Review - CME

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Rheumatological ultrasonography: a focus on arthritides

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Musculoskeletal ultrasonography is increasingly being utilized in the rheumatology clinic, to aid earlier diagnosis, improve the clinician's ability to manage disease and to give prognostic information. This review will discuss how ultrasound is currently being applied in rheumatology, with a particular focus on arthritis. It highlights how ultrasound can meet the needs of rheumatologists as a complementary tool in daily clinical practice.

Keywords: arthritis • gout • osteoarthritis • psoriatic arthritis • rheumatoid arthritis • rheumatology • ultrasonography

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LEARNING OBJECTIVES

Upon completion of this activity, participants should be able to:

- Assess the potential benefits of the use of ultrasound in cases of arthritis
- Discuss the use of ultrasound in synovial imaging
- Discuss the use of ultrasound in bone and cartilage imaging
- Evaluate potential barriers to the use of ultrasound in the assessment of patients with arthritis

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Rheumatology is a medical discipline, which perhaps more than many others has relied upon the physician's clinical acumen to guide diagnosis and management. Few of our diseases have sensitive and specific pathognomonic tests, or established, validated and useful biomarkers to assist with our clinical care. However, recently we have been searching for more robust markers of diagnosis and disease activity to improve outcomes for our patients. For example, in the setting of rheumatoid arthritis (RA), the anticyclic citrillunated peptide antibody is a specific, although less sensitive, test and imaging such as ultrasonography (US) and magnetic resonance imaging (MRI) have been utilized to identify subclinical objective synovitis. Another example is utilizing the disease activity score 28 to guide management decisions rather than relying on the physician's acumen. As rheumatologists reach for better outcomes for our patients, we are searching for investigations to aid our clinical management of patients. An ideal investigational tool should provide detailed pathoanatomical information that is valid (truthful and reliable), repeatable and comparable [1,2]. It should be of value, in providing information in addition to that obtainable clinically, alter management, aid intervention and improve outcomes [1,2]. Additionally it should be accessible and available to the clinician. The purpose of this review is to examine the degree to which US demonstrates these traits, and has potential to assist clinicians in the diagnosis and management of rheumatic diseases, with a focus on rheumatoid arthritis.

What is ultrasonography?

US in rheumatology relies upon exploiting the physical principles of sound to provide information about structural features of the human body. Very high frequency sound (5–20 MHz) [3] is generated through conversion of electrical energy to sound by piezoelectric elements in a transducer [3]. This sound is emitted in waves from a transducer (or probe), directing the sound waves through matter toward the joint or feature of interest. The properties of both sound (frequency) and bodily tissue (acoustic impedance) will affect how the waves travel through the body [3]. For example, high frequency sound has a short wave length and limited depth penetration compared with sound waves of a lower frequency [3]. Sound travels at the same velocity through blood, muscle and fat, but undergoes more absorption and scatter in soft tissue than fluid, such as synovial fluid and blood, that transmit sound very well [3]. Similarly, although sound travels through bone with high velocity, the high density and resulting high acoustic impedance of cortical bone means sound tends to be reflected and absorbed, but not transmitted; hence US can image only the surface of bone and not underlying structures [3]. Variable amounts of sound waves are reflected as echoes when they meet the interface of two tissues. The reflectivity of an interface is greatest when the two tissues have very different acoustic impedances [3]. For example the interface between bone and fat is very reflective. Echoes returning to the source/probe are recognized and amplified in the scanner [3]. The returning echoes are displayed as a two-dimensional image in shades of grey (grey scale: GS) on a monitor [3]. Higher intensity signal is displayed as brighter dots on the screen, and is referred to as hyperechoic: no or low intensity signal appears blacker and is termed anechoic or hypoechoic (Figure 1).

The Doppler effect is utilized in rheumatological US to identify inflammation [4–7]. The Doppler effect is that a frequency shift occurs when transmitted sound is reflected by a moving object (i.e., an erythrocyte) [8]. The altered frequency of the returning echo can be recognized and displayed as color on a monitor. In the medical setting, the Doppler effect is largely utilized to identify, for example, blood cells traveling through vessels [9,10].

