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MUSCULOSKELETAL ULTRASOUND

Stephanie Creel RT(R), RDMS, RVT

INTRODUCTION

Sonography is rapidly becoming a more widely accepted imaging technique for the evaluation of musculoskeletal pathology. Although musculoskeletal sonography has been used as the primary imaging technique for musculoskeletal indications in Europe for many years, this imaging modality has been much slower to gain popularity in the United States. This is likely due to the availability of magnetic resonance imaging (MRI).[1] However, musculoskeletal sonography is proving to be a reliable alternative to MRI for many musculoskeletal indications. It is a rapidly developing modality that has many intrinsic advantages over more costly imaging techniques such as MRI[1] and is a non-invasive alternative to arthrography.[2] Recently, notable advancements in imaging resolution have been made in ultrasound technology that have contributed to enhanced imaging quality of musculoskeletal anatomy. For these reasons and several others, the role of sonography is evolving into an applicable modality for several areas of the musculoskeletal system.

BASIC ULTRASOUND PRINCIPLES

Sound waves are a form of energy transmission.[3] Ultrasound is considered to be any frequency of sound that is greater than that which is audible by humans. The frequency range of human hearing is 15–20 kiloHertz (kHz); therefore, ultrasound occurs at frequencies greater than 20 kHz. Medical ultrasound imaging is performed using frequencies in the range of 2–15 megaHertz (MHz).[4] For musculoskeletal sonography, frequencies in the higher ranges of 7–15 MHz are generally applied.[3]

Diagnostic ultrasound imaging uses transducers that contain piezoelectric crystals. When an electrical current is applied to the crystal, it changes shape; as the crystal contracts and expands, a sound wave is created. This is described as the *piezoelectric effect*.[3-5] As the sound beam propagates through the body, the sound waves encounter tissue interfaces of different acoustic impedances, and reflection back to the transducer occurs.[5] The reflected acoustic energy is then converted to electrical current in order to display an image.[4,5] Several terms are used to characterize the reflections from different tissue interfaces as they appear on the imaging screen: *hyperechoic*—bright echo; *isoechoic*—echo intensity equal to the background or an adjacent structure; *hypoechoic*—low echo; *anechoic*—no echo.[3,5]

Musculoskeletal ultrasound focuses on several different types of tissue, all of which have their own specific ultrasound characteristics on the image display. The following tissues/structures can be evaluated with musculoskeletal ultrasound and exhibit an appearance as follows:

* Tendons demonstrate a fibrillar pattern and appear hyperechoic when imaged at a perpendicular angle[5] (Figure 1).

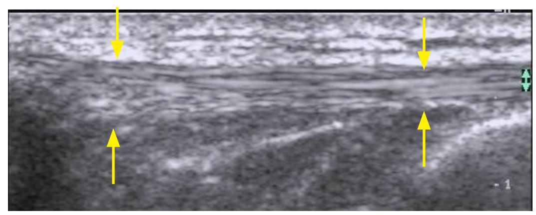

FIGURE 1. Tendon Indicated by Arrows

* Muscles exhibit hypoechoic muscle fibers separated by hyperechoic fibroadipose septations[5] (Figure 2).

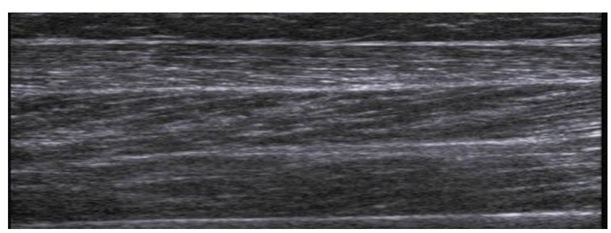

FIGURE 2. Muscle Indicated by Arrows

* Ligaments appear hyperechoic with a compact fibrillar pattern[5] (Figure 3).

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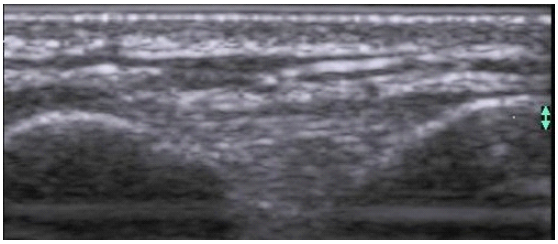

FIGURE 3. Ligament Indicated by Arrows

* Bones generate a hyperechoic appearance at the highly reflective surface of the cortex. The sound beam does not penetrate beyond the surface of the cortex[5] (Figure 4).

