# AIUM Practice Parameter for the Performance of a Musculoskeletal Ultrasound Examination

*Parameter developed in conjunction with the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU).*

The American Institute of Ultrasound in Medicine (AIUM) is a multidisciplinary association dedicated to advancing the safe and effective use of ultrasound in medicine through professional and public education, research, development of parameters, and accreditation. To promote this mission, the AIUM is pleased to publish, in conjunction with the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU), this AIUM Practice Parameter for the Performance of a Musculoskeletal Ultrasound Examination. We are indebted to the many volunteers who contributed their time, knowledge, and energy to bringing this document to completion.

The AIUM represents the entire range of clinical and basic science interests in medical diagnostic ultrasound, and, with hundreds of volunteers, the AIUM has promoted the safe and effective use of ultrasound in clinical medicine for more than 65 years. This document and others like it will continue to advance this mission.

Practice parameters of the AIUM are intended to provide the medical ultrasound community with parameters for the performance and recording of high-quality ultrasound examinations. The parameters reflect what the AIUM considers the minimum criteria for a complete examination in each area but are not intended to establish a legal standard of care. AIUM-accredited practices are expected to generally follow the parameters with recognition that deviations from these parameters will be needed in some cases, depending on patient needs and available equipment. Practices are encouraged to go beyond the parameters to provide additional service and information as needed.

## I. Introduction

The clinical aspects contained in specific sections of this parameter (Introduction, Supervision and Interpretation of Ultrasound Examinations, Specifications for Individual Examinations, and Equipment Specifications) were developed collaboratively by the American Institute of Ultrasound in Medicine (AIUM), the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU). Recommendations for Qualifications and Responsibilities of Personnel, Written Request for the Examination, Documentation, and Quality Control and Improvement, Safety, Infection Control, and Patient Education vary among the 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 that occur.

## II. Qualifications and Responsibilities of Personnel

See www.aium.org for AIUM Official Statements, including *Standards and Guidelines for the Accreditation of Ultrasound Practices* and relevant Physician Training Guidelines.[1]

## III. Indications

Indications for MSK ultrasound include but are not limited to:

A. Pain or dysfunction.

B. Soft tissue or bone injury.
C. Tendon or ligament pathology.
D. Arthritis, synovitis, or crystal deposition disease.
E. Intra-articular bodies.
F. Joint effusion.
G. Nerve entrapment, injury, neuropathy, masses, or subluxation.
H. Evaluation of soft tissue masses, swelling, or fluid collections.
I. Detection of foreign bodies in the superficial soft tissues.
J. Planning and guiding an invasive procedure.
K. Congenital or developmental anomalies.
L. Postoperative or postprocedural evaluation.
M. Joint laxity, stiffness, or decreased range of motion.
N. Malalignment.
O. Sensory deficits or paresthesias.
P. Motor weakness.

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

## IV. Written Request for the Examination

The written or electronic request for an ultrasound examination should provide sufficient information to allow for the appropriate performance and interpretation of the examination.

The request for the examination must be originated by a physician or another appropriately licensed health care provider or under the physician's or provider's direction. The accompanying clinical information should be provided by a physician or other appropriate health care provider familiar with the patient's clinical situation and should be consistent with relevant legal and local health care facility requirements.

## V. Supervision and Interpretation of Ultrasound Examinations

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).

## VI. Specifications for Individual Examinations

Depending on the clinical request and the patient's presentation, the ultrasound examination may involve a complete assessment of a joint or anatomic region, or it may be limited to a specific anatomic structure. A complete examination will typically include evaluation of the joint and synovium, bones, muscles, tendons and sheaths, ligaments and fascia, and/or capsule and other supporting structures and any additional abnormalities visible in the region.

General ultrasound scanning principles apply. Images should always be obtained with the ultrasound beam perpendicular to the region of interest to minimize artifacts. When applicable, relevant structures should be integrated in more than 1 plane. Abnormalities are measured in 2 orthogonal planes. Patient positioning for specific examinations may vary depending on the structure being examined and the patient's clinical condition.

### *A. Specifications for a Shoulder Examination*

A shoulder examination is most commonly indicated to evaluate for rotator cuff pathology such as a partial- or full-thickness tear, calcific tendinitis, or tendinosis. Other indications include evaluating for biceps tendon pathology, including tendon instability, subacromial-subdeltoid hypertrophy/bursitis, joint effusion, acromioclavicular arthritis, a paralabral cyst, and nerve compression.