Doppler may utilize either color or power modalities. Color Doppler provides information about flow direction and velocity, and power Doppler provides

quantitative information about flow volume. Power Doppler is theoretically more sensitive to low levels of blood flow than color Doppler [8]. In the setting of an inflamed joint, information about the amount of vascularity, rather than the direction or speed of blood flow, is generally of more interest to the clinician [8]. However it has been suggested that with modern, high end imaging technology, for uncertain reasons, the sensitivity of each modality will depend on the machine, and cannot be determined theoretically [8].

Does US provide valid pathoanatomical information?

Synovial joints are the most common type of joint in the human body and most relevant to rheumatic diseases. They are composed of two surfaces that are lubricated to create frictionless surfaces as they slide over each other. Synovial joints are stabilized by ligaments and fibrous tissues, activated by the motion of muscles and tendons, and cartilage and synovial fluid allow cushioning and frictionless movement. US is able to provide detailed anatomical images of joints, demonstrating pathology, which appears to be valid, when using histology or other imaging techniques as comparators.

Synovium & synovial fluid

The synovium (a thin lamellar layer of cells lining the joint) covers all surfaces of the synovial joint except the cartilaginous portion. The normal synovium is between 1 and 3 cells thick, which is below the resolution of US; synovium is usually detectable by US only when it is abnormally thickened. Inflamed synovium becomes hypertrophied, with cellular infiltrates and vascular proliferation [11]. Synovitis is a generic feature of joint inflammation, with histological studies demonstrating that synovial pathology does not differ significantly between rheumatic diseases [12]. Pathological synovium can be detected by grey scale US as being thickened and flattened, or displaying prominent villi (Figure 1) [13,14]. In 2005, collaborating international experts under the umbrella of OMERACT (Outcome Measures in Rheumatology Clinical Trials) defined the US appearance of synovial hypertrophy (Figures 1 & 2, & Table 1) [15]. This definition was developed with reference to RA, but has since been widely applied to other rheumatological conditions such as osteoarthritis (OA) and gout [16]. US determined synovial morphology (thickened, flattened or villous, overlapping layers) at the knee joint has been shown to correlate well with arthroscopic findings [13,14,17]. Additionally, US performs comparably to MRI in studies examining the small joints of the hand [18], knees [19–22] and the acromio-clavicular joint [23].

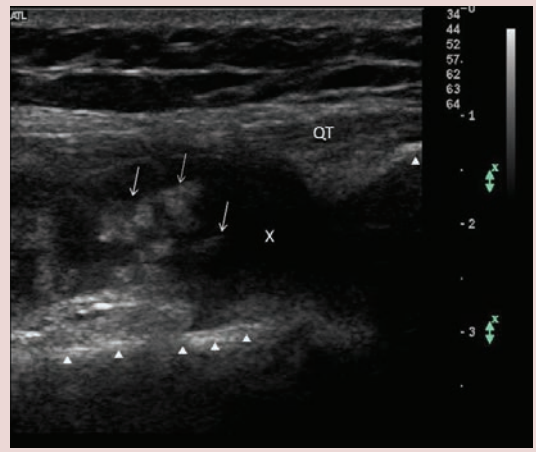

Figure 1. Knee synovitis. The fluid appears anechoic (X). The cortical bone of the femur (bottom left) and patella (far right) is hyperechoic (arrowheads). In this image, the quadriceps tendon is relatively hypoechoic to the surrounding tissue (QT). Note the villous like synovial hypertrophy (arrows) and fluid (X) in the supra patellar pouch.

Occasional studies (generally focusing on the small joints of the hand or feet) have found US to be either equivalent or more sensitive to grey scale synovitis than MRI [24]. Generally MRI detects more synovitis than US, particularly in regions poorly accessible with the US probe, such as the intercarpal and carpometacarpal joints [25,26], whereas US performs comparably to MRI in the joints easily accessible by US (such as the 2nd and 5th metacarpophalangeal [MCP] joints) [26]. In addition to morphological changes, synovial vascularity can be detected by US through application of the Doppler technique, generally considered to be a surrogate of inflammation as evidenced by histological studies [4–7]. Histological studies have demonstrated that synovial Doppler signal correlates with vascularity and histological features of inflammation [4–6]. Additionally, US Doppler score in RA wrists correlated with bone marrow edema score on low field MRI [27].