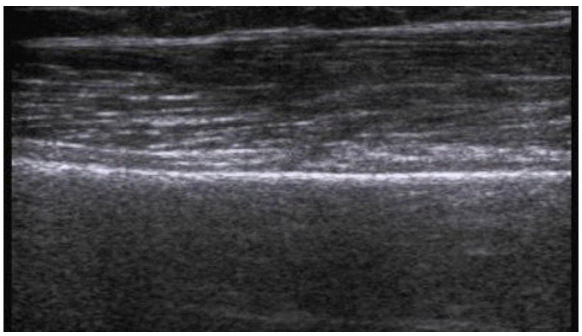

FIGURE 4. Bone Indicated by Arrows

* Peripheral nerves appear as hypoechoic bands separated by multiple hyperechoic parallel linear areas that demonstrate a fascicular appearance[5] (Figure 5).

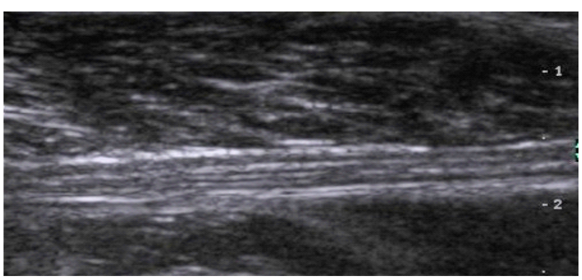

FIGURE 5. Nerve Indicated by Arrows

* Air and gas appear as bright punctate echoes with posterior reverberation artifact or comet-tail artifact.[5]

* Metal objects demonstrate a hyperechoic, highly reflective surface with posterior reverberation or ring-down artifact.[5]

* Simple fluid is anechoic and demonstrates acoustic enhancement of the soft-tissue posterior to the fluid collection.[5]

ARTIFACT

An important sonographic occurrence one should be familiar with when imaging the musculoskeletal system is *anisotropy*. Anisotropy is a term used to describe a very significant sonographic artifact that occurs frequently when evaluating soft-tissue structures such as muscles and ligaments, but is most notable when examining tendons.[6] These structures consist of collagen fibers organized in a parallel manner that demonstrate the highest reflectivity of transmitted sound when the beam angle is directed perpendicular to the fibers. Anisotropy occurs when the ultrasound beam is not perpendicular to the fibrillar structure of the tendon; this results in an artifactual hypoechoic appearance of the tendon, which may simulate tendon pathology (Figures 6A–6D).[1,6,7] Awareness of proper transducer position by the sonographer is essential in preventing or reducing this artifact. Some manipulation of the ultrasound probe by employing heel-toe angulations may help reduce anisotropy. It is sometimes impossible to completely eliminate anisotropic effects when tendons course obliquely. Evaluation of these tendons should be performed in segments in order to obtain the appropriate beam angle on all portions of the tendon fibers. In these situations, the determination of tendon integrity is best evaluated during real-time imaging.[1,5]

Using a *linear array transducer* will help ensure that the sound beam is perpendicular for optimal imaging of musculoskeletal structures.[5] Linear array transducers are constructed with the elements aligned in a linear fashion. The elements are then fired in sequence to generate a series of parallel pulses that create an image beam that runs perpendicular to the transducer footprint.[4] Linear array transducers of frequencies in the range of 7–15 MHz offer high resolution of superficial structures and provide the best image detail. Imaging of deeper structures, such as the hip, may require the use of a *curvilinear transducer*. Curvilinear transducers, which operate at lower frequencies (2–5 MHz), offer deeper penetration of the sound beam and a wider field of view.[5]

