

# Progress in Musculoskeletal Ultrasound for Gout Diagnosis and Disease Monitoring

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**Abstract:** Gout is most often common in middle-aged and elderly men, which is mainly caused by the deposition of urate crystals in the joints and surrounding tissues. In recent years, with the change of lifestyle, the incidence of gout has been increasing year by year. At present, the diagnosis of gout mainly depends on clinical symptoms, blood uric acid and joint fluid and other indicators. However, these methods have some limitations in early diagnosis, disease monitoring and other aspects. As a non-invasive and real-time dynamic imaging technology, musculoskeletal ultrasound (MSUS) has gradually become an important means of gout diagnosis and disease monitoring. MSUS can not only clearly show the structural changes of joints and surrounding tissues, but also show the deposition of urate crystals, providing new ideas for the early diagnosis and precise treatment of gout.

**Keywords:** Musculoskeletal Ultrasound; Gout Diagnosis; Disease Monitoring.

## 1. Introduction

Musculoskeletal ultrasound can visually show the structural changes of joints and surrounding soft tissues, especially for urate crystal deposition, synovial thickening, and accumulation of joint fluid. Compared with traditional imaging, musculoskeletal ultrasound has the advantages of high tissue resolution, simple operation, and good repeatability, which can detect gout-related lesions earlier and more accurately. In addition, ultrasound guided joint puncture and drug injection technology also provides a new method for the diagnosis and treatment of gout, help to promote the application of the technology in clinical, improve the diagnosis and treatment of gout, improve the prognosis of patients, so to explore the application in gout diagnosis and monitoring of musculoskeletal ultrasound is of great significance.

## 2. The Rationale for Musculoskeletal Ultrasound

Ultrasonic imaging is based on the propagation and reflection of sound waves in water. After the ultrasonic probe sends high frequency sound waves into human tissue, the tissue of different densities will reflect back the echo signal of different intensity, and convert it into electrical signals, which are finally displayed on the display screen [1]. Muscles, tendons, ligaments, bones and other tissues show different echo patterns and gray scale images due to the differences of acoustic impedance characteristics. The core is the propagation speed and reflection intensity of sound waves in different media, so as to obtain a high resolution tissue structure. The myosonous ultrasound technique is characterized by high resolution, real-time and dynamic imaging. Myosoma ultrasound imaging uses a high frequency probe (7.5-20 MHz) with higher resolution than other imaging techniques, especially superficial tissue imaging. Ultrasound imaging is real-time and can be shown by real-time imaging, which is convenient for clinicians to observe

the dynamic changes of muscles, tendons, joints and other tissues in real time. This feature is important for the diagnosis of motor injury, inflammation, and acute damage to the muscle and skeletal system. In addition, ultrasound imaging can dynamically observe the structural and functional changes during the joint motion to further improve the diagnostic accuracy.

Myoculoskeletal ultrasound imaging has its unique advantages over other imaging techniques [2]. Compared with X-ray and CT, CEUS without ionizing radiation, high safety, especially suitable for children and pregnant women. Compared to magnetic resonance imaging, ultrasound equipment is small, cheap, not limited by magnetic field, can be used in bedside or sports field, with greater flexibility [3]. In addition, ultrasound can better display the soft tissue details, can clearly show the tendon, ligament, synovium and other tissue structures, but the X-ray image is difficult to distinguish. Ultrasound can also evaluate the blood flow status by Doppler imaging, which has an important diagnostic value for the vascular lesions and inflammation of the skeletal muscle system.