Patients should be examined in the sitting position when possible, preferably on a rotating stool. Examination of the shoulder should be tailored to the patient's clinical circumstances and range of motion. Color and power Doppler assessment may be useful in detecting hyperemia within the subacromial-subdeltoid bursa, biceps tendon sheath, joint synovium, or surrounding structures.

The long head of the biceps tendon should be examined with the forearm in supination resting on the thigh or with the arm in slight external rotation. The tendon is examined in a transverse plane (short axis), where it emerges from under the acromion, 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. These views should be used to detect effusion, synovial hypertrophy, or intra-articular loose bodies within the bicipital tendon sheath and to determine whether the tendon is properly positioned within the bicipital groove, subluxated, dislocated, or torn. Power or color Doppler imaging should also be used to detect hyperemia in the tendon sheath, which may indicate tenosynovitis.

The rotator cuff should be examined for signs of a full- or partial-thickness tear, tendinosis, and/or calcification. Both long- and short-axis views should be obtained.

To examine the subscapularis tendon, the elbow remains at the side while the arm is placed in external rotation. The subscapularis is imaged from the musculotendinous junction to the insertion on the lesser tuberosity of the humerus. Dynamic evaluation as the patient moves from internal to external rotation is helpful to evaluate dynamic biceps tendon subluxation or subcoracoid impingement and assess the integrity of the subscapularis tendon.

To examine the supraspinatus tendon, the arm is extended posteriorly, and the palmar aspect of the hand can be placed against the superior aspect of the iliac wing with the elbow flexed and directed toward the midline (instruct the patient to place the hand in the ipsilateral back pocket).

To scan the supraspinatus and infraspinatus tendons along their long axes, it is important to orient the transducer approximately 45° between the sagittal and coronal planes to obtain a longitudinal view. The transducer then should be moved anteriorly and posteriorly parallel to this imaging plane while continually adjusting to its angle to remain perpendicular to the investigated tendon.

Short-axis views of the tendons should be obtained by rotating the transducer 90° to the long axis. The tendons are visualized by sweeping medially to the acromion and laterally to their insertions on the greater tuberosity of the humerus. When necessary, the more posterior aspect of the infraspinatus and teres minor tendons can be examined by placing the transducer at the level of the glenohumeral joint below the scapular spine while the forearm rests on the thigh with the hand supinated. Internal and external rotation of the arm is helpful to identify the infraspinatus muscle and tendon and to detect small joint effusions. To visualize the teres minor tendon, the medial edge of the transducer should be angled slightly inferiorly. The teres major tendon can also be identified in the short axis by placing the transducer in a longitudinal plane at the surgical neck of the humerus where it inserts and scanning medially along the inferior border of the scapula.

Throughout the examination of the rotator cuff, the cuff should be compressed with the transducer to detect nonretracted tears. When evaluating for rotator cuff tears, comparison with the contralateral side may be useful. Dynamic evaluation of the rotator cuff also is useful in certain circumstances: for example, to evaluate the rotator cuff for 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. A partial-thickness tear should further be described as bursal, articular, or intrasubstance, and its thickness should be measured. 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 are located in the crescent of the cuff, 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, as these findings are associated with a poorer postoperative outcome. Comparison with the contralateral rotator cuff muscles is often helpful in confirming muscle atrophy and fatty infiltration. Rotator cuff thickness and echogenicity should also be evaluated; a thick, hypoechoic cuff indicates tendinosis.

During the rotator cuff examination, the subacromial-subdeltoid bursa should be examined for the presence of synovial hypertrophy. Power or color Doppler imaging should also be used to detect hyperemia. It is also important to evaluate the posterior glenohumeral joint for effusion, synovitis, or labral abnormalities. This can be accomplished by placing the transducer in a transverse plane at the level of the joint space. If symptoms warrant, the suprascapular notch and spinoglenoid notch also may 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.[3–5]