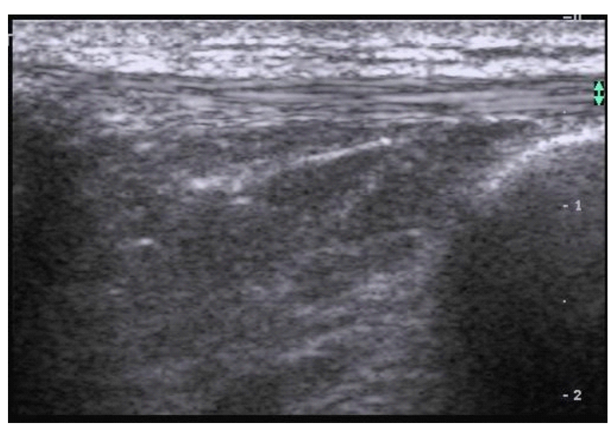

FIGURE 6A. Normal Tendon with Perpendicular Beam Angel, Longitudinal Plane

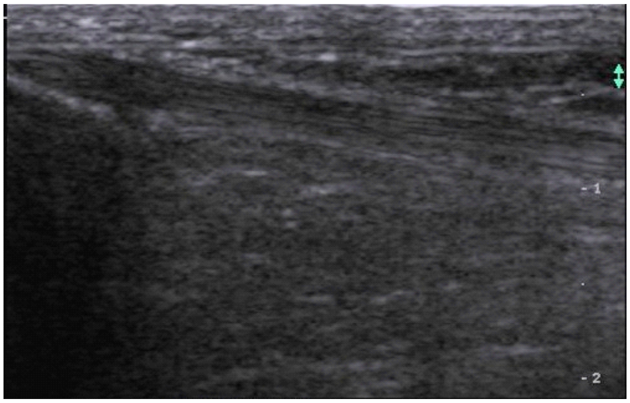

FIGURE 6B. Anisotropy of Tendon at Arrows, Longitudinal Plane

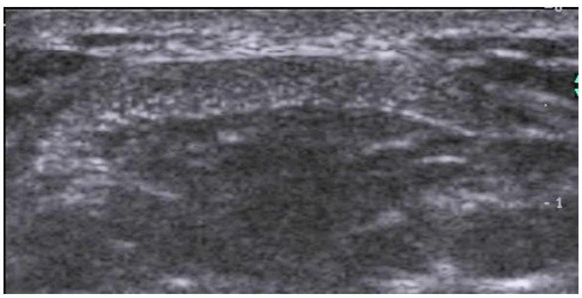

FIGURE 6C. Normal Tendon wiht Perpendicular Beam Angle, Transverse Plane

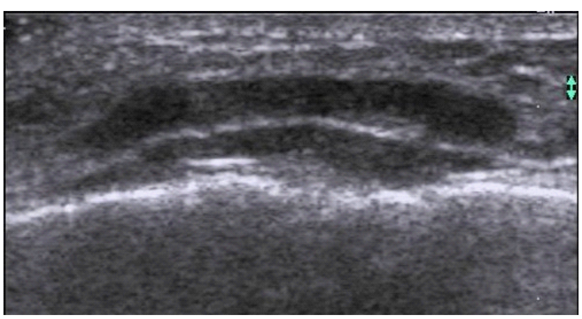

FIGURE 6D. Anisotropy of Tendon, Transverse Plane

ADVANCEMENTS IN TECHNOLOGY

Several technological advancements in sonographic image quality within recent years have made a dramatic impact on the role of ultrasound in musculoskeletal imaging. High-frequency transducers offer exceptional spatial resolution by providing excellent detail of superficial structures. The spatial resolution of ultrasound is actually greater than that achievable by MRI without using non-standard coils or imaging parameters.[8-10] Improvements in detection of color flow by power Doppler imaging offer increased sensitivity to blood flow. This provides improved demonstration of hyperemia associated with soft-tissue inflammation and enhances visualization of subtle vascularity in solid masses.[1,3,5,7,11] Equipment capabilities offered on some of the most current ultrasound machines allow imaging in a wider field of view. This increased field of view provides a means to display larger abnormalities to more accurately assess their size and overall extent.[1,3,11] Using the split-screen or dual-imaging function that is available on most equipment provides a means of side-by-side comparison of anatomical structures.[1]

WHY MUSCULOSKELETAL ULTRASOUND?

Aside from great advancements in technology, there are also several advantages of musculoskeletal ultrasound over other imaging modalities that are likely contributing to the growing popularity of ultrasound evaluation of joint and soft-tissue diseases. Ultrasound is an easily accessible and widely available modality. Conversely, MRI sometimes requires long delays for examination scheduling due to limited availability of imaging equipment.[1,5] Another important benefit of ultrasound in comparison to MRI is the low cost. Ultrasound is considered to be relatively inexpensive, which makes this modality an appealing alternative.[5,8,10]

Sonographers have the advantage of interacting with the patient directly throughout the examination, thus providing the opportunity for open communication. This is a valuable feature because it allows the patient to localize areas that are painful during certain positioning movements. The patient is also able to demonstrate the specific motion that reproduces symptoms of pain, which ensures that the examination is focused directly on the patient's symptoms or physical findings.[5,12] Sonography is very adaptable in this sense because it is not limited to standardized protocols. The flexibility of ultrasound also offers the capacity of comparison to contralateral, asymptomatic structures. Contralateral comparison provides internal control because it helps differentiate a normal variant from an abnormality and can possibly provide a more confident diagnosis of an abnormality in difficult cases.[1]

Ultrasound also offers the unique ability of dynamic imaging. This provides real-time evaluation of musculoskeletal structures while they are maneuvered or manipulated to reproduce the patient's symptoms. This can be vital in determining the diagnosis when examining a patient whose symptoms are described as a snapping or clicking that occurs with a particular motion. This ability alone is a great advantage of ultrasound over other modalities because it provides the capability to diagnose intermittent subluxation or dislocation of tendons that otherwise may have gone undetected.[5] Dynamic imaging may also better demonstrate the extent of full-thickness tears by evaluation during muscle contraction and relaxation and also by applying compression with the transducer.[1,5]

Portability and multiplanar imaging make ultrasound an excellent modality for performing procedures such as guided biopsies and aspirations.[1] Other more obvious benefits of using sonography include the facts that ultrasound imaging does not employ ionizing radiation, is noninvasive, and is well tolerated by patients.[2,7,13]

CLINICAL INDICATIONS

There are currently a number of accepted applications of ultrasound imaging for the evaluation of musculoskeletal pathology. Of these, there are numerous indications in which sonography has been shown to yield results equal to MRI, as described in Table 1. The goal of the following section is to provide an overview of the most commonly sonographically evaluated structures or conditions in the musculoskeletal system, including tendons, ligaments, muscles, nerves, bone, soft-tissue masses, soft-tissue infection or joint effusion, and foreign bodies.

