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The EFSUMB Guidelines and Recommendations for Musculoskeletal Ultrasound – Part I: Extraarticular Pathologies

Die EFSUMB-Leitlinien und -Empfehlungen für den muskuloskelettalen Ultraschall. Teil I: Extraartikuläre Pathologien

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ABSTRACT

The first part of the guidelines and recommendations for musculoskeletal ultrasound, produced under the auspices of the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB), provides information about the use of musculoskeletal ultrasound for assessing extraarticular structures (muscles, tendons, entheses, ligaments, bones, bursae, fasciae, nerves, skin, subcutaneous tissues, and nails) and their pathologies. Clinical applications, practical points, limitations, and artifacts are described and discussed for every structure. After an extensive literature review, the recommendations have been developed according to the Oxford Centre for Evidence-based Medicine and GRADE criteria and the consensus level was established through a Delphi process. The document is intended to guide clinical users in their daily practice.

ZUSAMMENFASSUNG

Der erste Teil der Leitlinien und Empfehlungen für den muskuloskelettalen Ultraschall, die unter der Schirmherrschaft der European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) erstellt wurden, enthält Informationen über den Einsatz des muskuloskelettalen Ultraschalls zur Beurteilung von extraartikulären Strukturen (Muskeln, Sehnen, Gelenke, Bänder, Knochen, Schleimbeutel, Faszien, Nerven, Haut, subkutanes Gewebe und Nägel) und deren Pathologien. Für jede Struktur werden die klinische Anwendung, praktische Punkte, Einschränkungen und Artefakte beschrieben und diskutiert. Nach einer ausführlichen Literaturrecherche wurden die Empfehlungen gemäß den Kriterien des Oxford Centre for Evidence-based Medicine und den GRADE-Kriterien entwickelt, und der Konsensgrad wurde durch die Delphi-Methode ermittelt. Das Dokument ist als Leitfaden für klinische Anwender in der täglichen Praxis gedacht.

Introduction

General considerations

Musculoskeletal ultrasound (MSUS) has become a routine imaging modality in clinical practice. Its use has increased substantially not only in radiology but also in rheumatology, orthopedics, physical medicine and rehabilitation, sports medicine, podiatry, neurology, anesthetics, and many others. Several professional societies have contributed over time to the standardization, implementation, and training in MSUS. In Europe, significant work has been carried out by the European League Against Rheumatism (EULAR), European Society of Musculoskeletal Radiology (ESSR), and European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) [1–10].

Taking into consideration the huge number of MSUS indications and the multitude of users from a variety of medical specialties, the need for a multidisciplinary consensual position among MSUS experts has become evident. For this reason, under the umbrella of EFSUMB, a Steering Committee consisting of 8 international experts from 7 countries was created. The group identified the main topics that needed to be analyzed and invited other MSUS experts (rheumatologists, radiologists, orthopedic surgeons, physical and rehabilitation medicine doctors, pediatricians, dermatologists, anesthesiologists) in order to draw up valid recommendations. The authors group consists of 36 experts from 15 countries.

Based on an extensive literature review on the previously selected topics (▶ **Fig. 1**), the panel members produced a descriptive text on different aspects of clinical applications and a number of recommendations for each field. The level of evidence (LoE) was appraised using the Oxford Centre for Evidence-based Medicine (OCEMB) criteria [11]. The strength of the recommendation (SoR) was analyzed using the Grading of Recommendations

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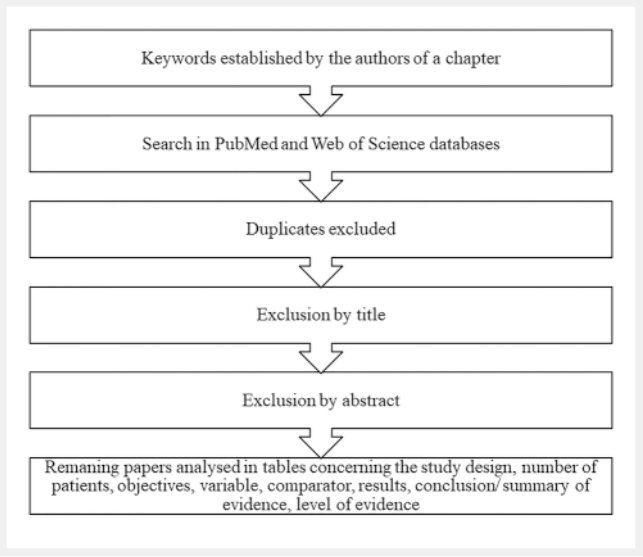

▶ **Fig. 1** The flowchart of the searching process used for every chapter of the musculoskeletal ultrasound recommendations.

Assessment, Development and Evaluation (GRADE approach) [12], and the consensus level between the task force members was established through a Delphi process following the EFSUMB policy document development strategy for Clinical Practice Guidelines [13].

Initially, 84 recommendations/statements were proposed. After the first round of voting, 2 recommendations were discarded and 75 were approved. After a second round of voting, an additional 7 recommendations were proposed and approved. In total, we produced 82 consensual recommendations. The results of the voting process are presented as follows: percent of participants who agree/disagree/abstain and the percentage of agreement. Consensus was considered strong when the percentage who voted in favor of a statement/recommendation was > 95 % and broad when the percentage was between 75–95 % [13].

US techniques used in MSUS

The US techniques used in MSUS are detailed in ▶ **Supplementary Table 1**.

Training

There are many forms of MSUS training (mentorship, theoretical and practical courses, cadaver courses stressing sonoanatomy and procedural proficiency, E-learning, self-teaching, team-based learning) that vary between different professional societies and across Europe [14–16]. In 2008, EFSUMB published the minimum training requirements for the practice of MSUS, comprising 3 levels, with the need to acquire competency for each level [17]. Many MSUS courses endorsed by EFSUMB take place throughout Europe.

EULAR has organized dozens of MSUS courses and published guidelines for conducting these courses (basic, intermediate, and advanced levels) [18]. The minimum training requirements for rheumatologists performing MSUS were also published, and a 3-level competency assessment (COMPASS) was established [9] and implemented [19]. Recommendations for Teaching the Teachers courses have been developed [20]. Important efforts have been made to standardize the MSUS examination and reporting [3, 21].

ESSR produced technical guidelines for the ultrasound examination of joints [22] and guidelines on clinical indications of MSUS [4, 6] and organized many courses accompanying their annual meetings [23].

Courses organized by national professional societies, including some with integrated competency assessment, deserve explicit acknowledgement, along with the general trend towards embedding MSUS into fellowship curricula of various specialties [24].

Terminology

▶ **Supplementary Table 2** provides the current US definitions of the main musculoskeletal structures and those of US pathologies [25–37].

Safety

Diagnostic US has been widely used in clinical medicine for many years with no proven deleterious effects [38], with possible biological effects of non-thermal origin being reported in animals [39] but none in humans. Contrast agents used for US are administered safely in several settings with minimal risk to patients. They are not excreted through the kidneys and hence can be safely administered to patients with renal impairment without risking contrast induced nephropathy or nephrogenic systemic fibrosis [40]. Based on the scientific evidence of US-induced biological effects to date, there is no reason to withhold diagnostic scanning during pregnancy, provided it is medically indicated and is used prudently by fully trained operators [41, 42].