Fluid collections within the joint can also be detected by US. The OMERACT US taskforce have defined synovial fluid (Figure 2 & Table 1). US detected synovitis may refer to both grey scale synovial hypertrophy and fluid with or without the presence of Doppler signal. US detected effusions have been confirmed by aspiration of fluid in a variety of joints including the small joints of the hand and the gleno-humeral joint [28–31]. Additionally, US has been demonstrated to reliably detect fluid injected into cadaveric ankles (providing the volume was greater than 2 ml) [32]. Hoving found that US detected more joint effusions than MRI in RA MCP and wrists joints, and was more sensitive to the presence of small joint effusions [25]. In contrast,

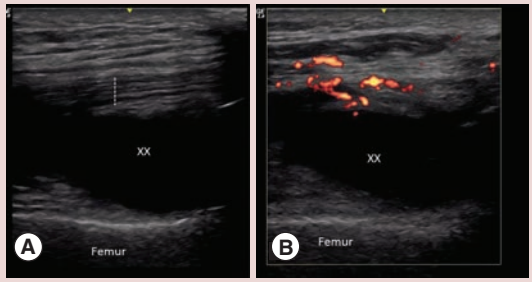

Figure 2. Knee synovitis. Longitudinal ultrasonography images of the **(A)** suprapatellar pouch full of fluid (XX) and the overlying quadriceps tendon (dotted line) and the **(B)** medial recess with fluid demonstrating power Doppler signal in a partially treated septic joint.

at the ankle, Jacobson found that a 1 ml effusion could be detected by MRI, and 2 ml of fluid was required for US to reliably detect effusion occasionally by US [32].

Bone

Cortical bone is highly echogenic, appearing as a uniform, continuous bright echogenic line [33]. Pathology is easily recognizable with US. The OMERACT US taskforce have published a definition of the rheumatoid erosion (Figures 3 & 4, & Table 1). Ultrasound detected erosions as seen in OA [34,35], cortical irregularities [35,36], osteophytes [33,35,37–39] and enthesophytes [40] have all been described. The OMERACT US taskforce are working toward definitions of osteophytes, cortical irregularities and erosions in other rheumatic conditions such as gout and OA.

Erosions have to date been the most studied pathology; the ability of US to detect erosions has been validated against computed tomography (CT, the imaging gold standard for cortical defects) [41] and MRI [42,43] with good sensitivity and specificity. The sensitivity of US depends on the characteristics of the cohort and the joints imaged. In RA several studies have found US to be most sensitive in joints that are easily accessible with the US probe, such as MCP2 and MTP 1 [44–46], and conflicting results have been found regarding the sensitivity of US in detecting bone erosions in OA [34,42,47].

Cartilage

Cartilage is a matrix of collagenous and elastic fibers interspersed with chondrocytes. The high water content gives cartilage a hypoechoic quality when imaged with US, although as previously discussed; visualization is limited to joints where an acoustic window allows transmission of sound waves. For example, if the knee joint is flexed to 90°, this brings the cartilaginous portion of the distal femur into visualization, as the patella moves relatively distal. Cartilage normally appears as a smooth, homogeneous, hypoechogenic band overlying cortical bone [33]. Several alterations to the US appearance of cartilage have been described in the literature [37,48], including loss of the clarity of the superficial border of cartilage, heterogeneity of the cartilage echo texture, irregularities in thickness and increased echogenicity of the cartilage/bone interface. While US can provide both qualitative and quantitative information about cartilage structure, the clinical relevance is uncertain. Because cartilage is generally intra-articular, due to the lack of an acoustic window, accessing the central load bearing cartilage in a joint is difficult to achieve, even when joints are fully flexed. Additionally, overlying structures such as the patella or osteophytes can create acoustic shadows (see image 6 for an example of a shadow) that further hinder visualization of cartilage *in vivo*.

Animal and human *in vitro* models have been used to demonstrate that US is reliable in measuring cartilage thickness and identifying focal chondral defects [49,50] compared with direct visualization and histological examination. The ability of US to determine cartilage thickness has been found to be reasonably sensitive

Table 1. US detected pathology and outcome measures in rheumatology clinical trial definitions.