TABLE 1. Most Accepted Indications in Which Musculoskeletal Ultrasound Yields Results Equal to That of MRI*

• Shoulder: tendon abnormality, calcium deposition, biceps subluxation
• Ankle: tendon abnormality, Achilles xanthoma
• Soft-tissue infection or joint effusion
• Foreign body detection/localization
• Soft-tissue masses (Baker's cyst and wrist ganglia)
• Carpal tunnel syndrome

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TENDONS AND LIGAMENTS

One of the most common clinical indications for musculoskeletal sonography is evaluation of tendon pathology. All normal tendons have uniform characteristics on sonography because they appear as hyperechoic structures that demonstrate a fibrillar pattern.[1,5] Tendon pathology ranges in severity from *tendinosis* (ie, tendon degeneration) to intrasubstance tear and partial-thickness tear to more severe abnormalities of full-thickness tear or complete rupture.[5] The ultrasound appearance of a tendon demonstrating loss of the fibrillar pattern is indicative of tendon disruption. Hypoechoic areas within a tendon may represent tendinosis, intrasubstance abnormality, or partial tearing. Tendinosis occurs as a focal or diffuse process causing a heterogeneous or ill-defined hypoechoic appearance without loss of tendon volume, whereas partial tears demonstrate a more defined defect within the tendon. A focal, hypoechoic, or anechoic gap or cleft through the tendon is consistent with a full-thickness tear. Nonvisualization of the tendon is diagnostic of a complete tendon tear with tendon retraction.[5,10] *Tenosynovitis* is another condition in which there is fluid within the tendon sheath surrounding the tendon. Thickened synovium and increased flow on power Doppler may also be present with this condition.[14]

Several ligaments of the musculoskeletal system can also be evaluated by sonography. Ligaments have ultrasound characteristics similar to that of tendons, but they display a more compact fibrillar pattern and are seen connecting bone to bone.[1,10] Ultrasound appearance of ligamentous injuries varies depending on whether the injury is acute or chronic. Acute rupture demonstrates discontinuity of fibers with hemorrhage or fluid. Ligament fibers in an acute partial tear are hypoechoic and thickened but intact. After a disrupted ligament has healed, its ultrasound appearance may return to normal, whereas chronic ligament disruption may result in scarring and the formation of granulation tissue.[5] These tendon and ligament abnormalities can be readily identified by sonography in several joints of the musculoskeletal system such as the shoulder, ankle, knee, elbow, wrist, and hip.

The tendons of the rotator cuff in the shoulder are one of the most frequently evaluated areas by musculoskeletal sonography. Routine examination of the rotator cuff includes sonographic evaluation of the following tendons: *biceps brachii, subscapularis, infraspinatus,* and *supraspinatus*. The supraspinatus is the most frequently disrupted tendon of the rotator cuff.[14] Sonography has been shown to be effective in the diagnosis of rotator cuff tears. One study demonstrated a sonographic sensitivity of 93% in detection of partial thickness tears and 100% sensitivity for full-thickness tears of the rotator cuff.[5,10] Nonvisualization of the supraspinatus tendon along with the deltoid muscle in direct contact with the humeral head has a 100% positive predictive value in the diagnosis of complete rotator cuff tear with tendon retraction.[5]

There are several situations in which dynamic imaging is useful in evaluating the shoulder. Subluxation of the biceps brachii tendon can be easily documented with dynamic ultrasound imaging. External rotation maneuvers of the arm are used to demonstrate medial displacement of the biceps tendon out of the bicipital groove. The biceps tendon may otherwise appear normal when the arm is in the neutral position.[5] Dynamic imaging during abduction of the arm is useful in the diagnosis of *shoulder impingement* and *adhesive capsulitis*.[10] Pooling of bursal fluid between the acromion and humeral head during lateral extension of the arm is suggestive of impingement. Adhesive capsulitis is likely when the supraspinatus does not slide under the acromion during abduction and bulging of the tendon occurs.[10]

