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ACR–AIUM–SPR–SSR–SRU PRACTICE PARAMETER FOR THE PERFORMANCE OF THE MUSCULOSKELETAL ULTRASOUND EXAMINATION

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care¹. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

¹ *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing* 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, *Stanley v. McCarver*, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

The clinical aspects contained in specific sections of this practice parameter (Introduction, Indications, Specifications of the Examination, and Equipment Specifications) were developed collaboratively by the American College of Radiology (ACR), the American Institute of Ultrasound in Medicine (AIUM), the Society for Pediatric Radiology (SPR), Society of Skeletal Radiology (SSR) and the Society of Radiologists in Ultrasound (SRU). Recommendations for physician requirements, written request for the examination, procedure documentation, and quality control vary between the 4 organizations and are addressed by each separately.

This practice parameter has been revised to assist practitioners performing a musculoskeletal (MSK) ultrasound examination. Although it is not possible to detect every abnormality, adherence to the following practice parameter will maximize the probability of detecting most abnormalities.

II. INDICATIONS

Indications for musculoskeletal ultrasound include, but are not limited to:

1. Pain or dysfunction
2. Soft tissue or bone injury
3. Tendon, ligament or fascial pathology
4. Arthritis, synovitis, or crystal deposition disease
5. Joint effusion and intra-articular bodies
6. Neurovascular entrapment, injury, neuropathy, mass, or subluxation
7. Evaluation of soft tissue masses, swelling, or fluid collections
8. Detection of foreign bodies in the superficial soft tissues
9. Planning and guidance for an invasive procedure
10. Congenital or developmental anomalies
11. Postoperative or postprocedural evaluation
12. Joint laxity, stiffness, decreased range of motion or misalignment

The above is a comprehensive list of general indications for musculoskeletal ultrasound; however, specific and unique indications pertaining to specific joints will be listed in the corresponding sections.

Musculoskeletal ultrasound should be performed when there is a valid medical reason. There are no absolute contraindications.

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR–SPR–SRU Practice Parameter for the Performance and Interpretation of Diagnostic Ultrasound Examinations](#) [1].

A. Physician

A physician must be available for consultation with the sonographer on a case-by-case basis. Ideally the physician should be on-site and available to participate actively in the ultrasound examination when required. It is recognized, however, that geographic realities may not permit the presence of an on-site physician in all locations. In this case, a supervising physician should be available for quality assurance and sonographer supervision via a picture archiving and communication system (PACS).

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for a musculoskeletal ultrasound examination should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

A. General Principles

Depending on the clinical request and the patient's symptoms, the ultrasound examination may involve a complete assessment of a joint or an anatomic region, or it may be limited to a specific anatomic structure. Examinations of joints, such as the elbow, hip, knee, and ankle, can be divided into four regions (anterior, medial, lateral, and posterior).

A complete examination includes evaluation of the joint and synovium, cortical outline of underlying bones, muscles, tendons and tendon sheaths, ligaments and fascia, capsule, and any additional abnormalities visible in the region. Color and power Doppler may be useful in detecting hyperemia or neovascularity within the tendon and/or tendon sheath, joint, or surrounding structures. Doppler flow is considered a key imaging finding for some pathologic conditions in musculoskeletal ultrasound. The equipment must be optimized for relevant Doppler sensitivity.

Images should always be obtained with the ultrasound beam perpendicular to the region of interest to minimize artifact. When applicable, relevant structures should be interrogated in more than 1 plane, at least 2 orthogonal planes. Patient positioning for specific examinations may vary depending on the structure being examined, the patient's clinical condition, and the operator's preference to obtain required short axis and long axis images. Dynamic evaluation is an important aspect of all musculoskeletal exam protocols to test for mobility, subluxation/dislocation, or impingement.

Transducer movements and manipulation are critical to provide accurate ultrasound images in musculoskeletal ultrasound. Heel-toe and tilting maneuvers help in avoiding anisotropy artifact by changing the angle of insonation while maintaining contact with the skin surface. Sometimes compression with the transducer may be performed to evaluate for solid versus cystic/fluid filled structures and/or to elicit symptoms (sonopalpation).

