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Standards for musculoskeletal ultrasound

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Abstract

Ultrasound has become the primary diagnostic tool in traumatic, inflammatory and degenerative soft tissue conditions. It is also used to monitor the condition of joints, ligaments, cartilage and muscles. Its widespread availability as well as cases of unsatisfactory quality of equipment and the lack of appropriate training of ultrasound examiners are reasons why standards need to be set for equipment requirements, the scope of ultrasound assessment and examiner's experience. The paper discusses ultrasound criteria that are common for many specialties as well as detailed criteria for the examined regions and structures along with their description. The aim of the paper is to harmonize the protocol for ultrasound examination in all ultrasound laboratories.

Due to the specificity of the diagnosed tissues, musculoskeletal ultrasound requires top-class equipment with the highest quality transducers and, if possible, full software options to improve image quality, i.e. resolution, contrast and the best possible artifact removal^(1,2). In addition to providing high quality grayscale images, ultrasound apparatus should also feature the most sensitive color Doppler options^(1,2).

It should be noted that these requirements are due to the wide range of sizes and anatomical relationships of the evaluated structures. There are MCS sites where two different structures, whose total thickness does not exceed 2 mm, overlap. Musculoskeletal ultrasound not only involves an assessment of large tendons and ligaments with a thickness of several millimeters, such as the Achilles tendon⁽³⁾, but also smaller structures, such as extensor digitorum tendons or the ligaments and retinaculum of the hand or nerve branches, whose thickness ranges between 0.1–0.6 mm⁽⁴⁻⁶⁾.

The person performing ultrasound examination should have:

- medical degree and physician licensure;
- documented training in at least the basic techniques used in ultrasound;
- detailed knowledge of the musculoskeletal anatomy;
- a course or training in the field of musculoskeletal diagnosis – in professionals with documented competencies in musculoskeletal ultrasound.

Each diagnostic musculoskeletal ultrasound should be regarded as final. However, the examiner should consult with a more experienced person in the case of uncertainty about the diagnosis based on their own findings or a significant discrepancy with the preliminary clinical diagnosis. Therefore, physicians considered to be experienced by virtue of seniority and teaching activity should use only top-quality equipment as they often establish the final diagnosis.

The minimum features of an ultrasound machine for musculoskeletal diagnosis include:

- a linear broadband transducer with a frequency of 5 to a minimum of 13 MHz with ultrasonic focusing at a depth of no more than 5 mm
- convex transducer with a frequency of about 2–6 MHz (for imaging obese patients or examining deep structures);
- harmonic imaging;
- spatial compound imaging
- Doppler options: color, power and tissue (microcirculation) imaging.

Documentation

Black and white images of the visualized pathologies should be printed as well as digital documentation should be recorded on the hard disk of the apparatus.

Technique

There is no repeatable ultrasound protocol for different musculoskeletal structures universal for all body regions. This results from the dynamic nature of this imaging technique due to the possible movement of multiple evaluated elements as well as the need to properly position the transducer over the examined element.

Good medical practice should involve such imaging of a structure that allows for its fullest possible evaluation. This requires imaging within the available range in at least two planes.

Musculoskeletal ultrasound involves not only the imaging of soft tissues throughout their available range, but also the visualization of elements structurally or functionally connected with them, e.g. the examination of muscle-tendon units should include the tendons at the muscle belly level and the naked (bare) part, their entheses, as well as all peritendinous elements, such as the peritendineum, sheaths, retinaculum, bursa, fascia, subcutaneous tissue, fat folds or bone outlines, main vessels and regional nerves.

If possible, the examination should include a dynamic assessment of passive or active movement to evaluate slide, rotation, tension, tissue/free or trapped body clicking, mobility ranges and tissue/bone conflicts.

The dynamic assessment further includes ultrasound-guided compression with an evaluation of resilience/elasticity of fluid reservoirs (pressure) or tissues (scar maturity, strain ratio of solid lesions and the surrounding tissues).

Furthermore, ultrasound-guided compression may be an important diagnostic element in functional conflicts, e.g. neuroconnective conflicts. The site of potential conflict (the passage of the deep branch of the radial nerve under the Frohse's arcade on the edge of the supinator muscle is the most typical example) may show no structural pathology, but exhibit high tenderness to precisely targeted compression, which is sufficient to diagnose the conflict⁽⁶⁾.

Both, the assessment of tissue lesions and fluid reservoirs should include an evaluation of vascular supply in the investigated region. However, it should be noted that increased vascular supply may be differently diagnosed in different situations.