Ultrasound is very useful in evaluating infants with glenohumeral dysplasia. These infants are examined in a decubitus position, and older children are examined seated. The shoulder is scanned from a posterior approach to evaluate the relationship between the humeral head and glenoid, as well as the shape of the posterior glenoid. Both static and dynamic images are obtained. The shoulder is scanned through the full range of internal to external rotation. Posterior subluxation is assessed visually and by measuring the α angle, which is the angle between the posterior margin of the scapula and the line drawn tangentially to the humeral head and posterior edge of the glenoid. The normal value of the α angle is 30° or less. The clavicle and proximal humerus are also evaluated for fracture.[6]

*B. Specifications for an Elbow Examination*

An elbow examination may be indicated to evaluate for synovial hypertrophy or synovitis, crystal deposition, loose bodies, joint effusion, tendinosis or a tendon tear, ligamentous abnormality, bursitis, or nerve pathology. In neonates and young infants, ultrasound may be used to evaluate for epiphysiolysis of the distal humerus.[7–10]

The patient is seated with the arm extended and the hand in supination, resting on a table, and the examiner sitting in front of the patient. The elbow may also be examined with the patient supine and the examiner on the same side as the elbow of interest. The examination is divided into 4 regions: anterior, medial, lateral, and posterior. The examination may involve a complete assessment of 1 or more of the 4 regions or may be limited to a specific structure, depending on the clinical presentation. Color and power Doppler imaging may be useful in detecting hyperemia within the joint or surrounding structures.

1. Anterior—The anterior joint space and other recesses of the elbow are assessed for effusion, synovial hypertrophy, and intra-articular bodies. Longitudinal and transverse scanning of the anterior humeroradial and humeroulnar joints and 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. If 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.[11] 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—To evaluate the lateral elbow, the patient extends the arm and places both palms together, or if the patient is supine, the forearm is placed across the abdomen. This position allows assessment of the lateral epicondyle and the attachments of the common extensor tendon, as well as the more proximal attachments of the extensor carpi radialis longus and brachioradialis. The hand is then pronated with the transducer on the posterolateral aspect of the elbow to scan the lateral collateral ligament complex. The radial nerve, including its deep branch entering the supinator, is also evaluated.

3. Medial—To evaluate the medial elbow, the hand is placed in supination, or if the patient is supine, the upper limb is placed in abduction and external rotation to expose the medial side of the elbow. The medial epicondyle, common flexor tendon, and ulnar collateral ligament are scanned in both planes. The ulnar nerve is visualized in the cubital tunnel region between the olecranon process and medial epicondyle. Static examination of the ulnar

nerve may be facilitated by placing the elbow in an extended position. Dynamic subluxation and dislocation of the ulnar nerve are assessed by imaging with flexion and extension of the elbow. Dynamic examination with valgus stress is performed to assess the integrity of the ulnar collateral ligament. During valgus stress testing, the elbow must be slightly flexed to disengage the olecranon from the olecranon fossa.

4. Posterior—To evaluate the posterior elbow, the palm is placed down on the table, or if the patient is supine, the forearm is placed across the abdomen, with the elbow flexed to 90°. The posterior joint space, triceps brachii tendon, olecranon process, and olecranon bursa are assessed.[12–14]

*C. Specifications for the Wrist and Hand Examination*

A wrist and hand 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 isolated tendon injury. Tenosynovitis, nerve entrapment syndromes, and peripheral nerve disorders such as carpal tunnel syndrome can also be evaluated. In a 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. Power or color Doppler imaging should also be used to detect active inflammation (synovitis).

To evaluate the hands and wrists, the patient is usually seated on a stool or chair if possible, with hands resting on a table. Color and power Doppler imaging may be useful in detecting hyperemia within the joint or surrounding structures. 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/Radial—Transverse and longitudinal images should be obtained from the volar wrist crease to the thenar muscles. The transducer will require angulation to compensate for the normal contour of the wrist. The flexor

retinaculum, flexor digitorum profundus and superficialis tendons, and 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. 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, scaphotrapezial joint, or flexor carpi radialis tendon sheath itself. 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. All of the tendons can be followed to their sites of insertion if clinically indicated.

2. 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 moved 90° 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.

