Introduction

Of the many advances that have come into the field of rheumatology today is the art of ultrasonography (US) of joints and soft tissue. It is popularly called musculoskeletal ultrasound (MSK US). More than 20 years ago the only clinicians to have been doing US were the cardiologist, who had mastered the art of doing US studies of the heart and called it echocardiography. In fact echocardiography became an extension of clinical examination of the heart. Subsequently obstetricians also quickly picked up the skill of US and this is being utilised in monitoring foetal wellbeing during the ante-natal period. In rheumatology US is a relatively new but rapidly developing field, and now forms an important part of curriculum of rheumatology training programmes in European countries and the USA. The aim of this review is to provide an introduction to the essentials of US in rheumatology.

Musculo-skeletal Ultrasound in Rheumatology Practice

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Abstract

In rheumatology ultrasound is a relatively new but rapidly developing field, and now forms an important part of curriculum of rheumatology training programs in European countries. Ultrasound is now an accepted procedure to differentiate between arthralgia and arthritis, to look for erosions in early arthritis which is otherwise not visible on plain radiographs, to scan tendons in enthesopathies and to image blood vessels. It is particularly useful in early undifferentiated arthritis, where presence of synovitis by ultrasound can predict development of rheumatoid arthritis. It is also useful to aid in diagnosis of a wide variety of rheumatic conditions like gout, vasculitis and scleroderma. It facilitates correct placement of needle during intra-articular injections. The advantages of ultrasound are it is relatively inexpensive, noninvasive, lacks radiation and the images are acquired in real time. Following in the footsteps of the cardiologist who are using echocardiography are the rheumatologists who are increasingly using ultrasound in their clinics, such that some authors have likened the US probe to the rheumatologist’s stethoscope.

Ultrasound in Rheumatology: The Art

Probably the first publications of musculoskeletal US were in 1972 by Daniel McDonald and George Leopold. They described the use of a contact B-mode scanner to differentiate Baker’s cysts from thrombophlebitis and for a long time this remained the only indicator for MSK US as per the major textbooks of rheumatology. Subsequently the indication was extended to rheumatoid arthritis (RA). Now US is performed to differentiate between arthralgia and arthritis, to diagnosis erosions in early arthritis not visible on plain radiographs, for enthesopathies, and to image blood vessels, etc. Some authors have likened the US probe to the rheumatologist’s “stethoscope”.

The reason which probably made musculoskeletal US popular were the inadequacies of clinical examination of the joints, especially deeper joints like the hip and sacroiliac joint, which made the clinicians to look for inexpensive and readily available tools to examine these joints. Other major reason was to guide intra-articular injections. Apart from this advantages of US are lack of radiation and the ability to look at tissue
perfusion and inflammation in real time. The major disadvantage of US is highly operator dependent. It takes time for a trainee to acquire the necessary skills which has to be maintained by regular practice. This hurdle can be overcome by appropriate training, and performance under supervision of a trained sonologist. The American College of Radiology recommends that US trainees should undertake 500 supervised scans in order to achieve an acceptable standard.¹ The European league against rheumatism (EULAR) conducts ultrasound course at three levels (basic course, intermediate course and advanced course) as part of its educational activity.²