For example, vascularization of a tumor-like focal lesion may indicate its metabolic activity and even aggressive nature; vascularization of the walls in a fluid reservoir may indicate its organization (hematoma, abscess) or inflammation (bursa); vascularization of a scar after a torn tendon or ligament reflect reparative processes, while vascularized scar adjacent to an edematous bursa or located inside the sheath may indicate a combination of inflammatory and reparative processes.

An assessment of tissue pathologies should include:

- their nature – diffuse/focal;

- borderlines – sharp/blurred;
- echogenicity relative to normal structures – hypoechoogenicity, normal echogenicity or hyperechogenicity;
- structure – homogeneous/heterogeneous with the determination of non-homogeneous lesions (solid, solid/fluid, containing calcifications);
- the size in at least two planes or maximum dimensions if the lesion is only partly visible;
- the ratio (including the distance) to the adjacent anatomical structures, vessels and nerves in particular;
- behavior during the dynamic assessment.

Description

Ultrasound findings consist of description and photographic documentation.

The description should include:

- patient's full name;
- patient's age or date of birth;
- date of examination;
- data on the person performing the ultrasound;
- specification of the examined region.

All evaluated structures, regardless of whether pathological or not, should be listed in the description.

As a result of differences in education, experience and the quality of equipment, examiners present different scopes of competences, which is reflected in ultrasound description. For example, if a person performing ultrasound examination describes that knee ligaments show no signs of pathology, this means that the person visualized all knee ligaments, including those whose visualization is not possible under current technological conditions and thus not described in the world literature. A description specifying the examined ligaments (e.g. the patellar ligament, patellar retinaculum, medial patello-femoral ligament, medial patello-tibial ligament, collateral tibial ligament, menisco-femoral ligament and menisco-tibial ligament of the medial meniscus, fibular collateral ligament, anterior and posterior crucial ligament) indicates that no other ligaments were evaluated or their evaluation was not possible.

If an assessment of an element was performed based on the dynamic behavior of tissues or bone landmarks (indirectly) rather than the visualized structure, this should also be described.

The exact location of the measurement should be provided for the assessment of structure size or thickness. It should be also noted that the description should contain conclusions rather than only structural characteristics or echogenicity description. In the case of examiner's uncertainty about the visualized structure, the description of the nature of the lesion should contain an appropriate comment (at least in the form of a question mark). The lack of conclusions due to lesion presentation or location, which seem untypical or unknown for the examiner, should also be reported.

Diagnostic conclusions may follow the description of the lesion or may be included in the summary. Suggestions to use other diagnostic techniques (X-ray, MRI, CT, scintigraphy) may be included.

Urgent, auxiliary and intraoperative ultrasound

In addition to the classical scheduled diagnostic ultrasound, urgent, bedside and clinical sonography as well as ultrasound-guided surgeries are increasingly common.

This type of examination may be useful for the preliminary assessment of injury location/layer, type and size; potential fluid evacuation; administration of pharmacotherapy; monitoring of minor ambulatory procedures or in the operating setting.

Here, apparatus requirements are far less demanding compared to typical diagnostic ultrasound. A portable ultrasound machine with the following features may be used for such applications:

- possible vascular flow imaging – color and power Doppler;
- a linear transducer with the maximum frequency of at least 10 MHz;
- black and white video printer.

Ultrasound-guided puncture technique outside the operating room

There are no significant differences between ultrasound-guided puncture and standard punctures in other body regions. It may be performed using a diagnostic transducer with a free-hand technique or using a needle guide. The guide must be sterilized before use under conditions recommended by the manufacturer.

After applying a thin layer of standard gel, the ultrasound transducer should be covered with a latex sheath. Most manufacturers prohibit the use of disinfectants/sterilizers directly on the surface of transducer.

Once standard sterilization (preferably with at least one drying) of the punctured site and the transducer sheath was performed using the available agents, the puncture may be performed.

Needle length and thickness should be adjusted to the type of puncture and the depth/location of the lesion. The length of the needle should allow for easy access to the bottom of the lesion. No local anesthesia is usually needed. Note: xylocaine/lignocaine should not be used for intra-articular injections or scar puncture to stimulate repair processes due to their reported effects damaging the hyaline cartilage and inhibiting platelet-derived growth factors and natural repair processes.

During puncture, the movement of the needle or the punctured tissues (for deeper structures), as well as, if possible,

the position of the needle point in the punctured lesion or layer should be traced, depending on the technique used.

Fluid evacuation or drug administration into a space or a layer should be followed by procedure documentation.

If fine-needle aspiration biopsy (FNAB) of the visualized nodular lesion is needed, an appropriate management standard, which requires an image documenting the location of the needle, is used.