3. Dorsal—The dorsal structures are very superficial, and a high-frequency transducer and large amounts of gel are necessary to optimize the examination and prevent compression of small vessels when using color or power Doppler imaging. 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, both 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 the Lister tubercle identifies the dorsal aspect of the scapholunate ligament, a potential site of symptomatic ligament tears and ganglion cysts. The remaining intercarpal ligaments are not routinely assessed. In patients with suspected inflammatory arthritis, the dorsal radiocarpal, distal radioulnar, midcarpal, metacarpophalangeal, and, if symptomatic, proximal interphalangeal joints are evaluated from the volar and dorsal aspects in both the longitudinal and transverse planes for effusion, synovial hypertrophy, and bony erosions. Other joints of the wrist and hand are similarly evaluated as clinically indicated.[15,16]

*D. Specifications for a Hip Examination*

A hip examination may be indicated to evaluate for tendinosis, a tendon or muscle injury, bursitis, hip effusion or synovitis, labral abnormality, a pseudotumor (in patients with total hip arthroplasty), “snapping hip,” hernia, bursitis, a focal soft tissue mass, or focal nerve pathology.

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 may involve a complete assessment of 1 or more of the 4 anatomic regions of the hip described below or may be limited to a specific anatomic structure, depending on the clinical presentation. Color and power Doppler imaging may be useful in detecting hyperemia within the joint or surrounding structures.

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 plane is used to evaluate the labrum, iliopsoas tendon and bursa, the femoral vessels, and the sartorius and rectus femoris muscles. The above structures are then scanned in the transverse plane, perpendicular

to the original scan plane. 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. This snap commonly occurs just proximal to where the iliopsoas tendon abruptly moves anteriorly over the acetabulum.[17]

2. Lateral—In the lateral decubitus position, with the symptomatic side up, transverse and longitudinal scans of the greater trochanter, greater trochanteric bursa, gluteus medius, gluteus maximus, gluteus minimus, iliotibial band, and tensor fascia latae should be performed. An iliotibial band or gluteus maximus muscle that snaps over the greater trochanter can be assessed in this position using dynamic flexion-extension.
3. Medial—The hip is placed in external rotation with 45° knee flexion (frog leg position). The distal iliopsoas tendon, due to 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, with short-axis images obtained perpendicular to this plane. In addition, the pubic bone and symphysis and the distal rectus abdominis insertion should be evaluated.
4. Posterior—The patient is prone with the lower extremities extended. Transverse and longitudinal views of the glutei, hamstrings, 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 greater trochanter, lying superficial to the quadratus femoris muscle.[18]

For information on the neonatal hip, see the *AIUM-ACR-SPR-SRU Practice Parameter for the Performance of an Ultrasound Examination for Detection and Assessment of Developmental Dysplasia of the Hip.*[19]

*E. Specifications for a Prosthetic Hip Examination*

The hip is assessed for joint effusions, extra-articular fluid collections, or soft masses (pseudotumors). Ultrasound guidance may be requested to evaluate for fluid aspiration in the clinical scenario of possible prosthetic joint infection. The region of the greater trochanter and iliopsoas is evaluated for fluid collections or tendon abnormalities such as tendinosis or tears of the iliopsoas, gluteus medius, and gluteus minimus tendons.[20,21] To assess for a pseudotumor, the anterior, medial, lateral, and posterior hip structures should be evaluated for joint and extra-articular fluid collections and soft tissue masses.[22,23]

*F. Specifications for a Knee Examination*

A knee examination may be indicated to evaluate for a tendon or muscle rupture/tear or tendinosis, joint effusion, crystal deposition disease, periarticular cystic lesions, a meniscal tear, bursitis, a ligamentous tear, or nerve pathology. The examination is divided into 4 regions. The examination may involve a complete 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. Color and power Doppler imaging may be useful in detecting hyperemia within the joint or surrounding structures.

1. Anterior—The patient is supine with the knee flexed to 30°. Longitudinal and transverse scans of the quadriceps and patellar tendons, patellar retinacula, and suprapatellar recess are obtained. The distal femoral trochlear cartilage can be assessed with the transducer placed in the suprapatellar space in the transverse plane and with the knee in maximal flexion. Longitudinal views of the cartilage over the medial and lateral femoral condyles are evaluated as indicated. The prepatellar, superficial, and deep infrapatellar bursae are also evaluated using adequate gel to prevent inadvertent compression of the bursae by the transducer.

2. Medial—The patient remains supine with slight flexion of the knee and hip and with slight external rotation of the hip. Alternatively, the patient may be placed in the lateral decubitus position. The medial joint space is examined. 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 magnetic resonance imaging (MRI) or computed tomographic arthrography if there are contraindications to MRI is recommended if clinically indicated.