In the last decade new imaging methods have been introduced, such as elastography, plane wave imaging, and vector Doppler. The EFSUMB Committee for Medical Ultrasound Safety (ECMUS) drew the following conclusions regarding the safety of elastography [43]: when acoustic radiation force impulses are used, significant temperature rises may occur, especially if bone lies in the beam; and when using ARFI, the temperature has its maximum at the focus, whereas in B-mode the maximum is close to the transducer.

Therefore, according to the ALARA (As Low As Reasonably Achievable) principle, diagnostic ultrasound can be considered safe [38] when the thermal and mechanical index values are as small as possible, while keeping the quality of the scan as high as possible [44].

Overarching principles

1. B-mode (grayscale), Doppler techniques, elastography and CEUS can be used for the musculoskeletal system examination. Broad consensus (27/3/6, 90 %)
2. Appropriate knowledge and training are necessary for performing MSUS. Strong consensus (34/0/2, 100 %)
3. The use of standardized US terminology is highly recommended. Strong consensus (34/0/2, 100 %)

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4. Although no side effects of grayscale and Doppler US are known, ALARA principles should be taken into consideration. Broad consensus (27/6/3, 81 %)

Extraarticular anatomical structures

Muscles

Background

The US appearance of skeletal muscles is determined by their histological structure, which consists of an alternance of hypoechogenic bundles of myofibrils and hyperechogenic intramuscular aponeuroses, septae, and fasciae. The blending of these fundamental components inside each muscle belly results in an inconsistent US appearance throughout the human body, as their relative quantity, respective relationship, and orientation change greatly depending on the particular specialized tasks of each muscle. Moreover, the US image of the same muscle is influenced by factors like sex, age, and fitness status [45, 46]. Thus, muscle appearance may be inconsistent among normal subjects. Finally, skeletal muscles are intrinsically highly anisotropic structures [47].

Clinical application

Intrinsic muscle injuries are most often caused by simultaneous contraction and elongation of the myofibrils and represent one of the more common indications for MSUS examinations. These injuries, which most commonly occur in muscles spanning two joints and in the proximity of the myotendinous junction [48, 49], are classified into four grades of severity [50]: Grade 0 when US is not able to detect any pathological finding in patients with local pain following an acute injury; Grade 1 lesions consist of minor destruction of the muscle fibers and may show subtle US alterations, such as intramuscular hypo- or hyperechoic areas or swollen aponeuroses; Grade 2 lesions are referred to as partial muscle tears and are caused by disruption of the muscle fibers and hematoma formation; Grade 3 lesions correspond to complete tears and are characterized by total discontinuity and retraction of the muscle belly. In Grade 0 and 1, dynamic evaluation may show hypomobility of muscle fibers. In Grade 2 and 3 lesions, US shows interruption and retraction of the muscle fibers, along with an intramuscular gap filled with blood. Torn muscle fragments may float inside the intramuscular collection, giving rise to the "clapper in bell sign" on US [51]. The role of US in patients with suspected muscle injury is to establish the extent of the damage and to rule out differential diagnoses, such as deep venous thrombosis [52]. Measurement of the cross-sectional area of muscle injuries has prognostic value, as it may predict time to recovery during rehabilitation [48]. Moreover, the time at which the hemorrhagic cavity is filled with hyperechoic connective tissue scar corresponding to the repair process can be considered safe for restarting low-level activity, in the absence of clinical symptoms [50]. However, US tends to underestimate the extent of muscle damage, especially when compared to magnetic resonance imaging (MRI) [48].

US may show the direct consequences of an extrinsic injury and it may detect local complications of muscle contusions, such as cysts, myositis ossificans, and, more rarely, calcific myonecrosis. Local swelling, focal irregularities/inhomogeneity of the muscle tissues, and partial or complete tears are the most common US findings in the context of contusion injuries. In the subacute/chronic setting, muscle hernia may develop if the external blow damaged the muscle fascia [52].

US commonly represents the imaging modality of choice for the initial evaluation of muscle masses, to confirm the presence of a mass and to gather information about its nature (solid or cystic), size, margins, compressibility, and vascularity [53–55]. US may establish the anatomical location and relationship with adjacent structures, detects signs of infiltration, and assists in imaging-guided sampling for histological evaluations. However, patients with a soft-tissue mass frequently need further evaluation with MRI [56, 57].

Recently, US has demonstrated its potential to quantify and qualify skeletal muscles in both young and old populations [58–61]. Several US parameters have proved reliable not only for the prediction of muscle strength and function, but also for the detection and monitoring of sarcopenia [62–69]. Muscle size, echogenicity, pennation angle, and vascularity appear most promising for this purpose [70, 71]. It is plausible that in the next few years US will be increasingly used for the diagnosis and follow up of sarcopenia [72].

US may assist with the diagnosis and characterization of disease activity in inflammatory myopathies (82.9 % sensitivity for detecting histologically proven myositis) [73]. Inflammation and edema cause an increased echogenicity of muscles, which may also appear swollen. In chronic disease, the muscles appear atrophic with reduced volume and further increased echogenicity due to progressive infiltration of fatty tissue [74].

Practical points, limitations, and artifacts in muscle examination are detailed in ▶ **Supplementary Table 3, 4**.

Recommendations

1. In muscle injuries, US should be performed to confirm the lesion, define its anatomic location, and establish its extension (LoE 2, SoR strong). Broad consensus (31/2/3, 94 %)
2. US should be used to confirm the presence of a muscle mass and provide information about its structure (LoE 1, SoR strong). Strong consensus (33/0/3, 100 %)
3. US might play a role in diagnosis and the monitoring of disease activity in patients with suspected myositis (LoE 2, SoR strong). Broad consensus (26/7/3, 79 %).

Tendons

Background

Tendinopathy refers to persistent tendon pain and dysfunction related to mechanical loading. While several models of tendon pathology exist, the continuum model proposed by Cook et al. [75, 76] is widely used to clinically describe and diagnose tendinopathy. This model proposed three key stages of tendon pathology: reactive tendinopathy, tendon disrepair, and degenerative

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tendinopathy. The staging of tendon pathology may be beneficial for clinicians to target treatment according to the tendon structure [77]. A clinical diagnosis of tendinopathy is primarily derived from the patient history and clinical tests. The latter have been shown to be sensitive for detecting tendinopathy, but they are not specific for identifying pathological changes when compared with imaging [78].

MSUS is the foremost imaging modality for tendon pathologies since it more sensitive than clinical examination and MRI for detecting pathological structural changes within tendons, but it does not always correlate with pain and dysfunction [79, 80]. Although reviews have demonstrated both an association and a dissociation between tendon structure, function, and pain, structural changes identified on US can be considered a risk factor for the development of symptomatic tendinopathy [81, 82]. Using Doppler US, neovascularization due to autoimmune inflammation, overuse, or trauma repair can be easily identified. Furthermore, nearly all tendons are readily accessible. The presence of blood vessels and accompanying nerves has previously been implicated as a source of pain, with moderate associations reported between the Doppler signal and the presence and location of pain [82, 83]. However, an increased Doppler signal is present in asymptomatic tendons, suggesting that blood vessels and accompanying nerves are not the primary source of pain. In addition, the reliability of detecting a Doppler signal is poor, as exercise has been shown to affect both intra- and peritendinous vascularity [84, 85].