## 3. Application of Musculoskeletal Ultrasound in the Diagnosis of Gout

### 3.1. Ultrasonic Feature

MSUS can not only display the structure of joints and soft tissues in real time, but also evaluate the lesions. The main pathological changes of gout are the deposition of uric acid crystals, inflammatory reaction and joint destruction. MSUS can provide detailed imaging information in these aspects [4]. Uric acid crystals are often deposited on the surface of articular cartilage, synovial membrane and joint capsule. On ultrasound images, urate crystals are mostly point or linear strong echo, often accompanied by acoustic shadow. Its ultrasound features are "double-track sign" (double contour sign), which is mainly manifested as uric acid crystals deposited on the surface of articular cartilage, forming a hyper-echoic zone, and forming bilateral hyper-

echoic structure [5] with the normal cartilage-bone interface. In addition, MSUS can detect gout nodules (Tophi), a hard block composed of large numbers of urate crystals, with irregular hyperechoic ultrasound findings, often accompanied by acoustic shadow. In addition, MSUS has a high sensitivity to synovitis and synovial thickening. In acute gout attack, the synovium is prone to liquid dark areas, manifested as anechoic or hypoechoic, often accompanied by synovial hypertrophy. Synovial fluid accumulation is another important manifestation of joint synovial inflammation, and its ultrasound manifestation is anechoic or anechoic fluid accumulation, mostly occurring in the joint cavity or smooth capsule [6]. Previous studies have shown that synovitis and the clinical symptoms of gout has a high correlation, ultrasound to the detection rate of synovitis is higher, MSUS can observe real-time articular cartilage destruction and bone destruction, chronic gout arthritis (gout) patients often accompanied by bone destruction, it is characterized by bone cortex irregular defect or depression, ultrasound performance is low, anechoic area, articular cartilage degeneration is the main cause of articular cartilage damage [7]. Studies show that MSUS has higher sensitivity and specificity for bone erosion in patients with gout, which is comparable to conventional X-ray, and is more advantageous for the detection of early lesions [8].

### **3.2. Diagnostic Sensitivity and Specificity**

MSUS has high sensitivity and specificity for the diagnosis of gout, which is an important indicator to evaluate its clinical application value. A large number of studies have confirmed that MSUS has high sensitivity and specificity for gout, which is a non-invasive and effective diagnostic method. In terms of sensitivity, MSUS can detect uric acid crystals early, which is of great significance for the early diagnosis of gout. MSUS is highly sensitive to urate crystals, while traditional imaging techniques such as X-ray are low. In addition, MSUS has a high sensitivity to synovial inflammation and synovial fluid accumulation, especially in acute gout attacks, reaching more than 85% [9]. In terms of specificity, MSUS can not only accurately reflect the typical pathological changes of gout, but also can effectively distinguish between other joint diseases, such as rheumatoid disease, osteoarthritis, etc. Among them, the specificity of the dual-track sign is relatively high, which is an important specific marker of gout. To further improve the diagnostic sensitivity and specificity of MSUS for gout, various ultrasound imaging techniques have been developed recently, such as [10]. Doppler ultrasound detects an increase in intra-articular blood flow, which is an important indicator of the inflammatory response. Doppler ultrasound has high sensitivity and specificity to synovial blood flow, and the elastography technique can reflect the change of tissue hardness and has good application prospects in arthralgia and synovial thickening.

### **3.3. Ultrasound Findings of Gout at Different Stages**

The pathological changes of gout vary in different periods, and MSUS can sensitively capture these changes, which is of great significance for clinical diagnosis and treatment. According to its course of gout, it can be divided into asymptomatic hyperuricemia, acute gout, intermittent and chronic gout, and MSUS in different periods shows different characteristics [11]. In the asymptomatic phase of hyperuricemia, the early deposition of urate crystals can be

found, although the patient has no obvious clinical symptoms. At this point, a slight dual-track sign and a small number of strong echo points can be found on the ultrasound wave, which is the early sign of urate crystals. The acute gout attack period is the critical period of MSUS treatment. During the acute attack, patients show severe arthralgia, redness and insufficiency [12]. MSUS provides real-time observation of synovial inflammation, synovial fluid accumulation, and urate crystallization. Acute phase synovitis is mainly anechoic or anechoic fluid in the joint cavity and synovial fluid accumulation. In addition, urate crystals are more significant in the acute phase, and the incidence of double helix signs increases significantly. Intermittent period refers to the slow stage after the acute attack, most of the clinical symptoms have disappeared, but there are still pathological changes. Residual urate crystals and mild synovial thickening were observed with MSUS. About 50% of intermittent gout patients still have urate crystals, when synovial inflammation and synovial fluid accumulation may be relieved, but close monitoring is needed to prevent another acute attack. Chronic gout is the end stage of a disease, often characterized by recurrent and persistent lesions, when MSUS can show significant joint destruction, bone destruction and large deposits of urate crystals of [13]. Chronic synovitis and synovial fluid accumulation are more persistent and extensive, while the low and unechogenic thickening of the synovium is more significant, showing irregular hypoechoic or anechoic areas in ultrasound examination.

