Clinical Application of Musculoskeletal Ultrasound in Rheumatic Diseases

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Since the development of the ultrasound machine, musculoskeletal ultrasound (MSUS) has become widely used in rheumatology practice. This tool allows important information to be obtained for several diseases, such as the early detection of synovial proliferation, effusion, and bone erosion in rheumatoid arthritis, the recognition of enthesitis or dactylitis in spondyloarthropathies, and visual guidance for invasive procedures, such as biopsies, injections, or aspirations. In addition, the use of MSUS in research has increased steadily over the past decade. In this review, we provide a brief introduction and an overview of the clinical application of MSUS in rheumatic diseases.

Introduction

Rheumatic diseases, which result from immune system dysregulation, may have diverse symptoms that involve bone, joints, muscles, tendons, blood vessels, or nerves. Historically, the diagnosis of rheumatic disease relied upon thorough history taking, physical examinations, serological tests, and X-rays. However, difficulties in the diagnosis of this disease arose from limitations in the sensitivity and specificity of serological tests and X-rays. Magnetic resonance imaging (MRI), which provides some help in the early diagnosis of rheumatic disease, has a number of disadvantages, including expense, time consumption, and renal function limitation, which limit the usage of MRI in routine practice. In contrast to MRI, musculoskeletal ultrasound (MSUS) has the advantage that it provides convenient, fast and real-time images for early diagnosis and routine follow-up [1]. Furthermore, ultrasound-guided procedures allow better assessments of target lesions with minimal injury to adjacent tissue, such as nerves or blood vessels [2]. Thus, MSUS has played a very important role in both the diagnosis and treatment of diseases in the field of rheumatology in recent years [3].

In most rheumatic diseases, disease severity is usually proportional to the degree of inflammation. Thus, all...
assessments of inflammation, such as clinical redness, swelling, local heat or tenderness, or increased serological erythrocyte sedimentation rates/C-reactive protein levels, in rheumatology are intended to quantify the amount of inflammation. In the same way, power Doppler ultrasound (PDUS), which measures blood flow, is used in MSUS to detect the degree of inflammation. However, soft tissue inflammation can be located in very superficial regions that have low-velocity blood flow. The operator must be careful to not gather false-negative results that are caused by the application of too much pressure to the tissue being investigated. The use of excess gel on the tissue with an anechoic part left on the top of the ultrasound image may help. Moreover, PDUS, which does not display either the direction or the velocity of blood flow, is more sensitive to blood flow detection than color Doppler ultrasound (CDUS), and it is more commonly used in the assessment of pathological rheumatological conditions with minimal vascularity, such as synovitis or enthesitis [4].

In this review, we provide a brief introduction and overview of the clinical application of MSUS in rheumatic diseases.

Images in arthritis

Rheumatoid arthritis (RA)

RA is a chronic and systemic autoimmune disease that has manifestations of peripheral joint effusion, synovial inflammation, and bone erosion. MSUS is very helpful for the diagnosis of RA, especially in the early stages of the disease when clinical manifestations and X-ray images remain obscure [3,5]. MSUS can detect synovial

![Fig. 1](image1.jpg) A case of rheumatoid arthritis with tenosynovitis in the wrist. (A and B) Widening of the tendon sheath that is filled with synovial proliferation and effusion in both longitudinal and transverse scans. Increased power Doppler signaling indicates active inflammation (C and D).

![Fig. 2](image2.jpg) A case of rheumatoid arthritis with carpal bone erosion, synovial proliferation, and effusion. A 1.4-mm bony surface discontinuity found in the carpal bone (B, white arrowhead) and the corresponding power Doppler ultrasound demonstrate a signal in the bone erosion site (A). Significant synovial proliferation (*) and effusion (+) are seen in the wrist joint. These findings indicate active synovial proliferation and ongoing bone erosion. Lun = lunate; Rad = radius.
proliferation, joint effusion, and bone erosions with more sensitivity, which helps with diagnosis. In addition, because MSUS is simple, convenient and radiation-free, it is ideal for long-term monitoring of treatment and bone erosion.

