EFSUMB Course Book
Student Edition
Editors: Jan Tuma, Radu Badea, Christoph F. Dietrich

Musculoskeletal Ultrasound

Giorgio Tamborrini

Ultrasound Center, Switzerland

Corresponding author:
KD Dr. med. Giorgio Tamborrini.
Ultrasound Center Basel
c/o Bethesda Hospital
Gellertstrasse 144
4020 Basel
Switzerland
Tel.: (+) 41 – 61315 - 2320
Fax: (+) 41 – 61315 - 2677
Email: giorgio.tamborrini@bethesda-spital.ch
Web: www.irheuma.com

Acknowledgment: None.
Content

Introduction

Ultrasound is an excellent and validated tool in the diagnostics and assessment of musculoskeletal diseases as inflammatory and non-inflammatory joint diseases. Musculoskeletal (MSK) ultrasound (MSK US) plays an important role in visualising several soft-tissue structures and MSK US is able to detect a variety of pathologic changes. We use predominantly linear scan probes. The generally applied frequencies are in a range between 5 MHz and 22 MHz, depending on the investigated tissue. MSK structures are assessed dynamically in real-time and static with the advantage of a multiplanar view. Further MSK US is a useful tool for guided interventions at the MSK system. Limitations of this technique are limited acoustic windows, difficulty in detection of pathologies in large/deep joints, the limited view and the operator dependence.

Anatomy

MSK structures have different echogenicity and various percentage of reflection that determine their specific MSUS appearance. In this chapter ultrasound patterns of normal musculoskeletal tissues are discussed.
Cartilage

In the MSK system we distinguish fibrocartilage from hyaline cartilage. Typical examples of fibrocartilage are the triangular fibrocartilage complex (TFCC) of the wrist [Figure 1], the menisci of the knee [Figure 2], the labrum of the hip [Figure 3] or the glenohumeral joint. Normal fibrocartilage appears iso- to hyperechoic depending on the insonation angle.

Figure 1 Triangular fibrocartilage complex of the wrist. ECU = extensor carpi ulnaris tendon; Ul = ulna; TFCC = triangular fibrocartilage complex.

Figure 2 Meniscus of the knee. F = femur; Me = meniscus; T = tibia.

Figure 3 Labrum of the hip. La = labrum; A= acetabulum; F = femur.
Hyaline cartilage can be assessed in almost all accessible joints. Hyaline articular cartilage can be visualized as a sharp anechoic band (using low gain) over the bony cortex. Normal hyaline cartilage is homogeneous, regular and has continuous margins. The hyaline cartilage can be well separated to the overlaying soft tissue by an hyperechoic interface. Another hyperechoic interface is between the cartilage and the subchondral bony cortex [Figure 4].

**Figure 4 Articular cartilage of the finger joint.** aC = hyaline articular cartilage; MCH = metacarpal head; > = interfaces.

**Bone**

Assessing bone structures we see one of the limitations of MSK US: we have a limited acoustic window and therefore a limited acoustic view. The bright bony cortex reflects most US waves and appears as a hyperechoic structure. This is due to the higher acoustic impedance of the bone compared to the adjacent soft tissues.
of deep structures as bone marrow is therefore not possible [Figures 5 and 6]. Normal periosteum can normally not be seen.

**Figure 5** Bone. Arrows = hyperechoic bone surface of the metacarpal head.

![Figure 5](image1)

**Figure 6** Bone. Arrows = hyperechoic bone surface of the femur. Fh = femoral head; Fn = femoral neck.

![Figure 6](image2)

**Tendons and ligaments**

Tendons and ligaments of joints appear as hyperechoic linear structures with echogenic fibrils corresponding to endo- and peritendineal septa [Figure 7]. Depending on the insonation angle tendons and ligaments change their echogenicity from hyper- to hypoechoic [Figure 8]. This phenomenon is called anisotropy and can be used in the differentiation in difficult anatomic areas as for example the volar wrist differentiating the median nerve from the flexor tendons.
Figure 7 Flexor tendons of the finger. dFT = hyperechoic deep flexor tendon; sFT = hyperechoic superficial flexor tendon; pu = A1 pulley; vP = volar plate.

