Ultrasonography in rheumatology: an evolving technique

Ultrasonography (US) has proved to be an excellent technique for a quick, efficient, and accurate evaluation of soft tissues involvement in rheumatic diseases. US is a powerful tool to look around or inside joints, or both, tendons, muscles, bursae, and nerves. Skin, salivary glands, parathyroids, and small and large vessels are other interesting targets of US in rheumatology. The main advantages of US, with respect to other imaging techniques, include absence of radiation, good visualisation of the joint cavity, low running costs, multiplanar imaging capability, quantification of soft tissue abnormalities. Moreover, US is rapidly performed and readily accepted by patients.

US is not a new technique, but it has undergone relatively little clinical evaluation in rheumatology (compared with other imaging techniques) because of the paucity of sonographic units in rheumatology departments and of rheumatologists capable of performing a sonographic examination.

Most ultrasound equipment is available in radiology departments and musculoskeletal ultrasonography is mainly performed by radiologists even if few of them have a specific interest in rheumatic diseases.

Over the past few years, an increasing number of rheumatologists has started to utilise ultrasounds in their daily clinical practice. Although there is great potential for US in rheumatological clinical activity, most rheumatologists are not familiar with US and many are hesitant to attempt a direct approach. This reluctance may be related to several factors including lack of adequate anatomical knowledge (anatomophobia is a common syndrome among many rheumatologists), the lack of interest and of expertise in pathoanatomy, the discouraging impact of untrained attempts to have a first direct sonographic experience, and the initial cost of a high quality sonographic equipment (not less than $65 000).

At present, US is still a tool in search of a job in rheumatology, but it seems to have many of the features of a big bargain. There is now considerable evidence that the role of US imaging in diagnosing and monitoring musculoskeletal diseases is growing year by year and that US routinely done by rheumatologists should be encouraged.[1 2]

In 1996, in Italy, a specific training in ultrasonography has been introduced in the new teaching programme of the postgraduate school that specialises in rheumatology. The new guidelines indicate that trainees do a minimum threshold number of 50 sonographic procedures and assist to a total number of 200 sonographic examinations. This is a relevant step for achieving adequate competence and skills in sonographic imaging for the future.

However, a number of problems have to be considered. They include the risk of underutilisation of sonographic equipments in rheumatology departments, the possibility of conflicts of interest with self referrals for ultrasound examinations of rheumatic patients, and the possibility of competition between radiologists and rheumatologists for the performance of sonographic imaging examinations. The best way to expand our knowledge of musculoskeletal ultrasound and to avoid any competition is to promote a didactic and scientific joint venture between radiologists and rheumatologists. This could dramatically improve diagnostic accuracy and clinical usefulness of US, which is the most operator dependent imaging technique available today.

Technique

Over the past few years many technical barriers to a more widespread use of US in rheumatology have been removed. Sonographic equipment has evolved considerably and the solution of many problems (for example, inadequate spatial resolution) has provided the opportunity for an increasingly refined analysis of anatomic details.

High frequency linear transducers (7.5, 10 MHZ) greatly enhance the potential role of US in non-invasive evaluation of soft tissue involvement in rheumatic diseases. Moreover, the current availability of very high frequency transducers (13, 15, 20 MHZ) allows highly accurate and precise quantification of fine anatomic details even on small joints such as metacarpophalangeal, proximal, and distal interphalangeal joints. The main limitation of the very high frequency transducers is the low penetration power of the ultrasonic beam. Twenty MHZ transducers have an axial resolution power of 0.038 mm, but do not allow an assessment of structures deeper than 1.5 cm.

The multiplanar imaging capabilities of US allow many views of the selected area, so an individual examination can be tailored to the clinical problem.

Colour Doppler and power Doppler sonography are recently available procedures with interesting perspectives of morpho-functional assessment.

Power Doppler sonography has proved to be a useful tool for evaluating soft tissue hyperaemia[3] and is of practical value in distinguishing inflammatory and infectious musculoskeletal fluid collections from those that are non-inflammatory.[4]

By combining power Doppler sonography with three dimensional technology, and sonograpic contrast enhancement, it may be possible to detect other interesting features such as blood flow in vessels with diameter of less than 1 mm, abnormal vessel architecture, areas of segmental infarction.[5]

A "gold" sonographic examination requires: (1) a deep knowledge of the clinical setting and of the specific questions that need to be answered; (2) a contextual clinical and sonographic assessment; (3) a trained mastery of the technical art of scanning; (4) a deep knowledge of sectional anatomy; (5) a high quality ultrasound equipment.

Knowledge of limitation and pitfalls of US is needed to avoid incorrect use and inappropriate interpretation of results. Operator dependency, limited field of view of some anatomic areas because of the lack of adequate "acoustic windows" are the main shortcomings of US. Potential pitfalls of musculoskeletal US in daily clinical practice are mostly related to misinterpretation of normal anatomy and to errors because of technical limitations.