Sonography is also effective in evaluating the ankle for tendon and ligament abnormalities. Ultrasound examination of the ankle includes assessment of the following tendons: *anterior tibialis, extensor hallucis longus,* and *extensor digitorum longus* in the anterior ankle; *posterior tibialis, flexor digitorum longus,* and *flexor hallucis longus* in the medial ankle; *peroneal longus* and *brevis* in the lateral ankle; and the Achilles tendon in the posterior ankle. The *anterior talofibular, anterior tibiofibular, calcaneofibular,* and deltoid ligaments can also be readily assessed during ankle sonography. The most commonly injured ligament of the ankle is the anterior talofibular.[15] Ultrasound can play an essential role in the assessment of ligament injury because ligament derangement can lead to ankle instability.[15]

Dynamic imaging plays a key role in ankle imaging to evaluate the peroneal tendons for *subluxation*. Dorsiflexion and eversion maneuvers are used to evaluate for displacement of the tendons out of their lateral malleolar groove. In the neutral position, these tendons of the ankle may appear normal.[10] It is important to evaluate for subluxation when a patient describes a symptom of snapping because early diagnosis and treatment may prevent development of a tendon tear.[5,10]

The Achilles tendon is easily accessible to sonography because it is a rather large tendon in a superficial location. In the case of a complete Achilles tendon rupture, the extent of tendon retraction can be measured by sonography. The foot is placed in passive dorsiflexion, and the distance between the torn tendon ends (ie, tendon gap) is measured. Placing the foot in plantar flexion is also useful to evaluate for approximation of the ruptured tendon ends. This can provide valuable information in the decision between surgical versus conservative treatment (eg, casting).[5,15] Another important role for sonography of the Achilles tendon is evaluation for xanthoma. Sonography is the preferred modality for diagnosis of xanthomas because it best demonstrates and quantifies these hypoechoic nodules that occur in the Achilles tendon. Identification of these nodules is significant because they are indicators of familial hypercholesterolemia.[8,15]

Musculoskeletal ultrasound examination of the knee includes the following tendons: *patellar, quadriceps, biceps femoris, iliotibial tract.* Evaluation of the patellar and quadriceps tendons by sonography is facilitated by their superficial location and large size.[10] Conditions such tendinosis of the proximal patellar tendon, known as *Jumper's knee*, can be readily assessed. Patellar tendinosis may demonstrate increased blood flow (ie, hyperemia) on color Doppler evaluation in addition to a hypoechoic, thickened tendon.[10] Sonographic sensitivity of 100% has been reported in the diagnosis of full-thickness tears of the quadriceps tendon.[10] Imaging the quadriceps tendon during passive flexion will make the complete discontinuity of the tendon more apparent.[5] The medial collateral and fibular collateral ligaments of the knee can also be routinely assessed for injury by ultrasound.[5]

Elbow examination by sonography includes evaluation of the following tendons: distal insertions of the *biceps brachii* onto the tuberosity of the proximal radius and the *triceps* onto the olecranon; *common flexor* and *common extensor* origins at the humeral epicondyles. Epicondylitis (ie, tendinosis) exhibits a hypoechoic and thickened common extensor or flexor tendon. Pain or point tenderness may be elicited by transducer pressure at the affected site.[5,10] The ulnar collateral ligament of the medial elbow can also be readily evaluated by ultrasound.[5]

Ultrasound is an excellent modality for evaluating the hand and wrist because their small structures are quite superficial. High-frequency probes provide optimal resolution of the tendon structure.[16] Examination of the hand and wrist includes evaluation of the *flexor tendons* on the volar aspect and the *six compartments of the extensor tendons* on the dorsal side. A symptomatic tendon surrounded by fluid is indicative of tenosynovitis.[5] Using specific joint movements can aid in isolating the tendon(s) that are causing symptoms, thus allowing the examination to be focused on that specific area. Dynamic imaging is useful in evaluating for full-thickness tendon rupture and tendon subluxation in the wrist. Tendon retraction with dynamic imaging is indicative of full-thickness tear.[10] Sonography is also capable of assessing the ulnar collateral ligament of the first metacarpophalangeal joint for injury (known as *gamekeeper's thumb*).[5]

Sonography of the hip is generally performed using a lower frequency transducer of 5–7 MHz because the structures to be evaluated may be quite deep. A curvilinear probe may also be used for deeper penetration and a wider field of view. Several tendon insertions around the hip can be evaluated with ultrasound, including the insertion of the *biceps femoris, semitendinosus,* and *semimembranosus* on the ischium posteriorly; *rectus femoris* on the anterior inferior iliac spine, *sartorius* on the anterior superior iliac spine, and the *iliopsoas* on the lesser trochanter of the femur. Dynamic evaluation of the hip is invaluable in the assessment of *snapping hip syndrome*. This condition involves a discernible (either audible or palpable) snapping during hip motion. Causes that may be detected by ultrasound include snapping of the iliotibial band over the greater trochanter of the femur or snapping of the iliopsoas tendon over a bony pelvic eminence.[10] With real-time imaging the patient's hip is evaluated during motion that elicits the snapping. Documentation of an abnormal motion of the involved tendon against the bone, in correlation with the snapping, is diagnostic of this condition.[10]