In calcific tendinopathy, cartilaginous metaplasia spontaneously occurs, together with calcium deposition inside the tendon matrix [86, 87]. The pathogenesis is still unclear (may be related to reduced oxygen tension, which can promote spontaneous metaplasia and cellular necrosis, in turn associated with calcium deposition [88]). Calcifications may occur in all tendons [89, 90] although the rotator cuff tendons are most frequently affected [91].

Clinical applications

US is widely used to detect inflammation, traumatic lesions, and degenerative alterations in tendons. The US study of tendon ruptures allows confirmation of partial or complete ruptures at many anatomical sites [92–97]. The degree of tendon inflammation in rheumatic disease, namely tenosynovitis, paratenonitis, or tendinitis, as well as the extent of tendon damage can be evaluated [98, 99]. Several US scores have been introduced and validated with good intra- and interobserver reliability [100–102].

The most common parameters used to characterize tendon pathology include tendon thickness, echogenicity, vascularity [103], and stiffness [104]. Abnormal tenocyte morphology and changes in proteoglycan content with a resultant increase in bound water are the primary changes in tendinosis. These changes have been described on US as increases in tendon dimensions and heterogeneous or diffuse changes in echogenicity [105, 106]. Furthermore, the shadowing generated by fibrillar disorganization and the lack of parallel-aligned fibers contribute to areas of hypoechogenicity within the tendon matrix [78].

US is the most accurate imaging modality to detect calcific deposits (sensitivity of 94 %, specificity of 99 %) [107]. Calcific tendinopathy usually shows hyperechoic foci within the tendon, with or without acoustic shadowing. However, the appearance changes depending on calcium content, which varies according to the stage of this condition. Occasionally, calcifications may also appear as hypo/anechoic fluid collections with no acoustic shadowing [108, 109].

Practical points, limitations, and artifacts in tendon examination are detailed in ▶ **Supplementary Table 3, 4**.

Recommendations

1. In patients with suspected tendon pathology, US is recommended as the first imaging modality after clinical examination (LoE 1, SoR strong). Strong consensus (33/0/3, 100 %)
2. Color/power Doppler US should be used to evaluate active inflammation in tendons and tendon sheaths (LoE 1, SoR strong). Broad consensus (30/3/3, 91 %)

Enthesis

Background

Enthesis is the insertion of a tendon, ligament, or capsule into the bone. Entheses may be affected in inflammatory conditions grouped under the term spondyloarthritis (SpA), where enthesitis is considered a key feature. The enthesis may also be the subject of overuse as seen in sport injuries and in crystal diseases. However, while the enthesis is the origin of the disease in SpA (with potential subsequent involvement of the tendon), the overuse condition is perceived to be a tendon disease with potential subsequent involvement of the enthesis.

The term “enthesitis” (i. e., inflammation of the enthesis) should only be used in relation to SpA and the term “enthesopathy” for any pathological condition of the enthesis regardless of cause. US provides a more sensitive assessment of entheses than clinical evaluation, comparable with MRI (except for locations not accessible to ultrasound, such as pelvis entheses, cruciate ligaments entheses, spinal, etc.) [110–119].

Clinical points

Definition

On grayscale US, pathological entheses are characterized by the loss of normal fibrillar echogenicity of the tendon insertion with or without an increase in tendon thickness, or intralesional focal changes at the tendon insertion, such as calcium deposits, fibrotic scars and bone or periosteal changes (erosions or new bone formation – enthesophytes). When using Doppler US, active inflammation is detected as abnormal vascularity in the area adjacent to the cortical insertion (< 2 mm). Additionally, involvement of the body of the tendon far from the enthesis, of adjacent bursae, and fat tissue may be observed. However, these processes can also be observed in the absence of enthesitis in other inflammatory and non-inflammatory diseases [28, 120].

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Diagnosis

US may be used for the early diagnosis of enthesitis and especially the presence of Doppler activity has been shown to be a sensitive marker [121–136]. Several enthesitis scoring systems exist for distinguishing between SpA and other joint diseases but the only consensus-based scoring system is the OMERACT (Outcome Measures in Rheumatology) enthesitis scoring system [28, 120].

Monitoring

At the moment only the consensus-based OMERACT scoring system appears suitable for monitoring purposes [28, 120]. Large international, multi-center studies assessing validity and sensitivity to change are still lacking, thus hindering the routine use of such instruments in both clinical practice and clinical trials. Only a few studies have evaluated sensitivity to change over time or responsiveness of US in SpA patients under anti-TNFα treatment, where Doppler activity has been shown to be the most sensitive to change [122, 124, 125, 130, 137–153].

Differential diagnosis

Whether and to what extent US can distinguish between enthesitis of different origins including local non-inflammatory conditions needs to be established [144–153].

Practical points, limitations, and artifacts in entheses examination are detailed in ▶ **Supplementary Table 3, 4**.

Statements

1. Ultrasound might be more sensitive than clinical examination and MRI for detecting peripheral enthesitis accessible to US (LoE 4). Broad consensus (27/6/3, 82 %)
2. Ultrasound findings should be interpreted in the context of clinical and laboratory data for etiological diagnosis of peripheral enthesitis (LoE 4). Strong consensus second round (31/1/4, 97 %)

Recommendation

1. US should be used as the first-line imaging modality for peripheral enthesitis diagnosis (LoE 2, SoR strong). Strong consensus (33/0/3, 100 %)
2. Increased vascularity of enthesis on Doppler US should be considered as the most diagnostic feature of enthesitis. (LoE 2, SoR strong). Broad consensus (28/2/6, 93 %)
3. Ultrasound may be used to monitor peripheral enthesitis (LoE 2, SoR strong). Broad consensus (30/2/4, 94 %)

Bursae

Background

Bursae, sac-like structures containing a small amount of synovial fluid, some communicating with the adjacent articular cavity, reduce the friction between soft tissues and bones [154–156]. Bursitis, inflammation of the bursa, appears in various pathological conditions: mechanical, degenerative, septic, inflammatory rheumatic diseases, tumors, etc. [157, 158]. The main US findings consist of an increased amount of synovial fluid (of variable echogenicity) with or without synovial hypertrophy, internal septation, mural nodules or loose bodies, but generally no specific appearance can be linked to any particular etiology [154]. Distinguishing from normal bursae is important, as in many situations a small amount of intrabursal fluid can be detected by US in healthy subjects [156, 159].

Clinical application

In patients with shoulder pain, the presence of subacromial-subdeltoid (SASD) bursitis was associated with acromioclavicular joint arthritis (70.4 %), supraspinatus calcific tendinopathy (67.8 %), rotator cuff full-thickness (96.7 %) or partial (72.7 %) tear, trauma (95.6 %), rheumatoid arthritis (RA) (94.7 %), or infection (100 %), often independently from the underlying pathology [160]. US can accurately detect subacromial bursitis in patients with painful arc syndrome (100 % specificity, 87 % accuracy) [161].

The detection of SASD bursitis by US improves the specificity of clinical and serological criteria for the diagnosis of polymyalgia rheumatica (PMR) from 68 % to 89 % [162]. Bilateral SASD had a specificity of 89 % (95 %CI 66 % to 97 %) and a sensitivity of 66 % (43 % to 87 %) for the diagnosis of PMR [163] and US was confirmed to be a useful tool to improve the classification and management of patients with PMR [164]. Bursitis is more severe and of proliferative type in the shoulders of patients with elderly onset RA compared with the exudative type in PMR [165, 166]. The severity of tenosynovitis of the long head of the biceps and that of SASD bursitis are independent predictors of an inadequate response to glucocorticoid treatment in patients with PMR [167].