MSUS observations in RA focus on: (1) detection of synovial membrane proliferation and the amount of blood flow; (2) detection of joint effusion; (3) cartilage thickness and integrity; and (4) detection of the location and extent of bone erosion [6]. Synovial proliferation is the abnormal proliferation of intra-articular tissue. Echogenicity varies from hypoechoic (relative to the subcutaneous tissue) to hyperechoic (such as in crystal arthropathy). Most synovial membrane proliferations have a high degree of angiogenesis, and thus, the PDUS signal is significantly increased. Sometimes, chronic synovial membrane thickening (synovial hypertrophy) lacks angiogenesis, and the PDUS signal is not significant. Joint effusion, like synovial proliferation, is a type of intra-articular substance that results in widening of the joint space. The important characteristic findings that help distinguish joint effusion and synovial proliferation include hypoechoigenicity, easy compressibility, and displacability without a PDUS signal (Fig. 1). Bone erosion is indicated by bone surface discontinuity that is observed in two vertical planes. Sometimes, hypoechoic substances with increased vascularity can be seen in the bone erosion site, and these represent synovial proliferation with ongoing erosion (Fig. 2). Conversely, if echogenicity in the bone erosion is relatively high and without blood flow, it might be caused by fibrotic pannus (Fig. 3) [6]. Tendon sheath widening, which is the characteristic presentation of tenosynovitis, may arise from effusion (Fig. 4), proliferative synovitis, or both (Figs. 1A and 1B).

The semiquantitative scoring system is currently the most common method that is used for the quantification of intra-articular PDUS signaling in clinical and research applications [7] (Fig. 5). The quantitative scoring system is not yet used in clinical practice due to software limitations. In the future, the application of contrast medium in ultrasound examinations may increase the accuracy and sensitivity of blood flow detection.

**Spondyloarthropathy (SpA)**

SpA, which is also known as seronegative spondyloarthritis, is a group of diseases that include ankylosing spondylitis, reactive arthritis, psoriatic arthritis, spondylitis associated with inflammatory bowel disease, and undifferentiated SpA. The main clinical manifestations include spondylitis, sacroiliitis, enthesitis, and asymmetry of the lower extremity arthritis. Extra-articular manifestations include recurrent mucosal ulcers, iritis, or uveitis. Enthesitis is the most common manifestation of SpA, and therefore, it is an important focus of MSUS examinations of SpA. It can be helpful for the diagnosis of SpA in patients that lack obvious symptoms or whose physical examination findings are inconclusive.

Enthesitis consists of inflammation over the site of tendon or ligament attachment to the bone. It is usually observed in the lower extremities, such as in the superior pole of the patella (the insertion site of the quadriceps tendon), the inferior pole of the patella (starting point of the patellar ligament), the tibial tuberosity (patellar

![Fig. 3](image) A 5.9-mm bone erosion found in the metacarpal (Met) head of the right second finger. Relative hyperechoic synovial proliferation noted inside the bone erosion (white arrowhead) without PDUS signal (not shown) indicates fibrotic pannus formation. PP = proximal phalanx.

![Fig. 4](image) Biceps tendon effusion. Both longitudinal (A) and transverse (B) sections show hypoechoic effusion around the tendon.
ligament endpoint), the Achilles tendon, or the plantar aponeuroses [8]. Tendon fiber disarrangement with local thickening or calcium deposition can be observed near the insertion site. In addition, there may also be periosteal changes, such as bone erosion, or new bone formation [8].

Similar to RA, joint effusion and synovial proliferation can also be observed in SpA. In addition to peripheral small joints and sternoclavicular joints (Fig. 6), knee and ankle joints are also common sites of inflammation.

Crystal arthritis

Crystal arthritis consists of a group of inflammatory diseases that are caused by crystal deposition in articular or soft tissue that is adjacent to joints. As with other inflammatory arthritis diseases, crystal arthritis also results in joint effusion, synovitis, and bone erosion.

Gout is caused by the deposition of monosodium urate (MSU) in the joint cavity and surrounding tissue. MSU crystals strongly reflect ultrasound signals; therefore, MSU deposition on the cartilage surface looks like another hyperechoic line over the bone surface during an MSUS examination, and this is the so-called double-contour sign [9]. In addition, joint effusion in chronic tophaceous gout with acute attacks is filled with floating aggregates of variable echogenicity, the so-called snowstorm appearance (Fig. 7), and this can also be observed in pseudogout.

Pseudogout consists of arthritis that is induced by the deposition of another type of crystal, calcium pyrophosphate dehydrate. It occurs more often in the wrist, knee,
shoulder, and ankle. The sparkling reflectivity of the crystal within the cartilage in pseudogout looks like the double-contour sign of gout ([9]). The difference is that the hyper-echoic line is observed inside the cartilage (Fig. 8), rather than on the cartilage surface as in gout.