**The US Equipment (Machine), Principles and Techniques**

The cost of the equipment largely depends on the image resolution and quality. The cost can be significantly reduced by programming/selecting the system only for musculoskeletal use. US images are produced by high frequency sound waves, which are inaudible to the human ear, typically above 20 kHz. A US machine consists of a computer processing unit and a transducer. The transducer forms the most important part of the machine. The transducer based upon the pulse-echo principle occurring with ultrasound piezoelectric crystals, converts electricity into sound - pulse, and sound into electricity - echo. Pulse of sound is beam to soft tissues. The sound interaction with soft tissue is called bio effect. Pulsing is determined by the transducer or probe crystal(s) and is not operator controlled. Echo produced by soft tissues are received by the transducer crystals, interpreted and processed by the ultrasound machine to produce images. Reflected echo intensity is proportionate to the amount of difference between tissue impedances at that interface, mainly due to differing water content of tissues, which provides the signals that define the edges of images. Intense echoes, such as from bone, appear whiter or “hypechoic;” whereas weaker echoes from fluid or muscle make a darker, more “hypoechoic” image. Water is least reflective and appears black “anechoic” on screen. Most US images are presented in “black and white” or gray scale where the brightness of the while dot corresponds to the intensity of the reflected wave. This is known as B-mode or brightness modulated ultrasound. Doppler imaging which is increasingly used in rheumatology is superimposed on the B-mode image. There are two main types of Doppler US: colour flow Doppler (CFD) and power Doppler (PDS). Both produce a similar colour spectral map superimposed onto the gray scale image. CFD represents an estimate of the mean Doppler frequency shift and relates to velocity and distribution of red blood cells, whereas PDS denotes the amplitude of the Doppler signal, which is determined by the volume of blood present. CFD is better suited for evaluating high velocity flow in large vessels like the carotids, whereas PDS is better suited for assessing low velocity flow in small vessels like in the synovium.

Ultrasound transducers are commonly referred to by the operating, resonant or main frequency. Transducer frequency ranges used in medical ultrasound imaging are 2 - 20 MHz. Generally with high frequency there is improved resolution, but loss of depth of penetration, whereas low frequency transducers allow for full depth of penetration but with poorer resolution. Therefore low frequency 2.5 to 5 MHz is used for general abdominal imaging, whereas for musculoskeletal imaging the frequency is chosen 7 MHz and above. Modern transducers have multiple frequencies, so it is not necessary to have multiple transducers with different frequencies. Therefore a single transducer can have a frequency with range from 4 to 12.5 MHz. The transducer can be linear array, annular array or radial array based on the arrangement of the piezoelectric crystals. In musculoskeletal US the transducer is linear array whereby the piezoelectric crystals are arranged in parallel to one another, the surface is flat and produces rectangular image.

**Scanning Technique**

The transducer is best held near the imaging surface while anchoring the transducer to the patient with the small finger or the heel of the hand. This allows fine adjustments in transducer position and control the amount of transducer pressure. The resulting image is then optimised by adjusting the depth of the image to bring the area of interest to view. If the US machine has adjustable focal zones, these also should be moved to the depth of interest to optimise resolution. The gray scale gain then is adjusted for brightness of the image. When describing anatomic structures at US, one refers to the imaging plane relative to the structure itself, such as transverse and longitudinal, rather than the imaging plane relative to the body.

Ultrasound artifacts are echoes that do not correspond to a real target in either distance or direction. Several different types of artifacts need to be considered when interpreting images.

1. **Anisotropy** : This is the most common artifact observed in musculoskeletal scanning. It occurs when the region of interest is not perpendicular to the transducer, due to either the angle of transducer or the angle of object. If the beam is not perpendicular to the tissue being scanned, the sound waves are scattered rather than being reflected back to the transducer. This causes the structure to appear darker than it should and can result in wrong diagnosis.
2. Refractile shadowing: This is reflection away from the transducer when the US beam hits a structure with different acoustic impedance, at an oblique angle. This most commonly occurs when scanning tendons, when the edge of the tendon and tendon sheath may look erroneously hypoechoic.

3. Acoustic shadowing: This occurs when the US beam hits a highly refractile surface like bone. The region beyond the refractile surface appears hypoechoic or anechoic as very few sound waves can reach it.