Ultrasound-guided puncture technique in an operating room setting

After applying a thin layer of standard or sterile ultrasound gel, the transducer should be covered with a latex sheath. The sheath should be sterilized with appropriate agent with at least one drying. A few drops of sterile saline are added into a sterile arthroscopic sleeve. A transducer is inserted into the sleeve whose tip is bent to form a fluid pool at the base of the transducer. The bent arthroscopic sleeve is secured with a sterile adhesive tape. The transducer is ready for use. The sterilized surgical field/skin should be moistened with sterile saline.

Detailed section – examination of individual body regions

The shoulder^(6,7)

Shoulder ultrasound should include an assessment of:

- potential exudate or hematoma, edema of the shoulder synovial membrane, the tendon sheath of the long head of the biceps muscle, the subacromial-subdeltoid bursa, signs of its increased vascularization;
- the structures of the rotator cuff, which comprises the tendon of the subscapularis muscle, the supraspinatus muscle, the infraspinatus muscle and the teres minor muscle, anteroinferior and superior capsular-ligamentous complex and the bellies of supraspinatus, infraspinatus and teres minor muscles, primarily including the area of humeral insertion for these structures – to search for erosive scars, geodes, productive lesions (mineralizing scars or calcified cavities)
- the tendon of the long head of the biceps;
- the dynamic behavior of the rotator cuff/the greater tubercle during abduction – evaluation of the so-called subacromial conflict;
- the acromioclavicular joint;
- if indicated - deltoid muscle and pectoralis major muscle.

The elbow⁽⁴⁾

Elbow ultrasound should include an assessment of:

- potential exudate, edema of the elbow synovial membrane, signs of its increased vascularization based on power Doppler imaging;

- the thickness and potential contracture of the anterior and posterior capsule;
- the presence of foreign bodies, irregular bone outlines ('beaks', fractures and faults in the anterior and posterior compartment), their impact on joint mobility if limited;
- the presence of erosions, cysts/geodes, productive lesions;
- the common extensor tendon, the radial collateral ligament and the annular ligament;
- the common flexor tendon, anterior and posterior bands of the ulnar collateral ligament;
- the ulnar nerve in the region of and at the level of the elbow;
- the tendon of the triceps muscle;
- the olecranon bursa – for the presence of exudate, thickening, increased vascularization of the synovial membrane;
- the subcutaneous tissue.

The hand^(6,8,9)

The wrist

Wrist ultrasound should include an assessment of:

- potential exudate, edema and increased vascularization of the synovial membrane in power Doppler imaging;
- bone outlines – to search for fractures, productive lesions/osteophytes, erosions, cysts, deformities;
- ligament apparatus in the proximal carpal row;
- extensor tendons, their sheaths and retinacula as well as flexor tendons, their sheaths and retinaculum (the transverse carpal ligament);
- the medial and ulnar nerve, and, optionally, the superficial branch of the radial nerve;
- the subcutaneous tissue.

Metacarpus and the digits

Metacarpal and digit ultrasound should include an assessment of:

- bone outlines – to search for fractures, deformities, osteophytes, erosions, cysts/geodes;
- the metacarpophalangeal joints (MCP), the proximal interphalangeal joints (PIP), the distal interphalangeal joints (DIP) – to search for exudate, edema and increased vascularization of the synovial membrane;
- the bands of fibular extensor, the capsular ligamentous apparatus of MCP/PIP/DIP joints – to search for their rupture and scars;
- extensor tendons of the digits – for their rupture, scars;
- flexor tendons of the digits as well as their sheaths and retinaculums – for their rupture, sheath inflammation (coexistence of both these pathologies is common);
- palmar aponeurosis;
- if indicated in the referral or medical history – palmar and digital branches of the median and the ulnar nerve;
- short palmar muscles;
- the subcutaneous tissue.

In the case of a history of tendon rupture, it is important to specify the location of ruptured tendon stumps using topographical terms.

The groin

The groin is examined mainly in search for pathologies of the gracilis muscle, long and short adductor (common insertion), as well as the pectineus muscle.

Groin ultrasound should include an assessment of:

- pubic insertion bone outlines – to search for erosions and scars following tears;
- proximal muscle tendons (the pectineus muscle has no visible proximal tendon) – to search for ruptures, post-rupture scarring; in the case of total ruptures, it is necessary to determine the level of the distal and proximal stump (unless the insertion was torn – then the proximal stump only); tendons, including the intramuscular segments, should be evaluated;
- muscle bellies up to their femoral insertion.