Pathology	OMERACT definition
Synovial hypertrophy	Abnormal hypo echoic (relative to sub dermal fat, but sometimes may be iso echoic or hyper echoic) intra articular tissue that is non displaceable and poorly compressible and which may exhibit Doppler [15]
Rheumatoid erosion	An intra-articular discontinuity of the bone surface that is visible in two perpendicular planes [15]
Tendon lesion	Internal and/or peripheral focal tendon defect (i.e., absence of fibers) in the region enclosed by tendon sheath, seen in two perpendicular planes [74]
Enthesitis	Abnormally hypoechoic (loss of normal fibrillar architecture) and/or thickened tendon or ligament at its bony attachment (may occasionally contain hyperechoic foci consistent with calcification), seen in two perpendicular planes that may exhibit Doppler signal and/or bony changes including enthesophytes, erosions or irregularity [15]
Tenosynovitis	Hypoechoic or anechoic thickened tissue with or without fluid within the tendon sheath, which is seen in two perpendicular planes and which may exhibit Doppler signal [15]

compared with MRI in OA knees [19,22,51] and correlate with radiographic surrogates of cartilage loss in the MCP and proximal interphalangeal (PIP) joints of subjects with OA [52].

Other cartilage pathologies include identification of crystal deposition in gout [17,21,24,30] and calcium pyrophosphate deposition (CPPD) [18,19,21,29]. However imaging cartilage is perhaps of less interest than other joint structures in the management of RA (the focus of this review).

Tendons

The visibility of tendons by US is dependent on the tendon site, size and to some extent whether or not it has a sheath. The normal US appearance of tendons is of longitudinally aligned, tightly packed linear echoic structures (generally termed fibrillations), which appear as dots in the transverse plane [53]. The tendon border should be sharp and regular [53]. Tendon integrity, including tears, can also be assessed, comparing the echogenicity, size and vascularity of the tendon with what a normal tendon looks like [53]. A range of abnormalities can be imaged with US, including loss of homogeneity or interruption of the fibrillar pattern, thickening of the tendon, loss of the sharply defined tendon margins, hyperechoic intratendon calcifications and peri-tendinous hypoechogenicity, consistent with edema [53]. The OMERACT US taskforce have defined tendon lesions (Table 1). Few studies directly compare US against other imaging techniques [54], however a relatively old study utilizing techniques from prior to 1997, found that US was slightly better than MRI at detecting partial tendon tears in the fingers, but both imaging modalities lacked sensitivity compared with surgical exploration [55]. Similarly, a recent Cochrane review found that US and MRI performed comparably in detecting tendon tears in the rotator cuff, but that both tools lacked sensitivity in detecting partial tears [54].

An inflamed tendon sheath (tenosynovitis) can be easily detected as thickening of the sheath and/or fluid within the sheath [53,56,57]. The OMERACT US taskforce have defined tenosynovitis (Figure 5 & Table 1). Tenosynovitis, when present can augment visualization of the tendon substance by US, as the pathological halo of fluid around the tendon juxtaposes materials of dissimilar acoustic impedances thus increasing the reflectivity of the interface. Studies in early RA showed that US was able to detect more tendon sheath effusions than MRI, but more tendon abnormalities were seen overall with MRI compared with US at the wrist joint [25].

Enthesis

Enthesitis has also been defined by the OMERACT US taskforce (Figure 6 & Table 1). The definition recognizes pathology within the cortex and the tendon [15].

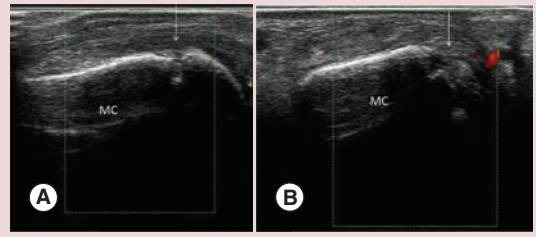

Figure 3. Erosion. An ultrasound image of the right distal MC, demonstrating an erosion (cortical break; arrow) in longitudinal **(A)** and transverse **(B)** planes. Note the absence of Doppler signal (color) in the vicinity of the erosion.
MC: Metacarpal head.
For colour images please see online www.futuremedicine.com/doi/full/10.2217/IJR.14.54

In addition to this definition, it has been recognized that bursitis may occur [58]. Assessing the validity of US in detecting enthesitis against other imaging techniques is difficult, because US measures both inflammatory change (unable to be visualize with CR) and chronic structural changes (not optimally imaged by MRI), and the gold standard of comparison with histopathology would be challenging [59]. However, comparisons between US and CR have shown high concordance in detecting the structural changes of calcification and enthesophytes [60]. Comparisons between US and MRI have shown that both the US and MRI are able to detect tendon thickening, but that MRI may be better at detecting associated bursal inflammation [61]. However, in early disease US may be a better test [62], as MRI is less sensitive at detecting calcification associated with structural changes and fatty degeneration until late in the disease process [63].