Clinical Applications of Ultrasound in Rheumatology

Musculoskeletal US is increasingly used to detect synovitis, bone erosions, effusions, tenosynovitis, enthesitis, and cartilage pathology. Some of these applications are discussed:

1. Synovitis and joint effusion: US is superior to clinical examination in detection of joint inflammation. It is a sensitive tool to detect synovitis and effusion in joints, normal on clinical examination in patients with very early synovitis (< 3 months duration) and arthritis only in a single joint. Study by Filer et al showed that presence of synovitis in early undifferentiated arthritis predicted the progression to RA. Normal synovium is not seen on US. Synovitis is diagnosed by the presence of abnormally thickened hypoechoic intra-articular tissue. Synovitis can be distinguished from effusion because in effusion the fluid is compressible and displaceable. US also increases the chance of successful placement of a needle in the joint cavity both for injection and aspiration of joint fluid. Power Doppler scanning is sensitive to detect even small increases in synovial perfusion.

2. Bursal effusion: In the case of significant knee effusion, increased intra articular pressure may lead to opening of a communication posteriorly, between knee joint and semimembranosus bursa, called Baker’s cyst. US of popliteal fossa shows the presence of effusion in a bursa as anechoic or hypoechoic lesion between two hyperechoic lines (Figures 1, 2). This is the most common bursa imaged by US. In olden days Baker’s cyst was virtually the only absolute indication for performing MSK ultrasound. Baker’s cyst can rupture and fluid percolate down in the calf and mimic acute thrombophlebitis. MSK US is the only way to differentiate the two.

3. Bone erosions: Erosion is defined as an interruption of the bone surface in two planes perpendicular to each other. It is well known that the finding of erosion on plain radiograph aids the diagnosis and is a very important outcome measure in RA and a prognostic marker. It has been shown that US can detect more erosions than plain radiographs in early RA. It may not be long before US criteria will be incorporated as an important criteria to aid in diagnosis and as an outcome measure in RA therapy trials.

4. Tendon diseases: US could soon become the gold standard imaging method for assessing tendon involvement in rheumatic diseases. Normally tendons have fibrillary pattern along long axis and stippled in transverse axis. In tenosynovitis fluid is seen adjacent to the tendon, and power Doppler shows increase in the vascularity. Later on, the tendon becomes thicker and loses its normal fibrillar characteristic. Tendinosis is characterised
by the presence of hypoechoic areas within the tendon substance. If there is complete rupture of tendon there will be absence of signal between the free edges of the tear and lack of movement of the tendon on dynamic imaging.

5. **Enthesitis**

Enthesitis is the hallmark of the spondyloarthritides, but may also be secondary to mechanical stress. Enthesitis is characterised by abnormally hypoechoic appearance of the enthesis, and/or increased thickness of tendon or ligament at its bony attachment. Other findings are enthesophyte, erosions, calcifications and adjacent bursitis. US is again more sensitive than clinical examination at detecting enthesitis (Figure 3).

6. **Sacroiliitis**

Preliminary data suggest that US Doppler may be useful to detect active sacroiliitis, though with difficulty due to deep location and angulation of the joint. More recently contrast-enhanced ultrasound (CEUS) technique using second-generation microbubbles, allows detection of active sacroiliitis, by showing deep contrast enhancement into the SI joints not detectable in inactive joints of patients or in controls. US may also be used to direct needle into the joint space to deliver local therapy for biopsy and/or to aspirate fluid.

7. **Crystal arthropathies**

Normal cartilage is anechoic. US of cartilage is useful in the diagnosis of crystal deposition disease. A characteristic US finding in gout is the double contour sign, whereby an echogenic line (representing MSU crystals) can be detected parallel to the cortex of bone (for example, a metatarsal head) with an anechoic region between, representing the hyaline cartilage. In gout the crystals appear as hyperechoic or mixed echogenicity areas which sit on superficial articular surface, whereas in chondrocalcinosis the hyperechoic lesions are seen in deeper areas of the cartilage. Some authors have reported the double contour sign to have a sensitivity of 36.8% and a specificity of 97.3% for the diagnosis of gout (Figure 4).