Subcoracoid bursae are rarely distended, generally in the presence of subcoracoid impingement [168, 169]. Bicipitoradial bursitis results more commonly from chronic mechanical friction and less commonly from inflammation, tumors, or infections [170]. Only case reports have been published about the bicipitoradial bursa [171, 172].

The most common etiology of olecranon bursitis is trauma and infection [173, 174]. Despite its superficiality, few reports about the US appearance of the olecranon bursae have been published [175, 176]. The olecranon bursa is very commonly involved in tophaceous gout [177, 178] and rarely in calcium pyrophosphate dihydrate crystal deposition disease [179].

Iliopsoas bursitis was identified by US in 2.2 % of patients with hip osteoarthritis (OA) [180] and in 5–6 % of patients with post-arthroplasty complications [181]. As compared to surgery, US had excellent results in evaluating the iliopsoas bursa wall thickness and internal texture but underestimated its size and the presence of communication with the joint [182]. US identified bursitis in 20.2 % of patients with great trochanteric pain syndrome [183]. Agreement with MRI was good to excellent [184, 185]. When compared to surgical findings, US had a sensitivity of 0.61, specificity of 1.0, positive predictive value of 1.0, and negative predictive value of 1.0 for diagnosing trochanteric bursa pathology [186]. However, US was unable to distinguish between bursitis in inflammatory diseases and bursitis with a mechanical origin [185].

US was able to identify bursitis in 9.5 % of patients with knee pain and, compared to MRI, had a sensitivity of 88.67 % and a specificity of 100 % with a kappa index of 0.92 [187]. In medial knee

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pain, US could detect pes anserine bursitis in 20 % of patients, with the incidence increasing with patient age and grade of knee OA [188]. US was as specific, but less sensitive than knee arthrography and as accurate as MRI in detecting Baker cysts [189].

In the heel area, a significant increase in both retrocalcaneal bursa detection and its thickness were shown in SpA patients [190]. A positive likelihood ratio of 4.6 % was found when a cut-off of >2 mm for retrocalcaneal bursa thickness was used. Of note, the retrocalcaneal bursa could be seen by US in 27.6 % of healthy people [191] and in nearly 50 % of military recruits [156]. In addition, retrocalcaneal bursitis was frequently observed in RA (in 24 % of established and 38 % of early RA patients) [165].

In the foot, US was able to identify forefoot bursae distention (intermetatarsal and plantar) with a high prevalence in both OA (94 %) and RA (88 %) compared to healthy subjects (56 %) [191]. These bursae are often missed by clinical examination (US vs. clinical examination: 92.6 % vs. 23.5 % in RA) and their presence is associated with self-reported activity restrictions and foot impairment [192]. In patients with metatarsalgia, US detected intermetatarsal bursae distention as the most common underlying pathology (in 20.5 % of cases, including in 21.5 % of clinically suspected Morton neuromas) [193].

Practical points, limitations, and artifacts in bursae examination are detailed in ▶ **Supplementary Table 3, 4**.

Statement

1. US findings in bursitis are nonspecific and must be completed with clinical and laboratory data and fluid analysis (**LoE 3b).** Strong consensus (30/1/5, 96 %)

Recommendation

1. US should be used as the first-line imaging method for diagnosing bursitis (**LoE 2b, SoR strong).** Strong consensus (31/1/4, 97 %).

Ligaments and retinacula

Background

US and MRI are complementary tools for assessing intrinsic and extrinsic ligaments and for diagnosing ligament tears, pulleys, and retinacular lesions [194, 195] including lax, torn, thickened, or absorbed ligaments and non-union avulsion fractures [196, 197]. US has the potential to provide a novel approach to the rating and treating of ligament injuries [198].

Ligaments, pulleys, and retinacula are composed mostly of collagen and appear as less echogenic, fibrillar structures on US. Ligaments are best visualized under strain, highlighting the importance of dynamic examination. Point-of-care ankle US was shown to be as precise as MRI for detecting ligament and tendon injuries and may be used for immediate diagnosis and further preoperative imaging [199].

Clinical applications

Lateral collateral ankle ligament complex

Acute ankle sprains are the most common reason for visiting the doctor after sports-related incidents.

Compared with operative findings, the sensitivity, specificity, and accuracy of US were 98.9 %, 96.2 %, and 84.2 %, respectively, for anterior talofibular ligament (ATFL) injury and 93.8 %, 90.9 %, and 83.3 %, respectively, for calcaneofibular ligament (CFL) injury, comparable to MRI results [200, 201]. A systematic review with meta-analysis showed that the pooled sensitivities were 0.99 (0.96, 1.00) with specificities of 0.91 (0.82, 0.97) for diagnosing chronic ATFL injury and 0.94 (0.85, 0.98) with specificities of 0.91 (0.80, 0.97) for chronic CFL injury [202].

Medial collateral ankle ligament (deltoid) complex

In the case of disruption, comparison between US and stress radiography revealed high sensitivity and specificity, proving that US is an accurate method for identifying the involved ligament components dynamically [203]. Although US may provide important information about the spring ligament complex and the ankle syndesmosis, available evidence for their US assessment is scarce [204]. Thickness measurement in a weightbearing position has been recommended to assess the dorsal Lisfranc ligament [205, 206].

Knee

Anterolateral knee ligament injuries that occur with anterior cruciate ligament tears are often associated with bone avulsion at the enthesis and are better viewed with US [207–209].

Structural changes of the lateral and medial patellofemoral joint retinaculum were found to be associated with patellofemoral pain. High-frequency US and MRI showed similarly high accuracy in diagnosing medial patellofemoral joint retinaculum lesions, with very good interobserver agreement for high-frequency US [210, 211].

Two meta-analyses demonstrated high diagnostic performance in anterior and posterior cruciate ligament injuries. However, future prospective studies comparing US and MRI are warranted [212, 213].

Acromio-clavicular joint (ACJ)

The acromio-clavicular ligament, which is always damaged when the ACJ is injured, can be reliably examined by US. Both distortion and rupture can be recognized morphologically, while instabilities due to a height difference between the clavicle and acromion edge or due to hypermobility, should be assessed in a dynamic examination. Two studies demonstrated the diagnostic value of US in comparison to X-ray imaging [214, 215]. Direct visualization of the coraco-clavicular ligament is almost as reliable with US as with the “gold standard” MRI [216].

Shoulder

The coraco-humeral and coraco-acromial ligaments, which stabilize the interval between the subscapularis and supraspinatus ten-

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dons, are relevant for the diagnosis of subacromial impingement. In adhesive capsulitis, the ligaments are noticeably different morphologically [217] or using elastography [218] and may show Doppler signal. The glenohumeral ligaments are difficult to visualize.

Elbow

The radial ligament complex can be examined morphologically as well as by testing the stability. The same applies to the ulnar ligament complex [219–221].

Visualization of the Struthers ligament may be helpful in the median nerve entrapment syndrome [222]. Similarly, assessment of the Osborne's ligament and the arcuate ligament in the entrapment syndrome of the ulnar nerve may provide relevant information.