Figure 8 Anisotropy in the biceps tendon, hyperechoic appearance when the insonation angle is 90 degrees (arrow head in the left image) or hypoechoic appearance when changing the angle (arrow head in the right image).

Muscles

Typically muscles have a hypoechoic pattern. In old age the structures get more echoic due to the loss of water, atrophy and more fatty infiltration. When a muscle is scanned in a transversal view several echoic to hyperechoic dots can be seen corresponding to endo-, peri- and epimysium. In a longitudinal view we visualize them as parallel and oblique echoic fibers [Figure 8].
Figure 9 Hypoechoic deltoid muscle on a transverse view and on a longitudinal view with parallel and oblique echoic fibers. DMt = deltoid muscle on a transverse view; DMI = deltoid muscle on a longitudinal view; Bi = biceps tendon.

Skin and fat

Using high frequency probes (18 to 22 MHz) the skin appears as a hyperechoic band [Figure 10], while subcutaneous fat appears as a hypoechoic lobulated structure with iso- or hyperechoic connective tissue fibers [Figure 11].

Figure 10 Skin. Ep = epidermis.

Figure 10 Hypoechoic fat at the lateral hip. Fa = subcutaneous fat; F = femur.
Nerves and vessels

Using high frequency probes we can see peripheral nerves [Figure 12]. Typically we see linear hypoechoic fascicles surrounded by the hyperechoic endoneurium and perineurium. The epineurium of a nerve looks like a parallel hyperechoic band. Blood vessels appear as anechoic compressible tubular structures (longitudinal view) or as round structures (transverse view) [Figure 12].

Figure 11 Median nerve at the level of the wrist. MN = median nerve; UA = ulnar artery.

Synovium and bursa

Normally the synovial lining of a joint, bursa or tendon sheath can be seen as a fine iso- to hyperechoic line with a small amount of hypoechoic synovial fluid [Figure 13]. The fluid is compressible and displaceable. Some physiological fluid inside a bursa can be found for example in the bursa subachillea [Figure 14] or in the deep infrapatellar bursa.

Figure 12 Synovial recess of the proximal interphalangeal finger joint. Ft = flexor tendons; Sy = synovial recess; vP = volar plate; Ph = head of the proximal phalanx
Examination technique

Dependent on the examined anatomical region the patient has to be positioned in a correct way to make the examination agreeable both for the patient and the examiner. The position of the patient and the standard scans depends on the respectively scanned area. For example examining the shoulder joint the patient is in a sitting position and at the beginning of the examination you prefer a 90° flexion of the elbow joint, the hand is positioned in supination on top of the patient’s thigh to scan the posterior or anterior structure. For a dynamic assessment active and passive external and internal rotation of the humerus is additionally performed. In the case of the examination of the hip joint, the patient is in a supine position while the hip joint stays in a neutral position. All structures are assessed with longitudinal and transverse scans. Optional oblique or unconventional views are added to make an additional in-depth assessment of specific musculoskeletal structures. An auxiliary helpful characteristic of MSK US is that it allows dynamic assessment by moving for example a joint with a steady probe and therefore winning fundamental functional information. This technique permits assessment of a structure on a static and dynamic way through active, passive or resisted movement with the advantage of direct anatomic and functional visualization. Moreover MSK US-guided interventions may be performed such as diagnostic synovial fluid aspiration or therapeutic injection. The structures should be scanned comparative bilateral to increase diagnostic certainty.

VIP: very important pathologies in MSK

Cartilage pathology

Osteoarthritis (OA) is one of the most frequent MSK diseases. In early disease we find a loss of sharpness, of homogeneity and of anechogenicity of the cartilage, further we see irregular interfaces to the overlying soft tissue and to the subchondral bone and finally focal or diffuse thinning of the hyaline articular cartilage [Figure 15]. These findings are not specific for OA, e.g. similar changes can also be found in one
of the most frequent inflammatory rheumatic diseases, namely rheumatoid arthritis (RA).

In crystal deposition diseases specific pathologic findings of the hyaline cartilage are present. In gout monosodium urate crystals (MSU) may be visualized as a hyperechoic diffuse or focal enhancement of the superficial margin of the hyaline articular cartilage (―double contour‖ sign) [Figure 16]. In calcium pyrophosphate deposition disease (CPPD) we typically find hyperechoic dots or lines inside the articular cartilage[Figure 17]. The same findings may occur in fibrocartilage, e.g. in themeniscus, labrum, wrist [Figure 18] orsymphysis. Degenerated or injured fibrocartilage can appear inhomogenous. In meniscal degeneration e.g. in OA the meniscus is extruded and parameniscal ganglion cysts may occur [Figure 19].