B. Specifications of the Shoulder Examination

A shoulder examination is requested to evaluate for rotator cuff pathology such as a partial- or full-thickness tear, calcific tendinitis, or tendinosis in adults, and joint-centered pathology in children. Other indications include evaluation of biceps tendon pathology, including tendon instability, subacromial-subdeltoid hypertrophy/bursitis, acromioclavicular arthritis, paralabral cyst, and nerve compression.

The long head of the biceps tendon is examined in a transverse plane (short axis) within the bicipital groove and to the musculotendinous junction distally. The insertions of the pectoralis major tendon on the humerus can be evaluated at the same time, when indicated. Longitudinal views (long axis) should also be obtained. Tendon position within the bicipital groove should be commented upon. Dynamic evaluation may be performed in the short axis to evaluate for tendon subluxation or dislocation.

The subscapularis is imaged from the musculotendinous junction to the insertion on the lesser tuberosity of the humerus in long and short axis planes. Dynamic evaluation in the long axis plane is helpful to evaluate possible subcoracoid impingement.

When scanning the supraspinatus and infraspinatus tendons along their long axes, it is important to orient the transducer in an oblique plane. Short axis views of the tendons should also be obtained by rotating the transducer 90 degrees to the long axis. Correct short axis positioning may be confirmed by visualizing the coracohumeral ligament in long axis medially, then moving laterally along the shoulder. Additionally, a short axis view of the long head biceps in the rotator interval can serve as a landmark for appropriate orientation to the supraspinatus and infraspinatus tendons in short axis. When necessary, the more posterior aspect of the infraspinatus and teres minor tendons can be examined by placing the transducer posteriorly at the level of the glenohumeral joint.

During the examination of the rotator cuff, the cuff should be frequently compressed with the transducer to detect nonretracted tears. Dynamic evaluation of the rotator cuff during shoulder abduction is useful to evaluate the rotator cuff for subacromial or subligamentous impingement. Tear length (partial-thickness tear) or the degree of retraction of the cuff (full-thickness tear) should be measured on longitudinal views, and tear width should be measured on short axis views. Tear depth should also be assessed. A partial-thickness tear should be described as originating from the bursal or articular side, or intrasubstance, and its thickness should be assessed. It is also useful to measure the distance between the intra-articular portion of the biceps tendon and the anterior edge of the tear on short axis views; most degenerative tears begin approximately 15 mm from the intra-articular portion of the biceps tendon [2]. In patients with a rotator cuff tear, the supraspinatus, infraspinatus, and teres minor muscles should be examined for fatty infiltration and atrophy, because these findings may influence postoperative outcome. Comparison with the contralateral rotator cuff muscles is often helpful to confirm muscle atrophy and fatty infiltration except when muscle atrophy is the result of a diffuse systemic process. Rotator cuff thickness and echogenicity should also be evaluated; a thick, hypoechoic cuff indicates tendinosis. The postoperative (rotator cuff after repair) rotator cuff may be hypoechoic and/or heterogenous in the early healing period, but that appearance may resolve over a period of time [3].

The subacromial-subdeltoid bursa should be examined for the presence of synovial hypertrophy or effusion. Power or color Doppler should also be used to detect hyperemia. Bursal bunching and snapping in the setting of subcoracoid, subacromial, and subligamentous impingement can be assessed with dynamic examination. Glenohumeral joint effusion is best assessed via a posterior approach. Glenohumeral effusion typically lacks Doppler flow and can be displaceable, whereas synovial thickening can contain Doppler flow and is not or only minimally compressible. Posterior labral abnormalities should also be evaluated using this approach. If symptoms warrant, the suprascapular notch and spinoglenoid notch may also be evaluated for a paralabral cyst. The acromioclavicular joint should be evaluated for arthritis, infection, or trauma by placing the transducer at the apex of the shoulder, over the acromion and distal clavicle [4-7].