Hand and wrist

The scapho-lunar ligament can be examined with US both for morphology and stability under dynamic conditions [223], albeit with low sensitivity but high specificity [224]. The trapezio-metacarpal ligament can be well visualized and examined for its stability [225]. In cases of instability of the ulnar collateral ligament of the thumb, its morphology can be examined and assessed in conjunction with a dynamic examination, especially if the ligament is dislocated over the aponeurosis of the adductor pollicis muscle [226].

The thickness of the flexor retinaculum of the carpal tunnel (transverse carpal ligament) and its position in relation to the median nerve can be readily assessed on US [227]. The triangular fibrocartilage complex is difficult to detect sonographically. Nevertheless, high-resolution US allows for radial and ulnar collateral wrist ligament assessment [228] and US findings have been shown to correlate with ulnar-sided pain and instability [229].

US can be used to evaluate finger pulleys in trigger fingers and annular pulley ruptures. Accurate static and dynamic US evaluation are of comparable value to MRI in distinguishing partial, complete, and combined pulley ruptures from overuse injuries [230–232]. Flexor tendon thickness and annular pulley measurements have been proven to be feasible and valid in cadaver studies as well as in patients and healthy volunteers with good inter- and intraobserver reliabilities [233, 234]. Collateral ligament tears, palmar plate injuries, and thumb sesamoid fractures may be critical in the diagnostic workup of closed finger joint trauma and US may help improve outcomes [235].

Practical points, limitations, and artifacts in ligament examination are detailed in Supplementary ▶ **Supplementary Table 3, 4**.

Statement

1. For the knee, US can be considered as an accurate and reproducible imaging technique for diagnosing medial/lateral ligament and retinaculum injuries (**LoE 2**). Broad consensus (23/7/6, 77 %)

Recommendations

1. US is useful to diagnose acute lateral ankle ligament injury (**LoE 1, SoR strong).** Strong consensus (31/1/4, 96 %)
2. US is useful to predict the prognosis of acute ankle sprain (**LoE 1, SoR strong).** Broad consensus (27/4/5, 87 %)
3. In addition to the manual anterior drawer test and stress radiography, dynamic stress US might be useful for diagnosing chronic ankle instability (**LoE 3, SoR weak).** Broad consensus (27/3/6, 90 %)
4. US might be used to evaluate the injuries of acromio-clavicular joint and ligament, as well as of the coraco-humeral and coraco-acromial ligaments (**LoE 3, SoR weak).** Broad consensus (28/5/3, 85 %)
5. In the elbow, US may be used to evaluate the medial/lateral collateral and annular ligaments, particularly during dynamic examination (**LoE 3, SoR weak).** Broad consensus (28/2/6, 93 %)
6. In the hand and wrist, US may be used for the assessment of injuries in ligaments (scapholunate and thumb ulnar collateral) or the annular pulley, as well as trigger finger pathology (**LoE 3, SoR weak).** Broad consensus (29/3/4, 91 %)

Bones

Background and clinical application

Enthesophytes

Enthesophytes have been defined in the OMERACT ultrasound group [28] and are included as one of the core elementary lesions of US-detected enthesitis [27]. High reliability has been found for enthesophytes compared to other elementary lesions in enthesitis [119]. Enthesitis is typical for psoriatic arthritis (PsA), and enthesophytes at typical sites were included among potential elemental US abnormalities able to distinguish PsA from controls [236]. However, a recent study on healthy volunteers found enthesophytes to be the most common lesion at tendon insertions, detected in 87.5 % of participants and 23.1 % of the entheses [237].

Bone erosions

In accessible areas, US was found to be highly accurate for the detection and semiquantitative assessment of bone erosions in patients with RA [238]. However, a recent review on the ability of US to detect erosions in patients with RA found a pooled sensitivity and specificity of US for the detection of early bone erosion of 58.4 % and 93.9 %, respectively [239].

Erosions, however, are not specific for RA. A study including patients with several inflammatory joint diseases found the presence of US-detected erosions not to be specific for RA, while larger erosions in selected joints, especially the 2nd and 3 rd MCP, 5th metatarso-phalangeal (MTP) joint, and distal ulna, were highly specific for and predictive of RA [240]. This was supported by a recent study exploring differences in radiographic and US detection of erosions between ACPA-positive and -negative patients. On both imaging methods, the most discriminating joint between the two groups was MTP5, especially in patients with bilateral erosion [241].

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Periostitis

Periostitis is a nonspecific finding corresponding to a thickening and elevation of the periosteum from the underlying cortex. It can be seen in malignant tumors, infections and inflammation, eosinophilic granuloma, aneurismal bone cyst, osteoid osteoma, hemophilia, or trauma [242, 243]. Radiographs are the first imaging modality to study periostitis although MRI or CT is the imaging reference standard.

Fractures

Bone fractures are a very common occurrence. Plain radiography is the imaging method of choice. In acute fractures, US can be used as a complementary method when radiographic imaging is negative but clinical suspicion is high. In these cases, US shows interruption of the cortical line, frequently together with periosteal thickening and hematoma [244, 245]. In stress fractures, plain radiography is often normal in the early stages. US may be highly effective in detecting the periosteal reaction and callus formation. MRI may also be used in cases where US is still negative [246]. After an acute fracture, US is superior to plain radiography for showing early organization of the bone callus. US and CEUS can be used to evaluate callus status in patients with bone nonunion before and after treatment, also predicting clinical outcome [247, 248].

Practical points, limitations, and artifacts in bones examination are detailed in ▶ **Supplementary Table 3, 4**.

Recommendations

1. US should be used to detect peripheral enthesophytes and erosions (**LoE 1, SoR strong).** Broad consensus **(30/4/2,** 88 %)
2. In accessible bone areas, when radiography is negative but clinical suspicion of acute fracture is high, US should be used (**LoE 1, SoR strong).** Strong consensus **(32/2/2,** 95 %)
3. In regions with an acoustic window, US should be used for monitoring fracture healing (**LoE 2, SoR strong).** Broad consensus **(22/7/7, 76 %)**
4. In regions with an acoustic window, US might be used to detect periostitis (**LoE 4, SoR weak).** Broad consensus **(25/8/3,** 76 %).

Nerves

Expanding evidence has supported the use of US as a valuable imaging modality to investigate the peripheral nervous system [249–252]. In the short axis, normal peripheral nerves demonstrate a characteristic stippled (honeycomb-like) appearance (axons arranged in fascicles and multiple layers of connective tissue supporting and binding the fascicle bundles together) [253]. In long-axis planes, nerves appear as elongated structures with alternating hypo- and hyperechoic bands. The development of ultrahigh frequency probes (up to 30 MHz) has provided new perspectives in the evaluation of sub-millimetric terminal nerve branches, visualized as single small hypoechoic dots within a hyperechoic frame lacking the expected classic "honeycomb" appearance [254–261].

Clinical application

Compression neuropathies

When investigating compression neuropathies, three main classes of nerves should be considered:

- Class 1 includes large nerves (e. g., median, ulnar, peroneal, tibial, etc.), which are readily evaluated by probe frequencies of up to 13 MHz. Diagnosis is based on pattern recognition analysis and on calculation of the nerve cross-sectional area (CSA) [262–267].
- Class 2 consists of small nerves (e. g., posterior and anterior interosseous, sural, suprascapular, etc.), which require probe frequencies of up to 24 MHz. In this case, pattern recognition together with side-to-side comparison of the major nerve diameter plays a significant role in diagnosing compressive neuropathies [268, 269].
- Class 3 includes both large nerves (e. g., the femoral and sciatic nerves in their intrapelvic course) and small nerves (e. g., the deep peroneal nerves) which are poorly visualized or undetectable with US due to their anatomical location. In this case, US diagnosis relies only on indirect signs of nerve damage, including signs of denervation of the skeletal muscles supplied by the affected nerve [270, 271].