**Figure 14 Osteoarthritis of the knee.** Ca = normal cartilage of the femoral condyles; > = thinning of the cartilage.

**Figure 15 Gout in the first metatarsal joint.** C = hyperechoic soft tissue calcification; Mt = metatarsal head; > = double contour sign.
Figure 16 CPPD knee. Ca = cartilage of the femur condyle; \(>=\) hyperechoic calcifications inside the hyaline cartilage.

Figure 17 CPPD of the wrist. Ul = ulna; Ca = calcifications of the TFCC; ECU = extensor carpi ulnaris tendon.

Figure 18 Paramensical ganglion. Ga = ganglion; Me = meniscus.

Bone pathology

A sign of degenerative joint disease is bony overgrowth. In OA called osteophytes, in MSK US they appear hyperechoic [Figure 20]. Osteophytes can also be found in inflammatory joint diseases as in Psoriasisarthritis (PsA) or in end stage RA. Erosions of the bone are typical in erosive RA [Figure 21] but also in erosive Osteoarthritis (eOA). An erosion is defined as an intra-articular discontinuity of the
bone surface that is visible in two perpendicular planes (OMERACT 7 definition). Another pathology of the bone that can be assessed is for example a fracture, with a discontinuity of the bony cortex and sometimes visible bulging of hyperechoic periosteum due to hypoechoic or anechoic hematoma [Figure 22].

Figure 20 Osteoarthritis of the knee. F = femur; Op = osteophytes; T = tibia.

Figure 19 Erosion of the metacarpal head in RA. Mc = normal metacarpal head; E = erosion.

Figure 20 Rib fracture. Fx = fracture; Ri = normal rib.

Tendons and ligaments pathology

Tendons and joint ligaments can be injured by mechanical overloading or trauma. Tendons degeneration (tendinosis) is frequent for example in Achilles tendon [Figure 23, 24 and 25], patellar tendon or in the rotator cuff of the shoulder or the hip [Figure 26]. Partial or full thickness tears may occur [Figure 27]. In tendinosis we often find calcium deposition inside the tendons or ligaments [Figure 28]. The calcium deposits
can penetrate the bone or the bursa and cause inflammation and pain. Quite often crystal deposition of tendons and ligaments can appear in inflammatory crystal deposition diseases as CPPD or in gout [Figure 29]. The insertion of ligaments and tendons to the bones are called enthesis. In mechanical overloading and in inflammatory diseases (for example in peripheral Spondyloarthritis = pSpA) inflammatory signs (thickening of the tendon, abnormal hypoechoic zones in the tendon, tendon calcifications, bursitis, increased vascularisation) and postinflammatory signs (bony overgrow = enthesophytes, irregular bone surface and erosions, especially in pSpA) can be found [Figure 30]. Modern techniques to assess stiffness and inflammation are elastosonography and 3D/4D-scans. Tenosynovitis is discussed in the section —Synovia and bursa pathology.

**Figure 23**  Achilles tendon tendinosis. Te = thickened Achilles tendon, Ca = calcaneus.

**Figure 24**  Achilles tendon full thickness tear. >< = tear; Ca = calcaneus.
Figure 25 Achilles tendon tendinosis with increased vascularisation, 3D Power Doppler scan. A = transverse view; B = longitudinal view; C = coronal view; 3D = 3D view.

Figure 26 Tendinosis of the supraspinatus tendon. Hu = humerus; Te = inhomogeneous thickened tendon.

Figure 27 Full thickness tear of the supraspinatus tendon. Hu = humerus; Te = tendon tear filled with anechoic fluid.
Figure 21 Calcification of the supraspinatus tendon. Ca = hyperechoic calcium deposits in the tendon with acoustic shadowing.

Figure 29 Achilles tendon calcification. AT = Achilles tendon; > = hyperechoic calcification; Ep = bony enthesophyte of the calcaneus.

Figure 220 Enthesitis in Spondyloarthritis. Ca = irregular bony cortex of the calcaneus; > = pathologic vascularisation of the Achilles tendon.

