US is an excellent first-line imaging method in the evaluation of a superficial soft-tissue mass. Many diagnoses can be made with confidence, as summarized earlier in this article. In most other instances, a combination of US findings and clinical history are adequate to guide appropriate management. Follow-up or alternative imaging, and/or possible biopsy will be required for atypical, nonspecific, or suspicious US findings or a conflicting clinical history.

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