US signs of compressive neuropathy consist of nerve flattening at the compression point and nerve swelling proximal or (less commonly) distal to it [272, 273]. The transition between swollen and flattened segments is abrupt ("notch sign"). In the early phases of compression, nerve enlargement is detected due to intraneural edema and venous congestion. With time, the nerve echotexture may appear massively subverted due to loss of the fascicular pattern and diffuse nerve hypoechogenicity. If nerve compression persists, irreversible intraneural fibrosis may occur and nerves with fibrotic changes remain swollen after decompressive surgery [256, 274, 275].

Nerve injuries

In *penetrating injuries* with complete nerve transection, stump neuromas develop in continuity with the edges of the nerve (round hypoechoic masses which may be displaced or retracted from the site of injury) [276, 277]. In partial nerve tears, a spindle neuroma may develop along the injured nerve tract and US can estimate the percentage of involved and preserved fascicles [278–280]. *Stretching injuries* most commonly affect nerves with a tortuous course and typically occur in relation to fixation points, such as where the nerve pierces fascial planes or crosses tight osteofibrous tunnels [281]. *Contusion injuries* most often occur where nerves run close to bony surfaces and are vulnerable to external pressure. The nerve may show various degrees of swelling with or without preservation of the fascicular echotexture, depending on the severity of trauma [282, 283].

Polyneuropathies

US findings in patients with dysimmune neuropathies are similar among the various forms and mainly consist of segmental nerve/fascicle swelling, which typically involves the nerve sections where

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conduction blocks are identified by electrophysiology [284–288]. US may demonstrate focal changes in nerve/fascicle thickness in early phases, when electrophysiology is still negative, and reduced fascicular swelling during treatment, before neurophysiological improvement occurs [289–291].

In leprosy, US findings consist of markedly swollen nerves with loss of the fascicular echotexture, thickened epineurium, and intense intraneural hyperemia on Doppler imaging ("nerve inferno") in acute neuritic phases [292]. In Charcot-Marie-Tooth (CMT), marked generalized fascicular enlargement, akin to an "onion bulb", and Schwann cell hypertrophy due to attempted remyelination are typical findings of CMT-1A [293–296]. In hereditary neuropathy with liability to pressure palsies patients, US demonstrates multifocal nerve enlargements (tomaculae) following minor trauma, which most commonly occur in areas where the nerves are prone to compression [297, 298].

Nerve tumors and tumor-like conditions

The US diagnosis of peripheral nerve sheath tumors relies on the detection of a soft-tissue mass in continuity with a nerve. Alternatively, the "fat-split sign", which consists of a rim of fat at the poles of an intramuscular mass, may suggest a lesion originating in the intermuscular space about the neurovascular bundle instead of the muscle itself [299, 300]. Although schwannoma and neurofibroma are often indistinguishable on US, schwannomas appear as eccentric ovoid masses arising from a single fascicle and displacing the unaffected fascicles to the periphery, whereas neurofibromas encase the fascicles of the parent nerve developing in a fusiform shape. Moreover, neurofibromas may show a "target sign" with a hyperechoic (fibrous) core and a hypoechoic (myxomatous tissue) rim. Compared to schwannomas, they are usually avascular or less vascular on Doppler imaging [301–303]. Malignant peripheral nerve sheath tumors tend to be larger (> 5 cm) and more heterogeneous and often show indistinct margins, calcifications, areas of internal bleeding and necrosis [304–307]. However, a definite diagnosis usually requires histological sampling.

Practical points, limitations, and artifacts in the examination of nerves are detailed in ▶ **Supplementary Table 3, 4**.

Recommendations

1. The cross-sectional area (CSA) of 10 mm^2 of the median nerve at the carpal tunnel inlet, together with wrist-to-forearm ratio of the median nerve CSA, should be used in the diagnosis of median nerve compression (LoE 2A, SoR strong). Broad consensus (24/6/6, 80 %)
2. In the diagnosis of carpal tunnel syndrome, cross-sectional area measurements of the median nerve should be considered complementary to electrodiagnostic tests (LoE 2A, SoR strong). Broad consensus (30/2/4, 94 %)
3. An ulnar nerve cross-sectional area within the epitrochlear groove of 10 mm^2 should be assumed as the cut-off value for diagnosing ulnar nerve entrapment at the elbow region (LoE 2A, SoR strong). Strong consensus second round (30/1/5, 97 %)
4. US should be used to identify, localize, and follow up full and partial thickness nerve injuries (LoE 1C, SoR strong). Broad consensus (29/2/5, 94 %)
5. US might be used to detect nerve alterations in acquired and inherited polyneuropathies (LoE 3B, SoR weak). Broad consensus (24/6/6, 80 %)
6. US might be used to recognize peripheral nerve sheath tumors, but histopathological examination is mandatory for differential diagnosis (LoE 3B, SoR weak). Strong consensus (32/1/3, 96 %)

Skin and subcutaneous tissues

Background

US of the skin is nowadays considered part of a wider US application known as dermatologic US [308]. Musculoskeletal diseases and alterations may affect the skin to some extent or may be an incidental finding during exploration.

Skin US is an imaging method complementary to clinical examination and histopathology. Correct interpretation of skin US images requires corroboration of all available patient information and thorough knowledge of skin diseases and their management [309].

Clinical applications

Normal skin

Aging and ultraviolet- or sex-related changes have been effectively studied using high-frequency B-mode (thickness or echodensity) US and elastography [310–314]. Of note, using even higher frequencies (> 50 MHz), US imaging correlates well with histological findings as far as hair follicles/tracts, glands, and erector pili muscles are concerned [315].

Scar

While scar type/depth or echogenicity differences can be safely ascertained on US [316], unlike normal skin, scar tissues have not been shown to correlate with histology in terms of skin thickness [317, 318].

Hidradenitis suppurativa

For more prompt diagnosis, staging, treatment planning, and monitoring, B-mode or Doppler US has recently been used to scan patients with hidradenitis suppurativa (HS) [318–326] including children [327, 328].

Infection

Point-of-care US has high sensitivity and specificity (range 89 %-96 % and 64 %-88 %, respectively) for diagnosing skin abscesses [329], distinguishing them from cellulitis [330], and following up treatment [331]. Furthermore, these values remained high for novice sonographers as well as experts [332–334].

Systemic sclerosis

Compared to clinical evaluation, US examination proved more sensitive and reliable for quantifying systemic sclerosis (SSc) skin involvement in both patients and controls [335–339]. A better

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discrimination between clinical and subclinical skin involvement [335–340], different forms of SSc, and disease stages [335–337] was achieved. An inverse relationship between skin echogenicity and thickness was identified in patients with SSc in the edematous phase of the disease [335, 336]. US findings were found to correlate with clinical activity scores (Rodnan Skin Score), degree of pulmonary involvement, specific histologic and pathogenetic features [336, 341, 342] and are sensitive for detecting longitudinal skin thickness changes and vascularity [341].

Elastography can quantify skin stiffness by adding information about the disease stage and helping to distinguish subclinical SSc involvement from healthy skin [340, 343, 344]. Shear wave velocity values were significantly higher in SSc patients than in controls at almost all modified Rodnan Skin Score sites and thus correlated with the degree of pulmonary involvement [339, 343].