MUSCLE

Another common application of musculoskeletal ultrasound is evaluation of muscle pathology. The mechanism of a muscle injury is categorized as either a direct or an indirect trauma.[5,10,17] A *direct injury* is a result of compression of the muscle by direct impact from an external force.[5,10,17] This type of injury commonly results in hemorrhage/hematoma within the muscle belly. Sonographic findings vary with the time interval from the injury. In the most acute stage, the muscle may be enlarged and appear slightly more hyperechoic.[5,10,17] Comparison of the normal musculature of the contralateral side may be quite useful in this situation. Within days the hemorrhage will become hypoechoic to anechoic. Ultimately, the injured muscle tissue will become hyperechoic with scar tissue or calcification that demonstrates posterior acoustic shadowing (myositis ossificans).[5,17] *Indirect muscle injuries* are caused by stretching during muscle contraction or by over-stretching the muscle.[10] These types of injuries often occur at the musculotendinous junction and commonly affect the muscles of the lower extremity.[5,10,17] Indirect injuries range in severity from strain, to partial thickness tear, to full-thickness tear.[10] Imaging commonly demonstrates fluid (hemorrhage) tracking along the torn muscle edge.[5]

BONE

Ultrasound plays a limited role in the imaging of bone because it is unable to penetrate beyond the highly reflective interface at the surface of the cortex. However, there are several instances in which bony irregularities can be detected by sonography. The normal cortex demonstrates a smooth contour. Ultrasound is able to demonstrate irregularities in the cortex such as cortical erosions or osteophytes.[5] Occult fractures of the greater tuberosity of the humerus may be identified during evaluation for rotator cuff tear. Stress fractures may also be detected with ultrasound. Fractures generally demonstrate disruption of the smooth hyperechoic cortex at an area of point tenderness.[5] Sonography of bone has also proved useful in the evaluation of bone healing over a fracture site because ultrasound can detect callus formation before radiography.[5,18]

PERIPHERAL NERVES

Normal nerves appear as hypoechoic structures with a fascicular pattern and are seen adjacent to vessels. Nerves are readily differentiated from tendons by their lack of motion with extremity movement.[19,20] Ultrasound can be used to evaluate nerve pathology, including nerve entrapment syndromes as well as some nerve tumors. Carpal tunnel syndrome is a nerve entrapment syndrome commonly evaluated by ultrasound. Sonography demonstrates a swollen hypoechoic median nerve at the level of the palmar crease.[5] In addition to assessment of the nerve, ultrasound is also capable of evaluating the cause of the nerve compression (eg, ganglion cyst or other mass within the carpal tunnel).[5] In some cases, dynamic imaging may be used to evaluate for nerve dislocation. Ulnar neuropathy may be caused at the cubital tunnel of the elbow by medial displacement of the nerve over the medial epicondyle during elbow flexion. Real-time imaging is the ideal modality to evaluate this transient condition because it will document the ulnar nerve located within the cubital tunnel during extension but will demonstrate the medial displacement of the nerve during elbow flexion.[10]

The full length of peripheral nerves can be examined rather quickly with sonography and can be used effectively in the evaluation of nerve lesions.[20] Peripheral nerve tumors, such as schwannomas and neurofibromas, are generally hypoechoic fusiform-shaped lesions that demonstrate posterior acoustic enhancement.[19-21] Nerve tumors may also appear hypervascular on color Doppler.[19,20] Demonstration of a lesion continuous with nerve fascicles that also produces radiating pain along a nerve distribution when compressed with the ultrasound transducer is sonographically diagnostic of a peripheral nerve tumor.[21]

SOFT-TISSUE MASSES

Musculoskeletal sonography also plays an important role in evaluating soft-tissue masses. Ultrasound can distinguish cystic masses from solid masses. Cystic masses are typically anechoic and demonstrate through-transmission.[5] Complex cysts may contain septations or debris. Using the transducer to compress over the mass may cause displacement of fluid confirming the cystic nature of the lesion.[5] Cystic masses generally do not demonstrate blood flow unless they are vascular in origin, such as in the case of aneurysm, pseudoaneurysm, arteriovenous fistula, or varicosity.[21]

Diagnosis of the cyst type can be determined by locating the cyst in relation to other anatomical structures. Ganglion cysts demonstrate a communication with a joint or tendon sheath.[5] Baker's cysts communicate with the posterior knee joint between the semimembranosus tendon and the medial head of the gastrocnemius.[5,21] Meniscal cysts and labral cysts may also be documented with ultrasound. Bursitis is diagnosed when the fluid collection is located in the anatomic area of a bursa.[21]