## **4. Application of Musculoskeletal Ultrasound in Disease Monitoring of Gout**

### **4.1. Assessment of the Condition**

MSKUS can clearly show the joint structure, synovial thickening, crystal deposition of urate, surrounding soft tissues such as bursa, tendon and other lesions. During the acute attack period of gout, MSKUS can show the enhancement of fluid accumulation, synovitis, and blood flow signal in the joint, reflecting the degree of inflammation [14]. The audiogram of joint effusion is characterized by no echo or low echo in the joint cavity, and the synovial thickening is strong and moderate echo. Color Doppler blood flow imaging (CDFI) can find enhanced blood flow signal in the synovial um. The acute stage of MSKUS shows hyperechoic synovium, periarticular soft tissue edema, and synovial fluid, which are important indicators to judge the activity and severity of the disease. In the chronic stage, its application range is more extensive. The crystalline deposition of urate in articular cartilage and soft tissue of patients with gout can form tophi, which is hyperechoic, well circumscribed, sometimes accompanied by [15]. MSKUS can identify early tophi and evaluate its size, quantity and distribution. In addition, MSKUS can show chronic synovitis, synovial thickening, fibrosis, so as to comprehensively evaluate the disease progression and the degree of chronic inflammation. MSKUS can also be used to assess pain in surrounding soft tissues such as tendons, ligaments, and cysts. The tophi is deposited in the tendon and bursa, often in a hyper-echoic or mixed echoic zone, accompanied by synovitis and soft tissue edema [16]. The assessment of these soft tissue injuries can better understand the effects of gout on the body and provide the basis for the individualized treatment of gout.

## 4.2. Evaluation of Treatment Effect

In order to evaluate the efficacy of gout, MSKUS can dynamically observe the changes of joint and soft tissue structure before and after treatment, objectively evaluate the treatment effect and efficacy, and provide intuitive imaging basis for its efficacy. Drug treatment is an important method for the treatment of gout, mainly including non-steroidal anti-inflammatory drugs (NSAIDs), glucocorticoids and uric acid-lowering drugs and other [17]. MSKUS can directly reflect the anti-inflammatory effect of drugs, including the reduction of joint effusion, the weakening of synovial blood flow signal and the decrease of synovial thickness. On this basis, the therapeutic effect of urate crystallization can be evaluated by regular ultrasound detection, such as the size and quantity of stones, and the formation of new tophi. Dietary control and lifestyle intervention are very important in gout treatment, which is caused by a high-purine diet, alcohol consumption, and obesity. Improvement of diet and lifestyle in soft tissue joint and joint damage can be assessed by MSKUS monitoring. Such as diet control and lifestyle improvement, can be found through ultrasound examination, reduced joint fluid, reduced synovitis, tophi reduced [18]. In addition, MSKUS monitors joint stress and inflammation during weight loss, thus guiding patients to lifestyle adjustments. MSKUS is important for the postoperative evaluation of surgical patients with gout and should be treated for refractory tophi, severe joint destruction and functional insufficiency. Preoperative and postoperative MSKUS can evaluate the thoroughness of tophi removal and the repair of the synovial and soft tissues. Regular postoperative ultrasound follow-up allows timely intervention of postoperative complications (e. g. area infection and effusion recurrence) to improve the efficacy [19].