Morphea

US provided qualitative and quantitative anatomical data, such as thickness measurements, detection of structural abnormalities, and Doppler analysis of the lesional and perilesional vessels in both clinical and subclinical stages of the disease [345–349].

Psoriatic plaque

In a psoriatic plaque, the epidermis and dermis appear thicker compared with the normal surrounding skin. A hypoechoic band in the upper dermis can be observed, representing inflammatory edema and vasodilatation within the papillary dermis. This sign was shown to be linked to the most active stages of the disease [350–354].

Lymphatic vessels

Currently, several studies have assessed the applicability of US and elastography as early methods for the diagnosis, staging, and assessment of clinical and subclinical lymphedema [355, 356]. High-resolution US was proven to distinguish lower limb lymphedema from other edematous conditions [357, 358]

Melanoma

In melanoma staging, US contributes to the primary staging and detection of metastases. The Breslow index (measurement from the granular epidermal layer to the deepest melanoma extension in millimeters) is the main predictor of lymphatic extension and prognosis worsening [359]. Most studies showed a high correlation between the Breslow Index and US measurements. In a retrospective cohort study [360–362], correlation with manual measurements reached r = 0.88, permitting a single stage excision in most cases.

Regarding US follow-up of melanoma patients, US was not superior to clinical follow-up in terms of survival in a prospective cohort study comparing these two follow-up modalities in stage IB IIA patients [363–365].

Nonmelanoma skin cancer (NMSC)

Most common NMSCs are basal cell and squamous cell carcinomas. The heterogeneity of studies and techniques does not permit a clear recommendation on the systematic use of US in NMSC management [364]. However, some retrospective cohort studies [366, 367] and multiple case series indicate the possibility of using US to detect occult basal cell carcinoma foci, to discriminate between high- and low-risk forms.

Other neoplastic and inflammatory skin lesions

US features of other skin lesions such as mycosis fungoides, other skin lymphomas [368, 369], Kaposi sarcoma [370], and dermatofibrosarcoma protuberans [371] have also been described.

Other benign skin tumors, such as pilomatrixomas [372], cysts [373], lipomas [374], and neurofibromas [375], have also been characterized and they present distinct sonographic patterns that are potentially useful for noninvasive diagnosis. However, these observations were derived from cross-sectional studies and small case series.

In other inflammatory skin diseases, such as panniculitis [376], pseudoxanthoma elasticum [377], atopic dermatitis [368], and sarcoidosis [378], US provides additional information that is useful for early diagnosis or follow-up.

Practical points, limitations, and artifacts in skin and subcutaneous tissue examination are detailed in ▶ **Supplementary Table 3, 4**.

Recommendations

1. US is recommended for prompt diagnosis, staging, treatment planning, and monitoring in patients with hidradenitis suppurativa (**LoE 2, SoR strong).** Strong consensus **(32/1/3/** 97 %)
2. US is recommended as the first-line modality in the detection of skin abscesses (**LoE 2, SoR strong).** Strong consensus (33/1/2, 97 %)
3. US is recommended for the qualitative and quantitative evaluation of skin layers, the differentiation between disease forms, and the staging and monitoring of skin abnormalities in systemic scleroderma patients **(LoE1, GoR strong).** Broad consensus (28/3/5, 90 %)

Fascia

Background

The fascia is a collagenous tissue continuum that surrounds and separates muscles, forms sheaths for nerves and vessels, and strengthens ligaments around joints [379]. The deep fascia has a complex structure formed by two or three layers of densely packed collagen fibers, interpolated by a layer of loose connective tissue [380].

Both morphological and dynamic properties (sliding, displacement) are important for the functional integrity of the fascia system [381]. Fascial layers have some sites of potential weakness which could give rise to hernias (sports hernia or incisional hernia) Herniation of skeletal muscles through fascial defects has also been described. The tibialis anterior, extensor digitorum longus, peroneus longus and brevis, the gastrocnemius are the most commonly affected muscles [382].

Deep fascia can be affected, though rarely, by a severe infection (necrotizing fasciitis) or inflammation (eosinophilic fasciitis).

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The former is a fulminant infection, which can follow minor injuries, while the latter is a chronic progressive condition which usually affects the limbs symmetrically.

Neoplastic lesions involving the fascia are generally uncommon, with benign lesions being far more frequent.

Clinical application

High-resolution US of fasciae can assess morphometric characteristics such as thickness and echogenicity [383] and allows visualization of fascia sliding or displacing [381].

The fascia generally appears as a linear hyperechoic structure with boundaries easily identifiable due to the adjacent hypoechoic muscles. It consists of a single or several discrete layers [380].

The plantar fascia is by far the most studied fascia with a well standardized scanning protocol (longitudinal scan at its most proximal part) [383] and an accepted cut-off point of 4 mm for its normal thickness [384]. There are no agreed-upon reference values for the normal thickness of other fasciae, though aponeurotic fasciae seem to be generally thicker than epimysial ones [381].

In detecting sport hernias, with laparoscopy as the gold standard, US has a high sensitivity (95 %) and specificity (100 %), as well as a positive and a negative predictive value close to 100 % [385]. In identifying incisional hernias, US was found to have an added value of 29.4 % over clinical examination alone [386]. Dynamic US or MRI can be used to confirm muscle hernias. An additional advantage of US is that the patient can be examined in a standing position [387].

Necrotizing fasciitis shows on US as marked subcutaneous edema and thickening, with interconnected fluid collections resulting in a cobblestone appearance and small bright foci with dirty acoustic shadowing representing microbubbles of gas [388]. Regarding the amount of deep fascia fluid accumulation, a study showed that a cut-off value of 2 mm had the best accuracy (72.7 %) with a sensitivity of 75 % and a specificity of 70.2 %. Patients with this level of fluid accumulation were hospitalized longer and needed amputation more often [389].

Eosinophilic fasciitis appears on US as a thickened fascia of altered echogenicity with thickening, hyperechogenicity, and markedly reduced compressibility of the subcutaneous tissue [390]. Thickness reduction was observed with treatment [391].

Plantar fibromatosis frequently exhibits mixed echogenicity in large lesions [392, 393] and hypoechogenicity in small lesions [392], with acoustic enhancement, a comb sign (linear hypoechoic areas located near isoechoic areas), and, possibly, internal vascularity. Increased stiffness of the nodular thickening on elastography was described in Dupuytren disease [394]. Hypoechogenicity of the nodules does not predict the progression of this condition [395].

Nodular fasciitis may have various appearances: a hypoechoic mass with internal echogenic foci [396, 397], a peripheral hyperechoic nodule or an echoic rim [397, 398], oval or round in shape with irregular or lobular margins, fascial tail [397], and usually avascular [398]. In children, this condition is found most frequently in the head or neck [399]. Proliferative fasciitis is a rare lesion described as an ill-defined hyperechoic structure with a thickened hypoechoic reticular pattern [400].

The relative reliability of thickness and echogenicity measurement of the plantar fascia was proven to be high (interclass correlation coefficient, ICC = 0.88) [401]. Good reproducibility was also found (intra- and interrater reliability, ICC > 0.821, ICC> 0.849) [402], as well as good agreement between an experienced and a novel sonographer [403]. In another study the intra-tester reliability was shown to significantly surpass the inter-tester reliability in plantar fasciitis (0.89 vs. 0.61, respectively) [404]. Multiple measurements showed higher reliability compared to a single measurement (ICC > 0.90) [404].