Ultrasound is also useful in the evaluation of solid masses. Although sonography is not able to provide a specific histological diagnosis of a lesion, there are soft-tissue lesions in which ultrasound imaging demonstrates specific characteristics that can suggest a likely diagnosis based on sonographic appearance.[21] Lipomas are soft, mobile masses that characteristically appear as elongated homogeneous masses oriented parallel with the skin and are compressible and demonstrate no vascularity. Lipomas can be located in the subcutaneous tissue or may be inter- or intramuscular; they may demonstrate variable echogenicity.[20-21] Hemangiomas are masses containing vascular channels that characteristically act as a sponge on color Doppler examination. During static examination, the mass demonstrates little to no flow; however, compression of the lesion with the transducer will demonstrate increased color flow within the vascular channels.[21] As described previously, some peripheral nerve tumors can also able be accurately described by sonography. Any mass that does not display characteristic appearances on ultrasound may require further imaging or a biopsy to confirm the type of lesion. Ultrasound can be used for localization and real-time guidance if biopsy is indicated.

SOFT-TISSUE INFECTION AND JOINT EFFUSION

Sonography is a very effective method for evaluating soft-tissue fluid collections. Ultrasound can easily diagnose *cellulitis, abscess,* or *joint effusion*, all of which may be hard to differentiate clinically.[8] Cellulitis is a condition of soft-tissue edema that sonographically demonstrates the subcutaneous fat lobules as hyperechoic structures surrounded by hypoechoic channels of distended lymphatics.[5,8] Abscesses generally appear as discrete hypoechoic or anechoic fluid collections with through-transmission. Complex abscesses may be difficult to differentiate from some soft-tissue masses. Applying compression over the collection with the transducer causes swirling of debris and is thus more suggestive of an abscess.[8] The presence of small gas bubbles within the collection is also suggestive of an abscess. On ultrasound, gas bubbles appear as hyperechoic foci with comet-tail reverberations.[5] Sonography is also able to identify fluid within a joint. The joint capsule will be distended with hypoechoic or anechoic fluid. A joint effusion that is complicated with internal debris may be suggestive of infection.[5,8] However, ultrasound appearance alone is non-specific, and aspiration of the joint fluid is usually required to exclude infection.[5,8] When either an abscess or joint effusion is localized, ultrasound can immediately provide real-time guidance for needle aspiration of the fluid collection.

Sonography plays a very significant role in the evaluation of fluid collections around orthopedic hardware. Metal hardware produces artifact on computed tomography (CT) and MRI that often obscures the soft tissues of interest. On ultrasound, the artifact from metal occurs as reverberation artifact deep to the hardware, making it possible to evaluate the superficial structures for fluid collections.[5,8,18]

FOREIGN BODY DETECTION

Ultrasound has found a role in the evaluation of foreign bodies in soft tissues because of its capability to provide detection and localization.[22] Although radiographs are routinely the first step in detecting foreign bodies, any foreign body that is not radiopaque will not be discovered.[5,8,22] Ultrasound has demonstrated a sensitivity of 95% in the identification of radiolucent foreign bodies such as wood.[5] On sonographic imaging, all acute foreign bodies appear hyperechoic.[5,8,22] Posterior shadowing may be seen deep to structures of wood or stone, whereas glass and metal particles usually demonstrate posterior reverberation artifact on ultrasound imaging.[5,22] Granulation tissue forms in response to the foreign body and is seen as a hypoechoic halo surrounding the hyperechoic structure.[5,8] This hypoechoic area, which is present from 24 hours to 6 months after the injury, aids in detection by making the echogenic foreign body more discernible.[5] Once a foreign body is detected with sonography, it can be accurately localized. The relationship to nearby structures such as tendons or small blood vessels can be documented, and the depth from the skin surface can also be measured. These findings provide pertinent information for foreign body removal.[5-8]

SUMMARY

There are many advantages to musculoskeletal imaging using sonography. Dynamic imaging cannot be overemphasized, as it is a unique capability of ultrasound that offers important information in evaluating the musculoskeletal system. The fact that these examinations are quite operator dependent should be mentioned because this is a common pitfall with the use of ultrasound for evaluation of musculoskeletal pathology. Sonographers must possess the expertise to perform consistently because these studies can be technically difficult and involve a long learning curve.[1,2,5] These skills can be achieved with the proper training and experience and standardized technique.

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MUSCULOSKELETAL ULTRASOUND POST TEST

Expires: July 15, 2009 Approved for 1 ARRT Category A Credit.