Other pathologies

US is able to image other pathoanatomical features that are of use in rheumatic diseases, such as nerve pathology (neuromas, carpal tunnel syndrome) [64,65],

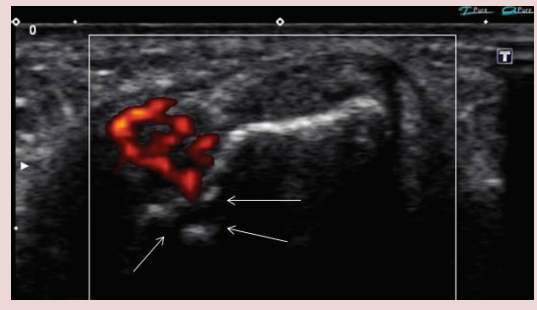

Figure 4. Erosion and power Doppler positivity. Transverse ultrasound image of the ulnar styloid with an erosion (cortical break; arrow) and power Doppler signal adjacent to and within the erosion.

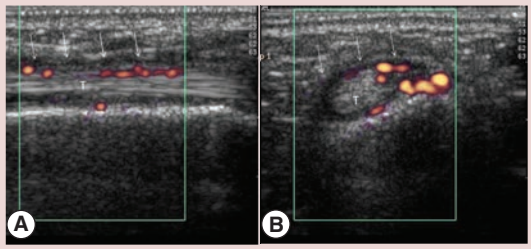

Figure 5. Tenosynovitis. Ultrasound image of the extensor carpi ulnaris tendon (T) in longitudinal **(A)** and transverse **(B)** demonstrating a tendon with a hypoechoic rim (arrows) with power Doppler signal (red color).

bursae [61,64,66,67] and soft tissue nodules (rheumatoid lesions, tophi) [68–70].

Is US reliable & repeatable?

US is often criticized as being operator dependent and subjective, suggesting it has poor reliability. Several systematic reviews have been published focusing on this issue. Joshua examined aspects of intraoccasion, intraobserver and interobserver reliability in two systematic reviews, one examining grey scale synovitis (2006), and the other Doppler signal (2007) [10,71]. Most striking was that reliability was rarely reported, particularly with regards to interacquisition reliability, but also with regards to rereading stored images [10,71]. However when reported, reliability was more than acceptable, with kappa's generally of a value that can be considered substantial or almost perfect [72]. This may reflect a publication bias, or merely a lack of available data due to a lack of recognition of the importance of this information. Since these reviews, there has been a recognition by the rheumatology US community that there was a need to document the reliability of US in detecting other pathologies (such as erosions, tendon lesions) [21], assess agreement between more than 2 observers and assess intermachine reliability. The OMERACT US taskforce and the EULAR US group have undertaken a series of exercises to address reliability. Acceptability of inter- and intrareader reliability has been documented for US detected synovitis and effusions [21,73], tendon lesions [21,73,74] tenosynovitis [73], enthesitis [21] and erosions [21,73].

The reliability of reading stored/still images remains higher than reliability requiring the images to be reacquired [75], confirming that reliability remains an issue in a highly skilled, operator dependent technique. However, the ongoing work by the OMERACT taskforce to define elemental lesions and develop scoring systems has led to improvements in this metric, and will likely to improve the acceptability of US as a clinical and outcome tool in the wider medical community.