The inter-rater reliability proved to be good also for the abdominal fasciae (ICC = 0.83) [405]. The intraobserver reliability of the echogenicity of Dupuytren's nodules was excellent (ICC = 0.996; 95 %CI, 0.993 to 0.998), while the interobserver reliability was fairly good but imprecise (ICC = 0.688; 95 %CI, 0.329 to 0.977) [388].

Practical points, limitations, and artifacts in fascia examination are detailed in ▶ **Supplementary Table 3, 4**.

Recommendations

1. Ultrasound may be used to assess muscular fascia's morphometric characteristics like thickness and echogenicity, as well as fascia sliding and displacement (LoE 3, SoR weak). Broad consensus (29/5/2, 85 %)
2. US should be used as point-of-care diagnostic imaging method in fascia infection (necrotizing fasciitis), proliferative diseases, and fascia defects (LoE 3, SoR strong). Broad consensus (29/4/3, 82 %)

Nails

Background

The nail plates, nail matrix, and nail bed form the nail unit. The periungual area is composed of the periungual folds, i. e., the proximal fold (eponychium), lateral folds (perionychium), and distal fold (hyponychium). The bilaminar nail plate is visualized as two parallel hyperechoic bands, i. e., ventral plate and dorsal plate, separated by a hypoechoic virtual space, i. e., the interplate space. The nail plate thickness varies between 0.3 and 0.65 mm. The nail matrix appears as a 1–5.3 mm long echogenic structure, located in the proximal aspect of the nail bed. The nail bed is seen as a 0.7–6 mm thick hypoechoic structure immediately deep to the nail plate and extending to the bone profile of the distal phalanx. Doppler mode shows a high level of low-resistance, low-velocity blood flow in the nail, especially in the nail bed [406–409].

Performance of nail US has been standardized through a consensus-based methodology by an international expert working group [410].

Clinical application

Psoriatic onychopathy (PsO)

US assessment of nails in psoriasis has recently emerged based on the fact that the nail is conceptually an extension of the distal

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interphalangeal enthesis. It is aimed at detecting early signs of psoriatic involvement [411]. A systematic review [412] showed that the evidence for the role of US in the detection of PsO is low, mainly due to methodology limitations, based on case-control cross-sectional studies with high variability in the US features measured. Despite these considerations, there is a marked tendency to show differences between patients with PsO and healthy controls mainly in nail bed and nail plate thickness, even before clinical PsO signs are evident [413]. However, no study was able to predict more severe disease or the development of PsA based solely on this parameter [414].

In both clinical and subclinical PsO patients there is a tendency towards increased Doppler signals [415]. The spatial relationship of these CD/PD signals with anatomical structures of the nails, such as the ventral plate [416] may warrant assessment in future studies.

The EFSUMB'S Position Statement on Dermatologic Ultrasound suggested US assessment of nails in patients with suspicion of clinical psoriasis to support the diagnosis of this condition [308].

Nail tumors

Scientific evidence to date on US and subungual tumors is very scarce, mostly as isolated clinical cases describing the ultrasonographic features of tumors, such as subungual schwannoma [417], keratoacanthoma [418], and squamous cell carcinoma [419].

In the review of onychomatricoma imaging tests by Cinnoti et al. [420], dermoscopy is highlighted as a first diagnostic step. In six cases US techniques were performed. In four cases hypoechogenic solid areas affecting the ungual matrix with hyperechogenic dots corresponding to the finger-like projections that deform the plate were found. Doppler US showed a non-specific hypovascular pattern.

Nakamura et al. [421] measured the tumor-to-bone distance of invasive subungual melanoma. In tumor sizes below 4 mm, the probability of bone involvement was low and non-amputative surgery was possible. This study was performed on surgical specimens and the authors raised the possibility of using US techniques to measure this distance.

The subungual glomus tumor is described as a subungual hypervascular mass, with bone erosion or bone remodeling. US is able to locate the tumor, is more cost-effective than MRI, and detects small tumors. US may be used as a complementary technique to clinical diagnosis and for surgical planning [422–427].

In subungual exostosis a hyperechogenic subungual image with acoustic shadowing connected to the phalanx was described as a pathognomonic finding in two case series [428, 429].

Other nail conditions

US can differentiate solid and cystic nail lesions and can be used as a valuable aid to optimize the clinical diagnosis of a number of nail disorders [430–435]. In onycholysis an anechoic gap between the nail plate and the nail bed is seen on US. In onychomadesis, the separation of the proximal edge of the nail plate from the nail matrix and bed is detected.

Based on a retrospective case-control study [434], diagnostic criteria for retronychia have been described as follows: 1) hypoechoic halo surrounding the origin of the nail plate; 2) distance between the origin of the nail plate and the base of the distal phalanx of 5.1 mm or less in big toes and thumbs and/or a difference of 0.5 mm of this distance or greater between the affected nail and the contralateral healthy nail; and 3) proximal nail fold thickness of 2.2 mm or greater for male patients or 1.9 mm or greater for female patients and/or a proximal nail fold 0.3 mm thicker or greater in comparison with the contralateral healthy nail. The presence of all criteria supports the diagnosis of unilateral retronychia and the presence of 2 or more criteria (one of them criterion 1) supports the diagnosis of bilateral cases.

In onychomycosis, US shows an increased thickness of the nail bed, diffuse thickening and irregularity of the nail plates, fusion of the nail plates, and later acoustic shadowing in the nail bed. On US, in paronychia, diffuse thickening of the periungual fold is seen, with areas of increased echogenicity interposed with hypoechoic areas and increased vascularity in Doppler mode. US abnormalities in SSc, lupus, and dermatomyositis can be found within the nail bed, mainly described as a decrease of both echogenicity and blood flow, secondary to microvascular changes. US has shown a high diagnostic accuracy for traumatic nail bed lesions and distal phalanx fractures [435].

Practical points, limitations, and artifacts in nails examination are detailed in ▶ **Supplementary Table 3, 4**.

Recommendations

1. US might be used to increase clinical diagnostic accuracy in structural, infectious, inflammatory, and vascular nail disorders (LoE 4, SoR weak). Broad consensus (25/4/7, 86 %)
2. US assessment of nails in patients with clinical suspicion of psoriasis may support diagnosis (LoE 4, SoR weak). Broad consensus (28/2/6, 93 %)
3. US assessment of subungual glomus tumors and exostoses may support the clinical diagnosis and help in surgical planning (LoE 4, SoR weak). Strong consensus (29/1/6, 96 %)

Conflict of Interest

Fernando Alfageme: Speaker honoraria: GE, Mindray; Equipment support: Esaote
David Bong: No Conflicts of interest
Angel Bueno: No Conflicts of interest
Vito Cantisani: Speaker honoraria: Bracco, Samsung, Canon
Paz Collado: No Conflicts of interest
Maria Antonietta D'Agostino: No Conflicts of interest
Daniela Fodor: No Conflicts of interest
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Hilde Hammer: Speake honoraria and/or consultancy; AbbVie, Lilly, Roche, Novartis
Andrea Klauser: No Conflicts of interest
Jens Kessler: No Conflicts of interest
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Dolores Mendoza-Cembranos: No Conflicts of interest
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