Osteoarthritis

Osteoarthritis consists of joint inflammation and pain that results from cartilage degeneration or destruction, which may further induce disability or deformity of the joint. Currently, X-ray is the basic diagnostic tool used in osteoarthritis. However, MSUS evaluation can offer information about not only bony spur formation, but also joint effusion, synovial proliferation, cartilage thickness, and adjacent soft tissue conditions (Fig. 9). In addition, PDUS can also provide information about the degree of inflammation.

Cartilage appears as a hypoechoic or anechoic substance in ultrasound examinations. Damaged cartilage manifests with local thinning, uneven surfaces, or a loss of homogeneity of the cartilage ([10] (Fig. 10). A bony spur (osteophyte) is a bony prominence that has an acoustic shadow (Fig. 11). Severe osteoarthritis may result in a mucous cyst or Baker's cyst in the adjacent soft tissue. These cysts are connected with the joint cavity, and the fluid aspirated from these cysts is mostly synovial fluid. Therefore, MSUS examination of the fluid inside the cyst shows a hypoechoic or anechoic appearance. Most of the Baker's cysts have only a few symptoms. However, ruptured Baker's cysts may extend between the calf muscles and induce painful
Fig. 11  Severe osteoarthritis of the knee joint. The X-ray image of severe knee joint osteoarthritis shows joint space narrowing and marginal osteophyte formation in the medial site (A). Two bony prominences (B, arrows) with acoustic shadows in the tibial (T) and femoral (F) junction are observed by ultrasound. C displays a focal enlarged image of the osteophytes (arrowhead) in A.

Fig. 12  Rupture of a Baker’s cyst. A Baker’s cyst is located in the popliteal area. The typical appearance is seen with ultrasound, including the superficial (A, s), neck (A, n), and base (D, b) parts in the longitudinal scan. In this case, rupture of the Baker’s cyst resulted in extension of the base part between the soleus muscle and gastrocnemius muscle (B–D). Clinically, this type of Baker’s cyst rupture presents as acute and painful swelling of the calf, mimicking the manifestation of deep vein thrombosis.
swelling in the calf, mimicking deep vein thrombosis (Fig. 12) [11].

**Images in vasculitis**

**Polymyalgia rheumatica**

Polyarthralgia rheumatica is a vasculitic syndrome that manifests with symmetrical proximal girdle pain that is accompanied by significant morning stiffness and sometimes slight muscle weakness. It must be carefully differentiated from inflammatory myositis (i.e., polymyositis or dermatomyositis). Subacromial—subdeltoid bursitis, a long head of the biceps tenosynovitis, glenohumeral joint effusion, and hip joint effusion are the most common features in MSUS examination of polymyalgia rheumatica [12]. Bilateral subacromial—subdeltoid bursitis (Fig. 13) is the most specific finding for polymyalgia rheumatica, and it can be used to distinguish it from other diseases. A good correlation of MSUS and MRI in the diagnosis of polymyalgia rheumatica [13] demonstrates that MSUS is a powerful diagnostic tool for polymyalgia rheumatica.

**Giant cell arteritis**

Giant cell arteritis, which is also known as temporal arteritis, consists of inflammation of the large or medium arteries, particularly those in the branches from the neck, such as the superficial temporal, facial or ophthalmic artery. Giant cell arteritis results in arterial wall inflammation and arterial obstruction. Clinically, giant cell arteritis develops with symptoms that are similar to those seen in polymyalgia rheumatica. A hypoechoic rim is observed around the blood flow under a CDUS-transverse scan, which is the so-called “halo sign” that is caused by intima inflammation and edema [14]. MSUS aids in the diagnosis and selection of the inflamed section for biopsy.

**Conclusions**

A growing number of research articles that have been published in the recent decades have demonstrated the importance of MSUS. Many studies have confirmed that ultrasound can be a useful tool, in that it provides timely and important information for differential diagnosis, in addition to that provided by clinical history taking, physical examination, or blood tests. However, the lengthy learning curve remains the most important obstacle to the application of MSUS in clinical practice. Repeated hands-on training and practice are the best way to decrease the learning time and increase clinical experience. More rheumatologists are needed to join this field and promote ultrasound examinations in daily practice.

**References**