Muscles pathology

MSK US is an excellent tool in the diagnostic of muscle tears [Figure 31]. We can visualize hematoma (early assessed with a hyperechoic pattern, later on changing to a hypoechoic pattern) [Figure 32] and see a loss of the normal architecture. Also in case of inflammatory diseases (eg myositis) we can see more hypoechoic oedema or hyperechoic ectopic calcifications in the muscle. Whenever muscles or other soft tissues are scanned a comparison with the other side should be performed.
Figure 31 Partial tear of the deltoid muscle on a transverse view, left image showing the normal deltoid muscle on the other side. Dm = deltoid muscle; > = tear; SuT = subscapularis tendon.

Figure 32 Hematoma and tear of the deltoid muscle on an extended transverse view. Dm = deltoid muscle; > = hyperechoic hematoma.

Skin and fat pathology

Typical rheumatic diseases involving the skin are connective tissue diseases (for example dermatomyositis, systemic lupus erythematos) or Psoriasarthritis (PsA). In these diseases by using very high frequency transducers (> 22MHz and up to 60 MHz) we can see an increased thickness or vascularisation of the affected skin. Even the nail in PsA can be scanned to assess texture irregularities and an inflammation of the nail matrix and a simultaneous enthesitis of the enclosed tendons and ligaments [Figure 33]. Another technique to determine the elasticity and stiffness of the skin (for example in systemic sclerosis) is elastography, not further discussed at this point. Moreover MSK US is an excellent tool to visualize foreign bodies or abscesses in the skin and subcutis. A typical pathology of fat is a benign tumor called lipoma. The typical appearance is hyperechoic compared to the surrounding hypoechoic fat [Figure 34].
Figure 33 Distal interphalangeal joint in PsA. > = thickened skin; Er = erosion; Nm = increased vascularisation at the insertion of the extensor tendon and nail matrix.

Figure 34 Lipoma. > = subcutaneous lipoma, SP = spinous process.

Nerves and vessels pathology

High resolution nerve ultrasound allows us to visualize different nerve pathologies as for example nerve tumours or neurinoma in clinically frequent nerve entrapment. Common entrapment sites are the carpal tunnel (median nerve) or the tarsal tunnel (posterior tibial nerve). In carpal tunnel syndrome a thickening and hypoechoic swelling of the nerve proximal of the stenosis can be seen [Figure 35]. Sometimes an increased vascularisation inside the compressed nerve can be detected and the nerve glides worse during finger movement. In large vessel vasculitis, for example in temporal arteritis (giant cell arteritis), we can see a stenosis of the artery and an increased thickness of the vessel wall generating a —halo[Figure 36].
Synovial and bursa pathologies

The definitions of synovial fluid, synovial hypertrophy and tenosynovitis according to OMERACT 7 are listed in Table 1.

Table 1 OMERACT 7 definitions.

<table>
<thead>
<tr>
<th><strong>Synovial Fluid</strong></th>
<th>Abnormal hypoechoic or anechoic (relative to subdermal fat, but sometimes may be isoechoic or hyperechoic) intra-articular material that is displaceable and compressible, but does not exhibit Doppler signal.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Synovial Hypertrophy</strong></td>
<td>Abnormal hypoechoic (relative to subdermal fat, but sometimes may be isoechoic or hyperechoic) intra-articular tissue that is nondisplaceable and poorly compressible and which may exhibit Doppler signal.</td>
</tr>
<tr>
<td><strong>Tenosynovitis</strong></td>
<td>Hypoechoic or anechoic thickened tissue with or without fluid within the tendon sheath, which is seen in 2 perpendicular planes and which may exhibit Doppler signal.</td>
</tr>
</tbody>
</table>
Synovial effusion can occur in osteoarthritis (OA) [Figure 37 and 38] and more often in inflammatory joint diseases such as rheumatoid arthritis (RA) [Figure 39 and 40], crystal deposition diseases, infections or spondyloarthritis. Table 2 shows the typical MSK US findings in OA compared to rheumatoid arthrits (RA). MSK US is a valuable tool in the monitoring of disease progression and in the assessment of response to local and systemic treatment, helping rheumatologists in the clinical management.

Table 2 MSK US findings in OA compared to RA.