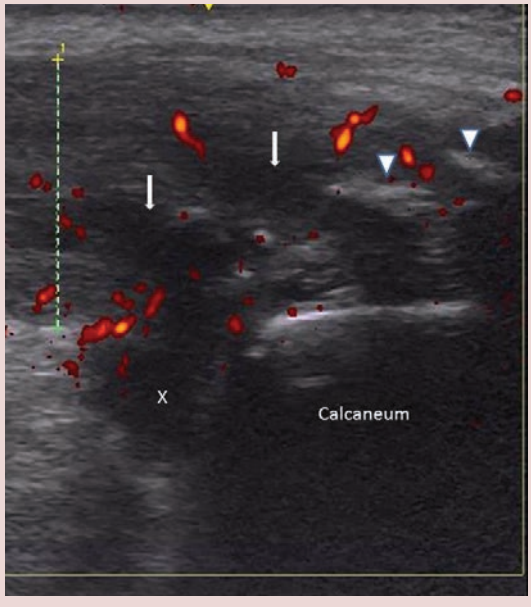

Figure 6. Enthesitis. Ultrasound of the Achilles tendon (dashed line) into the calcaneum in the longitudinal plane demonstrating a thickened tendon with loss of fibrillar architecture, a heterogeneously hypoechoic appearance (arrows), hyperechoic foci of calcification (arrowheads) with underlying hypoechogenicity, consistent with acoustic shadowing. Doppler signal (red color), note there is a small retro-calcaneal bursa (X).

Does US provide information in addition to what can be gained from history, clinical examination & conventional investigations?

Ultrasound consistently detects more synovitis and joint effusions than clinical examination [13,45,46,76–82]. Additionally, US is more sensitive to erosive change than CR; it is able to detect smaller erosions in early disease in people with normal radiographs. The EULAR recommendations for the use of imaging in the clinical management of rheumatoid arthritis report that US detects 2.2-fold more synovitis at the wrist and hand than clinical examination [83]; US provides a more accurate assessment of joint inflammation than clinical examination. The recommendations also suggest that US should be used to detect erosions if CR appears normal [83]. US can demonstrate pathology that is subclinical, or not apparent on routine CR, and assist in obtaining a more accurate indication of pathology.

The clinical utility of US can be considered in terms of localized pathology and systemic diseases.

In the setting of localized pathology, US has been shown to alter the site specific diagnosis in the majority of patients imaged, and affect the management plan [26,84,85], resulting in improved short term outcomes [85].

US has been utilized to guide local intervention. It has been shown that US guided injections are more accurate [31,86], and that more fluid can be aspirated if US guided [28]. Generally, more accurate injections are more efficacious [87,88], however it is unclear whether using US to guide injections translates to real long term benefits. A meta-analysis of 6 studies investigating shoulder pathology found that US guided injections resulted in better short term outcomes, but the differences may not represent clinically meaningful changes [89]. Additionally, a Cochrane review found no advantage of utilizing US to guide injections [90]. Theoretically, if a procedure is done under direct visualization, and is more accurate, it might have a lower incidence of adverse effects, such as damaging nearby structures, but this has not been tested in clinical studies.

The EULAR recommendation on the use of imaging in the clinical management of RA recommend when there is clinical doubt, utilizing US or MRI may improve the diagnostic certainty of RA [83]. If there is doubt over the presence of clinical synovitis in the setting of early RA, imaging is recommended in the revised ACR/EULAR diagnostic criteria [91]; indeed, it has been demonstrated that utilizing US improves the sensitivity and specificity of these revised diagnostic criteria [92]. Additionally, identification of synovial inflammation has prognostic significance, as in undifferentiated disease, this can predict progression to RA [93–95].

US has been shown to alter management as a result of the detection of subclinical synovitis, or a revised local or systemic diagnosis [77–79,84,85,96]. Additionally, in rheumatoid cohorts on treatment, US detected synovitis and Doppler signal, which are seen surprisingly frequently predict radiographic progression at follow-up [97]. Additionally, PD signal has been shown to predict relapse in remission cohorts [98]. Whether utilizing US to diagnose and guide management decisions results in long term benefits for patients with inflammatory arthritis is uncertain. However, the Targeted Ultrasound Initiative is currently undertaking a multicenter RCT utilizing US to guide management decisions to investigate this concept [99,100].

Is US feasible, available & accessible to the clinician?