Ultrasound is very useful as the first line screening for infants and young toddlers with clinically suspected glenohumeral dysplasia. It serves as an alternative to MRI, which provides a more global assessment, providing complementary information without the need for patient sedation. These infants are typically examined in the seated position on the caregiver's lap, facing away from the sonographer. Alternatively, the children can also be scanned in a decubitus position. Each shoulder, both symptomatic and normal sides, is scanned via a posterior approach to evaluate the morphology and alignment between the humeral head and glenoid. Both static and dynamic images are obtained with the shoulder in neutral position and in full internal and external rotation. Posterior subluxation is evaluated qualitatively and quantitatively, with the latter involving use of the α angle and humeral head translation. The α angle is formed between a line drawn along the posterior margin of the scapula and a line drawn tangentially to the posterior cortex of humeral head and posterior edge of the glenoid. An α angle of 30 degrees or less is considered normal. Humeral head translation measures the percentage of the humeral head that is displaced posterior to the axis of the scapula. The normal value for humeral head translation is 50% or less. Muscle atrophy is characterized by asymmetric decreased thickness and bulk when compared to the contralateral normal side. In infants with equivocal radiographs, the clavicle and proximal humerus can be evaluated for displaced fractures secondary to birth trauma [8] or nonaccidental trauma. In the latter scenario, the proximal humerus can be assessed for Salter Harris fractures. However, it is worth noting that nondisplaced fractures and incomplete fractures involving the cortex that is inaccessible by ultrasound can be subtle and missed, respectively. These can be assessed

using follow-up radiographs. In infants with Erb's palsy and history of shoulder dystocia, ultrasound is useful for mapping out injuries to the brachial plexus, associated muscle denervation injuries and glenohumeral subluxation [9]. Ultrasound can be helpful intraoperatively to confirm glenohumeral reduction.

C. Specification of an Elbow Examination

Examination of the elbow is divided into 4 regions: anterior, medial, lateral, and posterior.

1. Anterior

The anterior joint space and other recesses of the elbow are assessed for joint or bursal effusion, synovial hypertrophy, and intra-articular bodies. Longitudinal and transverse scanning of the anterior humeroradial joint, the humeroulnar joint, and both the coronoid and radial fossae is performed to assess the articular cartilage and cortical bone. The annular recess of the neck of the radius is scanned dynamically with forearm pronation and supination. The same dynamic assessment can be made for the biceps brachii tendon and its attachment to the radial bicipital tuberosity. When evaluating the distal biceps tendon from an anterior approach, the arm should be maximally supinated and extended. The distal biceps tendon can also be evaluated from a medial approach with the elbow flexed and the forearm supinated [10] or via a lateral approach [11] using the brachioradialis as an acoustic window. The insertion can also be imaged during dynamic scan with a posterior approach. Evaluation of the brachialis muscle, the adjacent radial and brachial vessels, and the median and radial nerves can also be performed as clinically warranted.

2. Lateral

Lateral elbow evaluation allows assessment of the lateral epicondyle the attachments of the common extensor tendon and the proximal attachments of the extensor carpi radialis longus and brachioradialis. Scanning the posterolateral aspect of the elbow allows evaluation of the lateral collateral ligament complex. The radial nerve, including its deep branch entering the supinator muscles (posterior interosseous nerve), is also evaluated.

3. Medial

Medial elbow scanning includes evaluation of the medial epicondyle, common flexor tendon, and ulnar collateral ligament [12,13]. The ulnar nerve is visualized in the cubital tunnel region between the olecranon process and medial epicondyle. Dynamic subluxation and dislocation of the ulnar nerve and adjacent medial head of the triceps muscle are assessed by imaging with flexion and extension of the elbow. Dynamic examination with valgus stress is performed to assess integrity of the ulnar collateral ligament. During valgus stress testing, the elbow may have to be flexed at variable angles to disengage the olecranon from the olecranon fossa.

4. Posterior

To evaluate the posterior elbow, the elbow is flexed to 90 degrees. The posterior joint space, triceps brachii tendon, olecranon process, and olecranon bursa are assessed [14-16].

In infants, who have not yet developed any elbow ossification centers, radiographic distinction between elbow dislocation and transphyseal fracture-displacement is challenging. Ultrasound can be helpful in this situation, made even more useful by comparison imaging of the contralateral, normal side. Placing the transducer in the longitudinal plane anteriorly or anterolaterally on the elbow can confirm the normal radiocapitellar alignment in the absence of a dislocation. It can assess for disruption at the level of the humeral physis too. Similarly, ultrasound can identify the components of a lateral condyle fracture when the distal humeral epiphysis is not yet ossified and fracture components are radiographically occult.