3. Lateral—The patient remains supine with the ipsilateral leg internally rotated or in a lateral decubitus position. A pillow may be placed between the knees for comfort. 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 (as well as in the anterior position). The joint line is scanned for lateral meniscal pathology, with varus stress applied as needed.

4. Posterior—The patient lies prone with the leg extended. The popliteal fossa, semimembranosus, medial, and lateral gastrocnemius muscles, tendons, and bursae are assessed. To confirm the diagnosis of a Baker 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 can be evaluated. The posterior cruciate ligament may be identifiable in a sagittal oblique plane in this position.[24,25]

*G. Specifications for an Ankle and Foot Examination*

An examination of the ankle and foot may be indicated to evaluate a focal abnormality such as plantar fasciitis, plantar fibromatosis, Morton neuroma, a ganglion cyst, or a tenosynovial giant cell tumor of the tendon sheath but may also be used to evaluate for a muscle, tendon, or ligament tear/rupture, tendinosis, tenosynovitis, joint effusion, and nerve pathology. An ultrasound examination of the ankle is divided into 4 regions (anterior, medial, lateral, and posterior). The examination may involve a complete assessment of 1 or more of the 4 regions described below or be limited to a specific anatomic structure, depending on the clinical presentation. Color and power Doppler imaging may be useful in detecting hyperemia within the tendon sheath, joint, or surrounding structures.

1. Anterior—The patient lies supine with the knee flexed and the plantar aspect of the foot flat on the table. The anterior tendons are assessed in long- 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, and the hyaline cartilage of the talus appears as a thin hypoechoic line. The anterior inferior tibiofibular ligament of the syndesmotic complex is assessed by moving the transducer proximally over the distal tibia and fibula, superior and medial to the lateral malleolus, and scanning in an oblique plane.

2. Medial—The patient is placed in a lateral decubitus position with the medial ankle facing upward. 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- and short-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 for the ultrasound beam to remain perpendicular to the tendons 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 proximally and also distally 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 patient is placed in a lateral decubitus position with the lateral ankle facing upward. The peroneus brevis and longus tendons are identified proximal to the lateral malleolus in their short-axis planes, and they can then can be assessed in long- 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. This latter aspect of the tendon can be scanned in the prone position, as clinically indicated. 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 lateral ligament complex is examined by placing the transducer on the tip of the lateral malleolus in the following orientations: anterior and posterior horizontal oblique for the anterior and posterior talofibular ligaments, and posterior vertical oblique for the calcaneofibular ligament. Dynamic testing of the ligaments can be performed as clinically indicated.

4. Posterior—The patient is prone with feet extending over the end of the table. A rolled towel may also be helpful under the ankles. The Achilles tendon is scanned in the long- 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 inserts on the posteromedial calcaneus. It should be noted that this tendon may be absent as a normal variant but 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- and short-axis planes from its proximal origin on the medial calcaneal tubercle distally where it divides and merges into the soft tissues.

5. 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.

6. Interdigital—The patient is supine with the foot dorsiflexed 90° 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 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, improving visibility. The intermetatarsal bursa lies on the dorsal aspect of the interdigital nerve, and care must be taken to correctly identify a neuroma and differentiate it from the bursa [26,27].

*H. Specifications for 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 the 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 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, as 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 a 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 Guyon 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 readily evaluated to determine the potential underlying cause of the nerve dysfunction. In addition, congenital abnormalities (eg, accessory muscles or vessels) can be assessed.[28]

*I. Specifications for a Soft Tissue Mass Examination*

The mass should be scanned in both long- and short-axis planes. Ultrasound is an excellent method to differentiate solid from cystic masses. The mass should be measured in 3 orthogonal dimensions and its relationship to surrounding structures, particularly joints, neurovascular bundles, and tendons, determined. Compressibility of the lesion should be evaluated. A color or power Doppler evaluation will help delineate whether the mass has internal vascularity.[29]

*J. Specifications for Interventional MSK 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 consent, local anesthetic, sterile conditions). Ultrasound provides direct visualization of the needle, monitors the needle trajectory, and shows the position of the needle within the target area. Direct visualization of the needle allows the practitioner to avoid significant intralesional and extralesional vessels, adjacent nerves, or other structures at risk.