The hip

Hip ultrasound should include an assessment of:

- the hip joint – to search for the following pathologies: exudate, edema and increased vascularization of the synovial membrane, cartilage defects on the surface of the anterior head of the femur, deformed femoral head edge and subcapital femoral deformation, damaged acetabular labrum, thickening of the anterior capsule;
- the iliopsoas bursa and the trochanteric bursa of the gluteus maximus;
- the rectus femoris muscle, the iliolumbar muscle, the gluteal muscles (medium and small); if indicated, the gluteus maximus muscle, hip rotators, the ischial nerve, the sacrotuberous ligament, the subcutaneous tissue.

The knee⁽¹⁰⁾

Knee ultrasound should include an assessment of:

- the presence of exudate/hematoma, thickening, increased vascularization of the synovial membrane;
- the dynamics of joint recess adhesions;
- the extensor apparatus (patellar ligament, patellar retinacula, the quadriceps tendon, Hoffa's fat pad, bursas: the prepatellar bursa, the superficial and deep infrapatellar bursa);
- the cartilaginous angle of the upper part of the intercondylar groove of femur (the norm for this angle is 140–160°);
- the height of the patella and its lateralization (static and dynamic);
- femoral condyle cartilage;
- bone outlines;
- the tibial collateral ligament, the menisiofemoral ligament and meniscotibial ligament; superficial pes anserinus tendons; this evaluation may further include, medial and lateral patellotibial ligaments;

- the fibular collateral ligament, the anterolateral ligament, the biceps femoris tendon and the popliteus tendon, the iliotibial band and its bursa;
- the anterior and posterior cruciate ligament, including dynamic assessment;
- the posterior capsule, the posterior knee compartment;
- the medial and lateral meniscus;
- the presence of abnormal tissue and fluid within the joint;
- the gastrocnemius-semimembranosus and semimembranosus bursa;
- the popliteal neurovascular bundle; nerve assessment may further include the common fibular nerve, as indicated;
- the subcutaneous tissue.

The foot

Dorsal foot

Dorsal foot ultrasound should include an assessment of:

- the presence of exudates/hematoma, edema, increased vascularization of the synovial membrane in the tarsal joints, metatarsophalangeal (MTP) joints;
- the ligaments of the lateral malleolus (anterior and posterior tibiofibular ligament, anterior talofibular ligament, calcaneofibular ligament);
- the deltoid ligament;
- Chopart's joint ligaments;
- Lisfranc joint ligaments;
- tendons of fibular and tibial muscles, long extensors and flexors as well as their retinacula, sheaths and bursas.
- bone outlines;
- the subcutaneous tissue.

The plantar foot

Plantar foot ultrasound should include an assessment of:

- plantar fat layer;
- plantar aponeurosis;
- fat pads and bursas under the heads of the metatarsal bones;
- common digital nerves;
- intermetatarsal bursas and their dynamic behavior (lateral compression to detect fold clicking and tenderness during the maneuver);
- tendons and sheaths of long flexors of the hallux and the digits;
- short flexors and abductors of the hallux and the fifth toe, including hallux sesamoid bones.

The Achilles tendon⁽³⁾

Achilles tendon ultrasound should include an assessment of:

- tendon structure and thickness (compared to the healthy side) from the calcaneal insertion up to the level of the bellies of the gastrocnemius muscle; in the case of

identified rupture or post-rupture scarring, their length, transverse dimensions, the origin of the damaged band (from which head of the triceps surae) and the healing stage should be determined;

- the outline of the calcaneal insertion to search for mineralized scars (vascular assessment) non-mineralized scars – most often due to asymptomatic chronic micro-injuries;
- peritendineum – to search for edema, increased vascularization, fibrosis;
- the Achilles tendon bursa and subcutaneous calcaneal bursa;
- the Kager's triangle fat pad – to search for edema.

The examination may additionally include the whole triceps surae if needed.

Muscles⁽¹¹⁾

Muscle ultrasound should include an assessment of:

- the tendinous system of the muscle – proximal tendon(s), distal tendon(s), endomysium and perimysium – to search for ruptures/pos-rupture scars; if traumatic pathology is found, the affected tendon and the level of its location, the nature of rupture (complete or partial) as well as the presence of hematoma/fluid in the rupture area should be determined;
- bony outlines of tendon insertions;
- tendon sheaths and muscle tendon retinacula – for long tendons of upper and lower limbs;
- potential conflicts.

Bones

Bone ultrasound should include an assessment of:

- bone outlines – to search for deformities, osteophytes, erosions, geodes, osseous or chondro-osseous overgrowths, fractures and other malformations (bone tumors);
- periosteum – to search for edema, fibrosis, increased vascularization, post-traumatic scarring;
- ossification nuclei, particularly at tendon insertions (Sinding-Larsen syndrome, Osgood-Schlatter disease^(12,13), shredding of the anterior inferior and superior iliac spine).

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the content of this publication and/or claim authorship rights to this publication.

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