D. Specifications of the Wrist Examination

A wrist examination may be indicated to evaluate a focal abnormality such as a tumor (tenosynovial giant cell tumor of the tendon sheath, peripheral nerve sheath tumor, or lipoma), ganglion, epidermal inclusion cyst, foreign body, or tendon injury. Tenosynovitis, nerve entrapment syndromes, and peripheral nerve disorders such as carpal tunnel syndrome can also be evaluated. In the patient with suspected inflammatory arthritis, the hands and wrists should

be evaluated for synovial hypertrophy, joint effusion, bony erosions, tenosynovitis, crystal deposition, and tendon rupture.

The examination may include a complete assessment of 1 or more of the 4 anatomic regions described below or may be limited to a specific anatomic structure, depending on the clinical presentation.

1. Volar

Transverse and longitudinal images should be obtained from the volar wrist crease to the thenar muscles. The transducer will require angulation changes to compensate for the normal contour of the wrist and to minimize anisotropy. The flexor retinaculum, flexor digitorum profundus, superficialis tendons and the adjacent flexor pollicis longus tendon should be identified within the carpal tunnel. Dynamic imaging with flexion and extension of the fingers will demonstrate the normal motion of these tendons. The median nerve normally lies superficial to these tendons and deep to the flexor retinaculum. The distal portion of the median nerve tapers and divides into multiple branches for the hand. The palmaris longus tendon lies superficial to the retinaculum, if present.

2. Radial

On the radial side of the wrist, the flexor carpi radialis longus tendon lies within its own canal. It is important to evaluate the region of the flexor carpi radialis and the radial artery for occult ganglion cysts, which can originate from the radiocarpal joint capsule, scapho-trapezial joint, or flexor carpi radialis tendon sheath itself. All of the tendons can be followed to their sites of insertion if clinically indicated.

3. Ulnar

Placing the transducer transversely on the ulnar styloid and moving distally will allow visualization of the triangular fibrocartilage complex (TFCC) in its long axis. Dynamic imaging with radial deviation may be helpful in assessing the integrity of the TFCC. The transducer is then rotated 90 degrees to view the short axis of the TFCC. The ulnomeniscal homologue may be seen just deep to the extensor carpi ulnaris tendon. The extensor carpi ulnaris tendon should be viewed in supination and pronation to assess for subluxation. In the setting of inflammatory arthritis, the extensor carpi ulnaris should be evaluated for tenosynovitis and rupture. On the ulnar side, branches of the ulnar nerve and artery lie within the ulnar tunnel. The flexor carpi ulnaris tendon and pisiform bone border the ulnar aspect of the tunnel.

4. Dorsal

Because the dorsal structures are very superficial, a high frequency transducer, even using a stand-off, gel is necessary to optimize the examination and prevent compression of small vessels when using color or power Doppler. The extensor retinaculum divides the dorsal aspect of the wrist into 6 compartments, which accommodate 9 tendons. These tendons are examined in their short axes initially and then in their long axes statically and dynamically, the latter being performed with flexion and extension of the fingers. The tendons can be followed to their sites of insertion when clinically indicated. Moving the transversely positioned transducer distal to Lister's tubercle identifies the dorsal aspect of the scapholunate ligament, a potential site of symptomatic ligament tears and ganglion cysts that may be evaluated with and without stress maneuvers. The remaining intercarpal ligaments are not routinely assessed.

E. Specifications of Hand Ultrasound

In patients with suspected inflammatory arthritis, the dorsal radiocarpal, distal radioulnar, midcarpal, metacarpophalangeal, and, if symptomatic, the interphalangeal joints are evaluated from the volar and dorsal aspects in both the longitudinal and transverse planes for effusion, synovial hypertrophy, synovial hyperemia, and bony erosions [17,18]. This component of the examination can be extended as clinically warranted to evaluate the flexor/extensor tendons and their pulleys for injuries and/or tenosynovitis. In the event of trauma, ultrasound can be used to detect avulsion fractures that may be associated with tendon injuries. Specific to the thumb, the ulnar collateral ligament may be evaluated with and without stress maneuvers.

F. Specifications of a Hip Examination

Depending on the patient's body habitus, a lower frequency transducer may be required to scan the hip. However, the operator should use the highest possible frequency that provides adequate penetration. The examination is divided into 4 regions: anterior, medial, lateral, and posterior.