Before any procedure, an ultrasound examination is performed to characterize the target area and its relationship with surrounding structures. Color or power Doppler imaging is useful to delineate any vessels within the target zone. 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 freehand. 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 imaging should be used to identify areas of vascularity; this indicates viable tissue and increases the chance for an adequate histologic specimen.

*K. Specifications for an Ultrasound Examination for Detecting Foreign Bodies*

Most foreign bodies are associated with an acoustic shadow (wood) or comet tail artifact (glass and metal). Retained foreign bodies can cause a surrounding soft tissue inflammatory reaction or abscess formation. Once a foreign body is detected, ultrasound can be used to demonstrate its location and relationship to adjacent structures. 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.[30] Color and power Doppler imaging is useful in detecting surrounding hyperemia. When available, 3-dimensional imaging may be useful for localization.

## VII. Documentation

Adequate documentation is essential for high-quality patient care. There should be a permanent record of the ultrasound examination and its interpretation. Images of all appropriate areas, both normal and abnormal, should be recorded. Variations from normal size should be accompanied by measurements. Images should be labeled with the patient identification, facility identification, examination date, and side (right or left) of the anatomic site imaged. An official interpretation (final report) of the ultrasound findings should be included in the patient's medical record. Retention of the ultrasound examination should be consistent both with clinical needs and with relevant legal and local health care facility requirements.

Reporting should be in accordance with the *AIUM Practice Parameter for Documentation of an Ultrasound Examination.*[31]

## VIII. Equipment Specifications

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 are typically required for deeper structures and higher frequencies for superficial structures. The most common transducer frequencies used range between 12 and 18 MHz. Color and power Doppler modes are valuable in assessing hyperemia and inflammation, determining the vascularity of a soft tissue mass, differentiating cystic from solid lesions, and assisting with ultrasound-guided biopsy and aspiration procedures.[32] Doppler frequencies should be set to optimize flow detection. Tissue harmonic imaging, compound imaging, and extended field-of-view imaging may all be useful in musculoskeletal ultrasound.

## IX. Quality Control and Improvement, Safety, Infection Control, and Patient Education

Policies and procedures related to quality control, patient education, infection control, and safety should be developed and implemented in accordance with the AIUM S*tandards and Guidelines for the Accreditation of Ultrasound Practices.*

Equipment performance monitoring should be in accordance with the AIUM *Standards and Guidelines for the Accreditation of Ultrasound Practices.*

## X. ALARA Principle

The potential benefits and risks of each examination should be considered. The ALARA (as low as reasonably achievable) principle should be observed when adjusting controls that affect the acoustic output and by considering transducer dwell times. Further details on ALARA may be found in the AIUM publication *Medical Ultrasound Safety*, Third Edition.

**Acknowledgments**

This parameter was revised by the American Institute of Ultrasound in Medicine (AIUM) in collaboration with the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU) according to the process described in the AIUM *Clinical Standards Committee Manual*.

Collaborative Committee: Members represent their societies in the initial and final revision of this parameter.

AIUM
Jon A. Jacobson, MD
Jay Smith, MD
Ralf Thiele, MD

ACR
Nirvikar Dahiya, MD, MBBS
Sandra O. DeJesus Allison, MD
Monica S. Epelman, MD
Levon Nazarian, MD
Sharlene A. Teefey, MD

SPR
Harris L. Cohen, MD
Ricardo Faingold, MD
Dayna M. Weinert, MD

SRU
William D. MIddleton, MD

AIUM Clinical Standards Committee
Joseph Wax, MD, FAIUM, *Chair*
John Pellerito, MD, FACR, FAIUM, FSRU, *Vice Chair*
Sandra Allison, MD
Bryann Bromley, MD, FAIUM

Anil Chauhan, MD
Stamatia Destounis, MD, FACR,
Eitan Dickman, MD, RDMS, FACEP
Joan Mastrobattista, MD, FAIUM
Marsha Neumyer, BS, RVT, FSVU, FAIUM, FSDMS
Tatjana Rundek, MD, PhD
Khaled Sakhel, MD
James Shwayder, MD, JD, FAIUM
Ants Toi, MD, FRCP, FAIUM
Isabelle Wilkins, MD, FAIUM

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Renamed 2015

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