1. **Medical ultrasound imaging uses frequencies in the range of**
   a. 5-10 kHz.
   b. 5-20 kHz.
   c. 2-15 mHz.
   d. 40-90 mHz.
2. **What type of crystal is incorporated into the transducers used in diagnostic ultrasound?**
   a. Piezoelectric crystals
   b. Orthorhombic
   c. Window crystals
   d. Covalent crystals
3. **The term isoechoic describes**
   a. bright echo.
   b. echo intensity equal to background or adjacent structures.
   c. low echo.
   d. no echo.
4. **What appearance will muscle exhibit on musculoskeletal ultrasound?**
   a. Fibrillar pattern, appearing hyperechoic when imaged at a perpendicular angle
   b. Hypoechoic muscle fibers separated by hyperechoic fibroadipose septations
   c. Hyperechoic with a compact fibrillar pattern
   d. Bright punctate echoes with posterior reverberation artifact or comet-tail artifact
5. **On ultrasound examination, which of the following will be anechoic and demonstrate acoustic enhancement posteriorly?**
   a. Ligaments
   b. Air
   c. Bone
   d. Simple fluid
6. **Anisotropy occurs when**
   a. the ultrasound beam is not perpendicular to the fibrillar structure of the tendon.
   b. sound strikes a strong reflective interface such as ribs or gallstones.
   c. there is low signal caused by inappropriate transducer selection or low gain settings.
   d. sound interfaces with two structures of markedly different acoustic properties.
7. **Which transducer type is most effective in reducing anisotropy artifacts?**
   a. Curved array transducer
   b. Sector transducer
   c. Linear array transducer
   d. Confocal transducer
8. **Which of the following are advantages of curvilinear transducers?**
   a. Highest resolution of superficial structures and best imaging detail
   b. Deeper penetration of the sound beam and a wider field of view
   c. Operate at higher frequencies than linear array transducers
   d. A narrow field of view offers increased sensitivity to blood flow
9. **One of the unique advantages of musculoskeletal ultrasonography compared to other imaging methods is it ability to provide**
   a. localization of lesions for biopsy procedures.
   b. multiplanar imaging.
   c. cross-sectional images.
   d. dynamic evaluation.
10. **One of the most common clinical indications for musculoskeletal sonography is evaluation of**
    a. synarthrodial joints.
    b. tendon pathology.
    c. craniomandibular joints.
    d. smooth, nonstriated muscles.
11. **Acute rupture of a ligament demonstrates**
    a. discontinuity of fibers with hemorrhage or fluid.
    b. hypoechoic appearance and thickening, but fibers intact.
    c. granulation of the tissue.
    d. loss of the fibrillar pattern.
12. **Routine examination of the rotator cuff includes sonographic evaluation of which of the following tendons?**
    a. Supinator longus, extensor carpi radialis longus, subclavius
    b. Palmaris brevis, abductor minimi digiti, lumbricales pedis
    c. Triceps, deltoid, pronator radii teres
    d. Biceps brachii, subscapularis, infraspinatus, and supraspinatus
13. **Externally rotating the arm may help demonstrate**
    a. fractures of the humeral head.
    b. medial displacement of the biceps tendon out of the bicipital groove.
    c. osteoporosis affecting the humerus or shoulder girdle.
    d. osteoarthritis affecting the shoulder joint.
14. **The most commonly injured ligament of the ankle is the**
    a. flexor digitorum longus.
    b. anterior tibialis.
    c. anterior talofibular.
    d. deltoid.
15. **Xanthomas have been linked to**
    a. familial hypercholesterolemia.
    b. Addison's disease.
    c. sickle cell anemia.
    d. primary hyperoxaluria.

16. What technique is useful for the evaluation of displacement of the lateral ankle tendons out of their lateral malleolar groove?
   a. Scanning in the neutral, non-weight-bearing position
   b. Dorsiflexion and eversion maneuvers
   c. Plantar flexion and inversion maneuvers
   d. Injection of a contrast medium into the joint space before scanning

17. The percentage of sonographic sensitivity in the diagnosis of full-thickness tears of the quadriceps tendon is reported to be
   a. 45.
   b. 65.
   c. 87.
   d. 100.

18. Injury of the ulnar collateral ligament of the first metacarpophalangeal joint is known as
   a. snapping hip syndrome.
   b. arthrogryposis.
   c. gamekeeper's thumb.
   d. camptodactyly.

19. Peripheral nerve tumors are generally demonstrated as
   a. hypoechoic, fusiform-shaped lesions with posterior acoustic enhancement.
   b. elongated homogeneous masses oriented parallel with the skin that are compressible.
   c. hypoechoic structures with a fascicular pattern seen adjacent to vessels.
   d. hyperechoic, round lesions with calcifications.

20. A fluid-filled sac that communicates with the posterior knee joint between the semimembranosus tendon and the medial head of the gastrocnemius is likely a
   a. Baker's cyst.
   b. dermoid cyst.
   c. pseudoaneurysm.
   d. Gartner's cyst.

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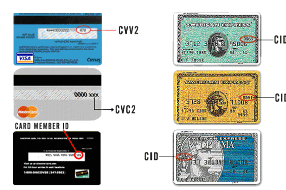

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