1. Anterior

In the supine position, a sagittal oblique plane parallel to the long axis of the femoral neck is used for evaluating the femoral head and neck and for detecting joint effusion or synovitis. The lower extremity should be rotated externally. The sagittal and axial planes are used to visualize the anterior labrum, the iliopsoas tendon and bursa, the femoral vessels, and the sartorius and rectus femoris tendon origins [19]. When an extra-articular cause of anterior "snapping hip" is suspected, dynamic scanning is performed over the region of interest using the same movement that the patient describes as precipitating the snap, usually precipitated by hip flexion and external rotation. This snap commonly occurs anteriorly, as the iliopsoas tendon crosses over the acetabular eminence [20]. Recent literature adds that the interchange of the muscle belly and the tendon is more likely the cause of a snap rather than the tendon snapping over the underlying acetabular eminence [20].

2. Lateral

In the lateral decubitus position with the symptomatic side up, transverse and longitudinal scans of the greater trochanter, greater trochanteric bursae, gluteus medius, gluteus maximus, gluteus minimus, iliotibial band, and tensor fasciae latae should be performed. Sonopalpation of the greater trochanter can be performed when assessing for trochanteric bursitis. An iliotibial band or gluteus maximus muscle that snaps over the greater trochanter can be assessed in this position using dynamic flexion extension of the hip.

3. Medial

The hip is placed in external rotation with 45-degree knee flexion (frog-leg position). The distal iliopsoas tendon, because of its oblique course, may be better seen in this position. The adductor muscles and their origins from the pubic tubercle are imaged in their long axes with the probe in a sagittal oblique orientation. Short axis images are obtained perpendicular to this plane. In addition, the pubic bone and symphysis, the distal rectus abdominis, and adductor origin should be evaluated for musculotendinous or aponeurotic injury [21].

4. Posterior

The patient is prone with the lower extremities extended. Transverse and longitudinal views of the glutei, hamstring tendons, and sciatic nerve are obtained. The glutei are imaged obliquely from their origins to the greater trochanter (gluteus medius and minimus) and linea aspera (gluteus maximus). The sciatic nerve is scanned in its short axis starting at its exit at the greater sciatic foramen, deep to the gluteus maximus. It can be followed distally, midway between the ischial tuberosity and the greater trochanter, lying superficial to the quadratus femoris muscle [22]. The hamstring tendons can be assessed in transverse and long axis for the presence of tears and tendinosis. The ischial bursa is not typically seen unless an effusion or thickening is present in the setting of bursitis.

For further detail on the examination of the pediatric hip for hip dysplasia, see the [ACR–AIUM–SPR–SRU Practice Parameter for the Performance of the Ultrasound Examination for Detection and Assessment of Developmental Dysplasia of the Hip](#) [23].

G. Specifications of a Prosthetic Hip Examination

The prosthetic hip is assessed for joint effusions, extra-articular fluid collections, iliopsoas bursitis, or soft tissue masses and/or necrosis (adverse local tissue reaction). Ultrasound guidance may be requested to evaluate for fluid aspiration in the clinical scenario of a possible prosthetic joint infection. The region of the greater trochanter and iliopsoas is evaluated for fluid collections or tendon abnormalities, such as tendinosis or tear of the iliopsoas, gluteus medius, or gluteus minimus tendons [24,25]. To assess for pseudotumor, the anterior, medial, lateral, and posterior hip structures should be evaluated for joint and extra-articular fluid collections and soft tissue masses [26,27]. In patients with suggestive symptoms, ultrasound can provide guidance for diagnostic injections to assess for possible psoas tendon impingement.

H. Specifications of a Knee Examination

The examination of the knee is divided into 4 regions. The examination may involve an assessment of 1 or more of the 4 regions of the knee described below or may be limited to a specific anatomic structure, depending on the clinical presentation.

1. Anterior

The patient is supine with the knee flexed to 30 degrees. Longitudinal and transverse scans of the quadriceps and patellar tendons, patellar retinacula, and suprapatellar recess are obtained. A portion of the distal femoral trochlear cartilage can be assessed with the transducer placed in the suprapatellar space in the transverse plane with the knee in maximal flexion. The prepatellar, superficial, and deep infrapatellar bursae are also evaluated using adequate gel to prevent inadvertent compression of the bursae by the transducer. Suprapatellar recess may be evaluated for detection of joint effusion.