## 4.3. Changes Over the Long-Term Follow-Up Period

MSKUS can conduct long-term follow-up of gout patients, monitor changes in the condition, guide individualized medication, and prevent recurrence and complications. Long-term follow-up is of great significance for gout patients, and MSKUS is a non-invasive, convenient and effective imaging method, which can provide a reliable basis for the long-term follow-up of gout patients. MSKUS can conduct long-term follow-up of tophi, dynamically monitor its changes, and regularly review the size, quantity and distribution of tophi, so as to detect the change of new tophi or old tophi in time. MSKUS can be used to assess the status of urate crystal dissolution in patients who have already taken urate-lowering drugs and to guide the adjustment of the treatment regimen [20]. If the volume and quantity of tophi become smaller, it indicates that the uric acid lowering treatment is effective, and the dosage and regimen can be adjusted appropriately; if tophi does not significantly change or increase, it is necessary to adjust the treatment plan, increase the dosage, or combine medication. In addition, MSKUS can provide long-term follow-up of joints and soft tissue structures. Gout is a common disease of chronic synovitis, synovial thickening and fibrosis. Regular ultrasound examination can understand synovial inflammation and dynamic changes of synovial thickness, so as to guide anti-inflammatory treatment. At the same time, MSKUS can also monitor the changes of soft tissue lesions such as joint effusion, synovial effusion and tendinopathy, so as to detect early complications and early

intervention to prevent further deterioration of the condition. MSKUS can also be used to evaluate the functional recovery of patients with long-term follow-up, and ultrasound examination can evaluate the degree of articular cartilage damage and repair status, so as to guide rehabilitation treatment. By detecting the thickness of articular cartilage, surface smoothness, subcartilage bone density and other indicators, it can reflect the health state of articular cartilage and provide scientific basis for rehabilitation training and physical therapy. In addition, MSKUS can also evaluate the elasticity and tension of tendons and ligaments, and monitor the repair of soft tissues, so as to guide patients with appropriate functional exercise and rehabilitation training.

## 5. Future Research Directions and Clinical Application Prospects

With the development of musculoskeletal ultrasound examination in the diagnosis and treatment of science and technology and the deepening of research, it will show a good clinical application prospect. With the improvement and standardization of the technology, the current musculoskeletal ultrasound technology has been able to identify and evaluate the urate crystals in the joints and soft tissues of gout patients. However, with the continuous improvement of the technology level, the resolution and sensitivity of the image will also be further improved, so as to enable a more accurate assessment of the range and severity of the lesions. High-frequency probes and advanced imaging technologies (such as elastography, Doppler ultrasound, etc.) can better display early lesions and help clinicians with early intervention of the disease. In addition, the ultrasound instrument is portable and easy to operate, which can provide a new way for clinical practice, improve the diagnostic efficiency, and improve the patient compliance. To ensure the consistency of ultrasound examination results, standardized surgical procedures and diagnostic criteria should be established. This project intends to adopt multi-center collaboration, expert consensus and other methods to establish a unified ultrasound examination standards, reduce the individual differences of operators, and improve the diagnostic accuracy and repeatability. Combining musculoskeletal ultrasound with other imaging techniques will be an important future research direction. Although musculoskeletal ultrasound has its unique advantages in the diagnosis of gout, the limitations of a single imaging technique make the combination of both inevitable. For example, dual energy CT (DECT) has high sensitivity and specificity for urate crystals, which can provide more comprehensive and accurate diagnostic information. Magnetic resonance imaging (MRI) can accurately evaluate the soft tissue, bone and other lesions, and has a high diagnostic value in complex cases. Ultrasound combined with CT, MRI and other imaging technologies can evaluate gout patients from angles and angles, and improve the accuracy and comprehensiveness of diagnosis. In addition, the combined application of multimodal imaging technology can be used to evaluate the efficacy and disease process, and provide a basis for individualized treatment.

## 6. Tag

In conclusion, myosoeous ultrasound technology has a good application prospect in gout diagnosis and disease monitoring. Due to its advantages of non-invasive, high resolution and real-time imaging, it can be used for early

detection of urate crystals and evaluation of efficacy. In the future, with the continuous development of ultrasound technology and the development of artificial intelligence technology, the application of myosseous ultrasound in the treatment of gout will be more and more widely used. On this basis, large-sample clinical studies should be further carried out to establish standardized operation procedures, improve its diagnostic accuracy, improve the standardization of clinical application, and provide more accurate and personalized diagnosis and treatment plans for patients.

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