While CR remains integral to the management and diagnosis of rheumatic conditions, the images obtained are two-dimensional representations of three-dimensional structures, and provide limited information about soft tissue components of the synovial joint, such as synovium, capsule, ligaments and tendons [101]. In contrast, newer imaging techniques allow many joint structures to be imaged, including soft tissue, in multiple planes. US has benefits over other imaging modalities, such as MRI or CT; it is relatively inexpensive, portable and lacks ionizing radiation, and does not require the use of intravenous contrast agents. These features mean that it is feasible for a clinician to use US in his or her rooms. The potential exists for the treating clinician to perform the US and interpret the images in real time, in his or her clinic rooms, with the patient present. This has the obvious advantages of allowing dynamic maneuvering of joints, while obtaining further information about symptoms [101]. Additionally, US can be repeated over time with little risk and inconvenience to the subject.

The caveat is that performing US in the clinical setting requires the clinician to develop and maintain competency, which is a time consuming and potentially expensive process, and that the ongoing use of US within the clinician's clinic is also time consuming. Several different organizations have created training courses to enable rheumatologists to develop competency in US. These range from short, intensive theoretical and practical workshops to long term portfolio driven 'apprenticeships'. It is uncertain what level of training is required to obtain competency. A rheumatology unit in Belfast found that without formal training, rheumatologists all developed general competency over a 5 year period [102], in contrast, in a more formalized training setting, an inexperienced doctor has been demonstrated to be able to achieve images sufficient for clinical use after a 2 h demonstration, followed by 24 nonconsecutive hours of scanning [103]. If the level of competency is reduced to that of being able to identify a single pathological feature in one joint (synovitis at the hip joint) then this has been shown to be achieved within hours of supervised training [104]. US training by rheumatologists is known to be varied, with few having undertaken formal competency assessments [105]. Being able to identify a single pathology in a single joint is of questionable clinical utility, and in reality training in US should almost certainly be a longer, supervised training framework. While supervised training in US is achievable for trainees, this is likely to expensive for qualified rheumatologists who would have to commit time, and perhaps pay a supervisor. Additionally, a machine, although increasingly affordable, remains a large upfront cost, however ongoing running costs are low.

Rheumatological US within the clinical setting performed by the clinician is generally considered to be feasible. A questionnaire of rheumatologists attending the EULAR annual scientific meeting in 1999, found that 40% of respondents were using US in their practice. A further 45% expressed interest in using it

in their clinical practice [106]. More recently, a Europe-wide questionnaire regarding the uptake of US by rheumatologists found that US was practiced by rheumatologists in the majority of countries, but that less than 10% of rheumatologists routinely perform it in clinical practice. Rheumatological US was part of the rheumatology training curriculum in over half the surveyed countries, suggesting the practice may increase in the future in the clinical setting. Since this time, the uptake of US by rheumatologists in North America and South East Asia is also increasing, evidenced by the increasing number of instructional courses and workshops aimed at rheumatologists offered by national rheumatological societies, and other imaging bodies.

Future perspective

As the training and uptake of US by rheumatologists increases across the globe, it is becoming part of routine clinical practice for increasing numbers of rheumatologists. It is known to be useful in the diagnosis, and management of RA, and further studies will ascertain whether this translates to improved outcome for our patients. The pathoanatomical findings discussed above are applicable to other joint disease other than RA, including OA, gout and psoriatic arthritis, and studies are underway to define pathological domains, and develop valid, reliable scoring systems. Clinical studies will also assist in determining the clinical utility of US in these other forms of arthritis.

In addition to imaging musculoskeletal structures, rheumatologists have been utilizing US to image bloods vessels in the setting of temporal arteritis, although to date, biopsy remains the gold standard in diagnosis. The submandibular US may prove to be a practical alternative to parotid sialography and other invasive measures in the diagnosis of primary Sjogren's syndrome [107]. Elastography for assessing skin stiffness in scleroderma, fusion technology, mapping one type of imaging to another and the use of contrast agents to increase US sensitivity are all ongoing developments relevant to rheumatologic US [1]. Additionally, technological advances such as 3D probes may improve the integrity of acquiring images, and rereading stored images, and fusion technology allows different imaging techniques to be overlaid (such as an US image of an MCP over an MRI of the same joint) [108].