2. Medial

During the ultrasound examination, the patient remains supine with slight flexion of the knee and hip and with slight external rotation of the hip. The medial collateral ligament, the pes anserine tendons and bursa, and the medial patellar retinaculum are scanned in both planes. The anterior horn and body of the medial meniscus may be identified in this position, particularly with valgus stress. If meniscal pathology is suspected either clinically or by ultrasound, further imaging with MRI is recommended. Alternatively, if there are contraindications to MRI, CT arthrography can be performed.

3. Lateral

The patient remains supine with the ipsilateral leg internally rotated. The popliteus tendon, biceps femoris tendon, fibular collateral ligament, and iliotibial band are scanned. The lateral patellar retinaculum can also be assessed in this position. The joint line is scanned for lateral meniscal pathology, with varus stress applied as needed. The common peroneal nerve can be localized in the popliteal fossa or identified posterior to the biceps femoris tendon and followed as it courses around the fibular neck.

4. Posterior

The patient lies prone with the leg extended. The popliteal fossa, semimembranosus muscle, medial and lateral gastrocnemius muscles, tendons, and bursae are assessed. To confirm the diagnosis of a popliteal cyst, the subgastrocnemius component of the semimembranosus-gastrocnemius bursa should be visualized between the medial head of the gastrocnemius and semimembranosus tendon. In addition, the posterior horns of both menisci may be evaluated. The tibial insertion of the posterior cruciate ligament may be identifiable in a sagittal oblique plane in this position [28,29].

I. Specifications of an Ankle Examination

Ultrasound examination of the ankle is divided into 4 regions (anterior, medial, lateral, and posterior). The examination may involve an assessment of 1 or more of the 4 regions described below or be limited to a specific anatomic structure, depending on the clinical presentation.

1. Anterior

The anterior extensor tendons are assessed in long axis and short axis planes from their musculotendinous junctions to their distal insertions. From medial to lateral, this tendon group includes the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius tendons (the latter being congenitally absent in some patients). The anterior joint recess is scanned for effusion, intra-articular bodies, synovial hypertrophy, and synovitis. The anterior joint capsule is attached to the anterior tibial margin and the neck of the talus. The hyaline cartilage of the talus appears as a thin hypoechoic line paralleling subchondral bone.

2. Medial

The tibialis posterior, flexor digitorum longus, and flexor hallucis longus tendons (located in this order from

anterior to posterior) are initially scanned in the short axis plane proximal to the medial malleolus to identify each tendon. They are then assessed in long axis planes from their proximal musculotendinous junctions in the supramalleolar region to their distal insertions. To avoid anisotropy, the angulation of the transducer must be adjusted continuously, especially as they curve under the medial malleolus. The tibial nerve can be scanned by identifying it between the flexor digitorum tendon anteriorly and the flexor hallucis longus tendon posteriorly, at the level of the malleolus. The tibial nerve can then be followed along its course to assess the medial and lateral plantar nerves. The flexor hallucis longus may also be scanned in the posterior position, medial to the Achilles tendon. The deltoid ligament is scanned longitudinally from its attachment to the medial malleolus to the navicular, talus, and calcaneus.

3. Lateral

The peroneus (fibularis) brevis and longus tendons are identified proximal to the lateral malleolus in their short axis planes and can be assessed in long axis and short axis planes from their proximal (supramalleolar) musculotendinous junctions to their distal insertions. The peroneus longus can be followed in this manner to the cuboid groove, where it turns to course medially along the plantar aspect of the foot to insert on the base of the first metatarsal and medial cuneiform. The peroneus brevis tendon is followed to its insertion on the base of the fifth metatarsal. The peroneus brevis and longus tendons can be assessed for subluxation in real time by asking the patient to dorsiflex and evert the ankle. Circumduction of the ankle can also be a helpful maneuver. The overlying retinaculum can be assessed for thickening or integrity. The lateral ligament complex is examined including the anterior inferior tibiofibular ligament, anterior and posterior talofibular ligaments, and the calcaneofibular ligament. Dynamic testing of the ligaments can be performed as clinically indicated by applying varus stress.