<table>
<thead>
<tr>
<th>Tissue</th>
<th>OA</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>joint/bursa/tendon</td>
<td>- joint effusion - synovial hypertrophy and hyperaemia - joint capsule thickening - bursitis - meniscal tears, meniscal extrusion</td>
<td>- joint effusion - synovial hypertrophy and hyperaemia invading the bone erosions - joint capsule thickening - bursitis, tenosynovitis, rheumatoid nodules, tendon tears, secondary nerve entrapment</td>
</tr>
<tr>
<td>Cartilage</td>
<td>- loss of sharpness - loss of homogeneity - loss of anechogenicity - irregularities of the anterior and posterior margins - focal or diffuse thinning of the cartilage</td>
<td>- loss of sharpness - loss of homogeneity - loss of anechogenicity - focal or diffuse thinning of the cartilage</td>
</tr>
<tr>
<td>Bone</td>
<td>- osteophytes - erosions and mucoid cysts especially in erosive finger/hand osteoarthritis</td>
<td>- erosions - secondary osteoarthritic signs, e.g. osteophytes</td>
</tr>
</tbody>
</table>

Synovial membrane thickening and joint effusions can reflect inflammation. There is an association with the damage of the articular cartilage or the amount of conventional radiographic changes. Inactive inflammatory processes color or power Doppler MSK US can demonstrate an increased pannus vascularisation [Figure 41 and 42] and may be predictive of radiographic damage in the course of RA. ContrastEnhanced US (CEUS) may improve the measurement of synovial thickness and activity of synovial processes and allows a more sensitive differentiation between effusion and synovial proliferation. In both degenerative and inflammatory joint diseases, bursitis or tenosynovitis may occur [Figure 43 and 44]. In shoulder impingement an inflamed and thickened subdeltoid bursa can be detected [Figure 45]. Tenosynovitis is an early finding in RA [Figure 46] and is also common in crystal deposition disease, mechanical overload or spondyloarthritis.
Figure 37 Osteoarthritis of the distal interphalangeal joints. Arrows = hypoechoic effusion; > = osteophytes; mP = middle phalanx, dP = distal phalanx.

Figure 38 Osteoarthritis of the knee joint. Arrow = hypoechoic effusion in the suprapatellar recess; Pa = patella; Ti = tibia.

Figure 39 Mild synovial effusion in the metacarpal joint. Arrow = hypoechoic effusion in the proximal dorsal recess; Mc = metacarpal head.
Figure 40 Hypoechoic synovial effusion in the humero-radial elbow joint. Arrow = hypoechoic effusion; Co = lateral condyle of the humerus.

Figure 41 Active synovitis in the metacarpal joint. Arrows = increased pannus vascularisation in the Power Doppler mode; Mc = metacarpal head.

Figure 42 Active synovitis in the radiocarpal joint. Arrow = increased pannus vascularisation (Power Doppler mode); Ra = radius; Sy = synovitis (B-Mode).
Figure 43 Prepatellar septic bursitis. Arrow = hypoechoic prepatellar bursitis; Pa = patella; Ti = tibia.

Figure 44 Semimembranosus gastrocnemius bursa (baker’s popliteal cyst), left image in a transverse view, right image in a longitudinal. Arrow = hypoechoic bursitis; Ga = medial head of the gastrocnemius muscle.

Figure 45 Subdeltoid bursitis. Arrows = synovial proliferation; > = effusion; SuT = subscapularis tendon.
Interventional MSK US

Real time MSK US is a validated useful tool when performing interventions of the MSK system. MSK US guides the correct application of the needle and facilitates atraumatic joint aspiration. Ultrasound guided diagnostic and therapeutic interventions are characterized by their excellent accuracy and improvement of clinical effectiveness compared to unguided procedures [Figure 47 and 48].

Figure 47 Injection in the subdeltoid bursa. Arrows = needle; Bu = bursa; SpT = supraspinatus tendon.
Figure 48 Injection in the tendon sheath of the peroneal tendons. Arrows = needle; PIT = peroneus longus tendon; PbT = peroneus brevis tendon; Fi = fibula.

Recommended reading and references

• Tamborrini G, Marx C. [Muskuloskelettaler Ultraschall]. ISBN 978-3-9524150-1-6