It is likely that in 5–10 years rheumatological US will be more widespread; as trainees understand the usefulness of this clinical tool in tertiary training settings, and take this skill with them into future practice wherever it may be. It is likely that technology will become increasingly affordable, for example, a three-dimensional probe at present is prohibitively expensive for many community rheumatologists, but would likely significantly improve the ease of obtaining images. Improving technology, along with improved accessibility will likely contribute to the spread of rheumatological US.

Conclusion

US is able to provide detailed pathoanatomical information that is valid, repeatable and relatively comparable. It is of clinical value, providing information in addition to that obtainable clinically, alters management and aids intervention. It is becoming increasingly accessible and available to the clinician. It is a technique which is evolving and further studies will demonstrate whether it results in improved outcomes for our patients. Ongoing research will continue to contribute to understanding of disease, application of new technologies and defining the place of US in rheumatology practice.

Executive summary

- Medical ultrasonography (US) is a technology that relies on emitted sound waves returning as echoes to image structures within the body.
- US can be utilized to image normal musculoskeletal anatomy and identify pathology such as synovial inflammation, joint effusions, bursitis, erosion, osteophytes, cartilage loss, urate and other crystal deposition in cartilage, tendon pathology and enthesitis, amongst others.
- These pathologies have been extensively, yet somewhat variably validated against histology and other imaging techniques.
- The rheumatological US community has responded to reliability concerns by defining pathology relevant to arthritides commonly managed and demonstrating reliability.
- US is more sensitive to synovitis than clinical examination, and more sensitive than X-ray to structural damage.
- US has been demonstrated to alter the site specific diagnosis, systemic diagnosis, and improve the performance of the diagnostic criteria for RA.
- US is increasingly accessible to the clinician, and feasible to undertake in the clinical setting.
- In the future the use of US in rheumatology is likely to be more widespread, and our understanding of its role in clinical practice better understood.

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Papers of special note have been highlighted as:
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Rheumatological ultrasonography: a focus on arthritides

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Activity evaluation: where 1 is strongly disagree and 5 is strongly agree.					
	1	**2**	**3**	**4**	**5**
The activity supported the learning objectives.					
The material was organized clearly for learning to occur.					
The content learned from this activity will impact my practice.					
The activity was presented objectively and free of commercial bias.					

1. You are seeing a 55-year-old woman referred to your clinic for possible rheumatoid arthritis after 3 months of increasing pain in her hands bilaterally. Radiographs of her hands were taken, which failed to show significant pathologic changes. You consider conducting further imaging with ultrasound. Which of the following statements regarding ultrasound in the evaluation of arthritis is ***most*** accurate?
   - ☐ **A** Ultrasound is less sensitive than clinical examination in detecting joint inflammation overall
   - ☐ **B** Ultrasound is less sensitive than clinical examination in detecting joint effusions
   - ☐ **C** Ultrasound is more sensitive than conventional radiographs in the detection of early erosive joint change
   - ☐ **D** There is no evidence that using ultrasound to evaluate joints changes disease management

2. You initiate ultrasound evaluation of this patient's joints. Which of the following statements regarding synovial findings in arthritis is ***most*** accurate?
   - ☐ **A** Even normal synovium is usually visualized well with ultrasound
   - ☐ **B** Thickened synovium on ultrasound is highly specific for rheumatoid arthritis
   - ☐ **C** Ultrasound generally detects more synovitis than magnetic resonance imaging (MRI), especially at the intercarpal joints
   - ☐ **D** Ultrasound is reliable in detecting fluid collections in joints

3. Which of the following statements regarding ultrasound imaging of the bone and cartilage is ***most*** accurate?

- ☐ **A** Ultrasound lacks sensitivity and specificity for joint erosions compared with computed tomography
- ☐ **B** Reduced echogenicity of cartilage is the usual pathologic sign of arthritis
- ☐ **C** The clinical value of ultrasound in the imaging of cartilage remains uncertain
- ☐ **D** Joint flexion is sufficient to allow full view of central articular cartilage

4. What are some of the potential barriers to applying ultrasound for this patient?

- ☐ **A** No research has documented inter-reader reliability of ultrasound for synovitis and joint effusions
- ☐ **B** No research has documented intrareader reliability of ultrasound for synovitis and joint effusions
- ☐ **C** A minority of rheumatologists routinely practice ultrasound
- ☐ **D** Maintenance costs of ultrasound technology are frequently high