4. Posterior

The patient is prone with feet extending over the end of the table. A rolled towel under the ankles may also be helpful. The Achilles tendon is scanned in the long axis and short axis planes from the musculotendinous junctions (medial and lateral heads of the gastrocnemius and soleus muscles) to the site of insertion on the posterior surface of the calcaneus. Dynamic scanning with plantar and dorsiflexion may aid in the evaluation of tears. The plantaris tendon lies along the medial aspect of the Achilles tendon and typically inserts on the posteromedial calcaneus. This tendon may be absent as a normal variant. Of note, it is often intact in the setting of a full-thickness Achilles tendon tear. The retrocalcaneal bursa, between the Achilles and superior calcaneus, is also assessed and a small amount of fluid may be normally seen in this bursa. Assessment for a superficial retro-Achilles bursa is facilitated by floating the transducer on ultrasound gel and evaluating for fluid within the subcutaneous tissues. The plantar fascia is scanned in both long axis and short axis planes from its proximal origin on the medial calcaneal tubercle distally where it divides and merges into the soft tissues.

J. Specifications of a Foot Examination

1. Digital

In patients with suspected inflammatory arthritis, the metatarsophalangeal joints and, if symptomatic, the proximal interphalangeal joints are evaluated from the plantar and dorsal aspects in both the longitudinal and transverse planes for effusion, synovial hypertrophy, synovial hyperemia, and bony erosions. Other joints of the foot are similarly evaluated as clinically indicated [30].

2. Interdigital

The patient is supine with the foot dorsiflexed 90 degrees to the ankle. Either a dorsal or plantar approach can be used. The latter will be described here. The transducer is placed longitudinally on the plantar aspect of the first interdigital space, and the examiner applies digital pressure on the dorsal surface. The transducer is moved laterally with its center at the level of the metatarsal heads. The technique is repeated for the remaining interspaces and then repeated in the transverse plane. When a Morton's neuroma is clinically suspected, pressure can be applied to reproduce the patient's symptoms. In addition, manual medial and lateral compression of the forefoot with plantar imaging transverse to the metatarsals (Mulder's maneuver) will often displace a neuroma in a plantar direction along with a palpable click, improving visibility. The intermetatarsal bursa lies on the dorsal aspect of the interdigital nerve. Care must be taken to correctly

identify a neuroma and differentiate it from the bursa, [31,32] which typically flattens with compression.

K. Specifications of a Peripheral Nerve Examination

Nerves have a fascicular pattern with hypoechoic longitudinal neuronal fascicles interspersed with hyperechoic interfascicular connective tissue and epineurium, best appreciated when imaged in short axis. Nerves course adjacent to vessels and are readily distinguished from the surrounding tendons with a dynamic examination, during which the nerve demonstrates relatively little movement and less anisotropy compared with the adjacent tendons. Nerves may become more hypoechoic as they pass through fibro-osseous tunnels, as the fascicles become more compact.

Examination in the short axis plane is usually preferred to assess the course of the nerve because it may be difficult to separate the nerve itself from the surrounding tendons and muscles on a longitudinal scan. Assessment at the level of fibro-osseous tunnels may require dynamic examination. A statically subluxated or dislocated nerve is readily identifiable on ultrasound, but an intermittently subluxating or dislocating nerve requires dynamic examination. Perhaps the most commonly subluxating nerve is the ulnar nerve within the cubital tunnel region (see elbow examination). Entrapment neuropathies also typically occur within fibro-osseous tunnels (eg, cubital and ulnar tunnels for the ulnar nerve, carpal tunnel for the median nerve, fibular neck for the common peroneal [fibular] nerve, and the tarsal tunnel for the tibial nerve). Adjacent pathology of tendons, soft tissues, and bone can be evaluated to determine the possible cause of the nerve dysfunction. In addition, congenital abnormalities (eg, accessory muscles or vessels), can be assessed [33].

The sonographic appearance of peripheral nerve sheath tumors can be variable, although most share the common features of being hypoechoic and homogeneous, with posterior acoustic enhancement and peripheral nerve continuity [34].

L. Specifications of a Soft Tissue Mass Examination

The mass should be scanned in both long axis and short axis planes. Ultrasound is an excellent method to differentiate solid from cystic masses. The mass should be measured in 2 orthogonal dimensions with its relationship to surrounding structures, particularly joints, neurovascular bundles, and tendons, determined. Compressibility of the lesion should be evaluated. Color or power Doppler evaluation will help differentiate solid from cystic masses, and to determine if a mass has internal vascularity [35]. Dynamic evaluation helps in evaluation of mobility relative to adjacent structures. An attempt should be made to differentiate between superficial soft tissues masses and deep soft tissue masses by commenting on their location in relation to the deep investing fascia.