8. **Vasculitis**

US with colour Doppler has emerged as an important imaging modality in large vessel vasculitis especially giant cell arteritis (GCA). Characteristic features of GCA include a hypoechoic swollen artery wall with surrounding oedema (‘halo sign’) and an irregular narrowed lumen. One study found this sign to have a high negative predictive value, that means absence of the halo sign can practically rule out GCA. The halo sign was also found to correspond with a pronounced inflammatory infiltrate of the temporal artery on biopsy. A recent meta-analysis showed that the sensitivity and specificity of the halo sign to be 68% and 91% respectively. The usefulness of US also lies in guiding biopsy of involved vessels, particularly in GCA which is characterised by ‘skip lesions’.

9. **Diseases of muscle**

Presently MRI is more sensitive than US in detecting muscle oedema in inflammatory myositis and in guiding muscle biopsy. Ultrasond’s usefulness lies in detecting muscle tears, localisation and aspiration of muscle abscess in pyogenic myositis, to detect calcifications and myositis ossificans.

10. **Nerve entrapments**

In rheumatology practice the most common nerve entrapment syndrome is the carpal tunnel syndrome (CTS). By US the median nerve can be easily identified from tendons as it is hyperechoic and speckled in transverse section and has a hypoechoic fascicular pattern in longitudinal section. The cause of nerve compression can also be identified, e.g., tenosynovitis, tendon effusion, increased fatty tissue, ganglion cyst etc. An increase in the cross sectional area of the median nerve of greater than 9 mm² at the level of pisiform bone, aids in confirming the clinical diagnosis of CTS. Local injections can be given with US guidance, so that the needle tip is visualised continuously and the needle is placed in the desired location, thus avoiding the risk of nerve damage.

11. **Scleroderma**

The availability of high frequency transducers (13-20 MHz) has enabled evaluation of skin thickness in scleroderma and to assess the severity of skin disease and response to treatment. Also, cellulitis can be differentiated from subcutaneous abscesses.

### Interventional Musculoskeletal US

The common bedside procedures in rheumatology are aspiration of joint fluid and intra-articular injection. These procedures have always been performed blind. In 1993, Jones et al studied the accuracy of 109 injections into various joints, by mixing the depot steroid with a radiographic contrast medium. They found that approximately one third of knee and ankle injections were extra-articular,
only half of the wrist injections were definitely intra-articular, with even less accuracy for shoulder injections. Musculoskeletal US can be used to guide aspiration of joint fluid and intra-articular injection, to ensure correct placement of needle and injection of the medication. This is particularly important when injecting the hip joint, shoulder joint and sacro-iliac joint. Needle visualisation is usually good by US because of the reflective nature of the needle. US can also be used for cyst decompression (e.g. Baker’s cyst).

**Limitations of Ultrasound**

Like every diagnostic procedure in medicine, US is not without limitations. First of all as it is highly operator dependent, one has to ensure that the operator has been trained adequately. Studies from the OMERACT group show that with standardisation, operator dependency can be diminished. To become an experienced sonographer requires long period of training, dedication and practice. Also since US beam does not penetrate bone, oedema of bone marrow cannot be visualised.

**Conclusion**

Musculoskeletal US has proved to be an invaluable diagnostic tool in rheumatology. US aids in achieving a correct diagnosis in undifferentiated arthritis and a wide variety of rheumatic conditions. It facilitates correct placement of needle for intra-articular injections. US is inexpensive, noninvasive and lacks radiation, and the images are acquired in real time. That is why the art and science of performing a musculoskeletal US is rapidly picking up. Most rheumatology training programmes in Europe and the US include musculoskeletal US in their curriculum. The OMERACT ultrasound special interest group has also published US definitions for common pathological lesions seen in patients with inflammatory joint disease, including synovitis, erosions, tenosynovitis, and enthesis.

In summary for this extremely useful tool the only initial hurdle to overcome is to procure a good machine and then allotting a specific amount of time for learning. A good knowledge of anatomy definitely helps.

**References**