M. Specifications of Interventional Musculoskeletal Ultrasound

Ultrasound is an ideal modality for image guidance of musculoskeletal interventional procedures. The usual standards for interventional procedures apply (ie, review prior imaging, appropriate informed consent, sterile conditions, and a local anesthetic). Ultrasound provides direct visualization of the needle or interventional device, monitors the trajectory, and shows the position of the needle/device within the target area. Direct visualization allows the practitioner to avoid damage to intralesional and extralesional vessels, adjacent nerves, or other structures at risk.

Prior to any procedure, an ultrasound examination is performed to characterize the target area and its relationship to surrounding structures. Color or power Doppler is useful to delineate any vessels within the target zone and to assess for potential infection in the overlying tissues. If significant hyperemia is noted in superficial tissues along the target pathway, an alternative procedure or pathway should be reconsidered to avoid introducing an infection into deeper tissues, particularly if the target position is intra-articular.

Ideally the shortest pathway to the region of interest should be selected, with consideration given to regional neurovascular structures and optimization of needle visualization. A needle guide can be used or the procedure can be performed free-hand. Slight “to and fro” movement (ie, jiggling) of the needle may be beneficial in visualizing the needle. When possible, the needle should be aligned longitudinally with the plane of the transducer at its center.

When biopsying a partially necrotic mass, color Doppler should be used to identify areas of vascularity, which indicates viable tissue and increases the chance for an adequate histologic specimen.

N. Specifications for Ultrasound Examination for Detection of Foreign Bodies

Most foreign bodies are hyperechoic compared with the surrounding soft tissues and are associated with an acoustic shadow (wood) or comet tail artifact (glass, metal). Retained foreign bodies can cause a surrounding hypoechoic soft tissue inflammatory reaction/granulation tissue or abscess formation. Once a foreign body is detected, ultrasound can be used to demonstrate its location and relationship to adjacent structures and help guide removal. A high frequency linear array transducer as well as a generous amount of gel should be used to scan superficial foreign bodies. Deeper foreign bodies may require a lower frequency transducer. Color and power Doppler are useful in detecting surrounding hyperemia. When available, 3-D imaging may be useful in localization [36].

V. DOCUMENTATION

Reporting should be in accordance with [ACR Practice Parameter for Communication of Diagnostic Imaging Findings](#) [37].

Adequate documentation is essential for high-quality patient care. There should be a permanent record of the ultrasound examination and its interpretation. Comparison with prior relevant imaging studies may prove helpful. Images of all appropriate areas, both normal and abnormal, should be recorded. Variations from normal size should generally be accompanied by measurements. Images should be labeled with the patient identification, facility identification, examination date, and image orientation. An official interpretation (final report) of the ultrasound examination should be included in the patient's medical record. Retention of the ultrasound examination images should be consistent both with clinical need and with relevant legal and local health care facility requirements. Video clips of structures of interest in transverse and longitudinal (or orthogonal planes) may be obtained to supplement static images.

VI. EQUIPMENT SPECIFICATIONS

Equipment performance monitoring should be in accordance with the [ACR-AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Real Time Ultrasound Equipment](#) [38].

Musculoskeletal ultrasound should be performed with high-resolution linear array transducers with a broad bandwidth. Transducer frequencies will vary depending on the structure being imaged and body habitus; lower frequencies (6-9 MHz) are typically required for deeper structures and higher frequencies for superficial structures. The most common higher transducer frequencies used range between 12 and 18 MHz. Newer transducers have a frequency range up to 24 MHz that help in evaluation of smaller, superficial structures like pulleys, tendons, and nerves. Color and power Doppler are valuable in assessing hyperemia and inflammation, vascularity of a soft tissue mass, differentiating cystic from solid lesions and in assisting with ultrasound-guided biopsy, injection, and aspiration procedures [39]. Doppler frequencies should be set to optimize flow detection. Tissue harmonic imaging, compound imaging, and extended field of view may all be useful in musculoskeletal ultrasound.

VII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (<https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement>).

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