General use and clinical indications

There are only a few reports in the medical literature describing the use of US for assessment of rheumatic diseases. Thus, both the sensitivity and specificity of US imaging of the musculoskeletal system are yet to be determined and there are no agreed guidelines. However, visualisation of soft tissues in a patient with clinical symptoms is undoubtedly helpful in routine clinical practice in the initial evaluation of the patient with a variety of rheumatic diseases including rheumatoid arthritis,[6] spondylarthritis,[7] osteoarthritis,[8 9] regional pain syndromes,[1] tendinitis,[10] bursitis,[11] synovial cysts,[12] Sjögren's syndrome,[13] systemic sclerosis,[14] temporal arteritis,[15] Tietze's syndrome,[16] dialysis related amyloidosis,[17] Behçet's disease,[18] rib fractures.[19]

US should be regarded as an extension of the clinical examination to otherwise inaccessible anatomic structures.[20] US allows an anatomic diagnosis instead of a syndromic diagnosis in several clinical situations (for example, shoulder pain, achillodinia).

The direct depiction of musculoskeletal fluid collections and synovial hyperthrophy seems to be a clear advantage of US compared with conventional radiology.

Joint or tendon sheath effusions and synovial proliferation can be shown and regionally assessed. US may be used to assist needle positioning within the selected target area and to facilitate arthrocentesis. Sonographic guidance makes easier intra-articular therapy and may help avoiding tissue injury (tendon or nerve) and associated complications (that is, intratendinous injection of corticosteroid, which has a high risk of tendon necrosis). US is also useful in the preoperative examination of patients undergoing synoviectomy or other surgical procedures and in the postoperative follow up.

Tendon

US is of relevant practical value for evaluating the integrity of tendons in rheumatic diseases. Normal anatomy of tendons is easily visualised on conventional sonograms. On longitudinal scans, when the transducer is perpendicular to the tendons, they show a typical internal network of linear fibrillar echoes (fig 1B). Conversely, when the ultrasonic beam is oriented obliquely to the tendons major axis, they show an artefactual anechoic pattern because of the lack of visualisation of the echogenic fibrils.

Homogeneous thickness, uniform fibrillar echotexture, and sharply defined echogenic margins are the main features that should be evaluated to exclude tendon inflammation, degeneration or rupture, or both.

The echogenic fibrils are the sonographic features of the endotendineum septa.[21] Loss of the fibrillar echotexture is always an abnormal finding. It can range from a diffuse blurring of the tendon texture to focal aspects of fibrillar interruptions. Very thin fibrils (<0.1 mm) can be depicted with 20 MHZ transducers.

Sonography may show evidence of tendon sheath widening resulting from effusion (anechoic pattern), proliferative synovitis (echoic pattern) or both (mixed pattern).[10] Other sonographic features of tendon involvement include irregularity of the tendon margin (irregular and/or blurred contour of the tendon), discontinuity of the tendon (partial or complete tendon tear), synovial cyst (circumscribed hypoechoic distension of the tendon sheath).

US allows visualisation of tendons both in a static and a dynamic manner. This permits a wide range of special views. A dynamic evaluation can be used for a better detection of the various tendons and to explore the mobility of the tendon within its sheath.

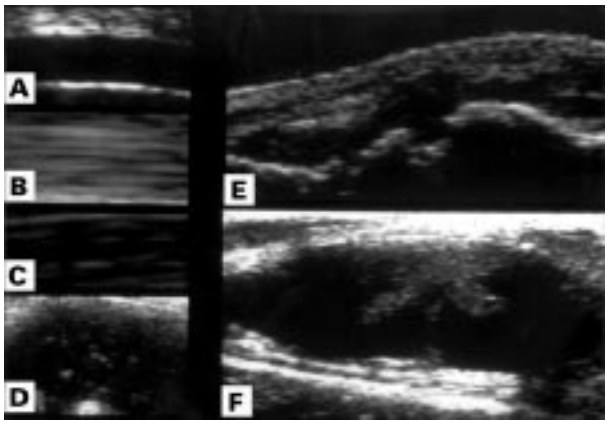

Figure 1 (A) Condylar cartilage in a healthy subject (transverse scan with a 7.5 MHZ linear transducer at the superior margin of the patella). Cartilaginous band is homogeneously hypoechoic with sharp inner and outer margins. (B) Normal appearance of finger flexor tendons (longitudinal scan with a 13 MHZ transducer). Note the typical fibrillar texture. (C) Median nerve in a healthy subject (longitudinal scan with a 13 MHZ transducer). Nerve echotexture is characterised by subtle, discontinuous hyperechoic bands on a hypoechoic background. This fascicular pattern can easily be differentiated from the fibrillar pattern of tendons. (D) Popliteal cyst in a patient with chondrocalcinosis (longitudinal scan with a 13 MHZ transducer). The small echoic (white) spots on the background of the anechoic (black) synovial fluid can be regarded as aggregates of calcium pyrophosphate dihydrate crystals. (E) Rheumatoid arthritis (longitudinal dorsal scan of a metacarpophalangeal joint with a 13 MHZ linear transducer). Note the joint space widening and the small erosion of the metacarpal head. (F) Small, superficial popliteal cyst (longitudinal scan with a 20 MHZ sector transducer) with clearly evident polipoid synovial hyperthrophy.

Joint space

US, as well as magnetic resonance imaging, has the ability to differentiate intra-articular and extra-articular soft tissue structures, achieving anatomical definition of several otherwise unmatched lesions.[20]

Joint space widening is the most common sonographic finding in patients with arthritis (fig 1E). Three different types of capsular distension can be distinguished on the basis of the joint cavity echogenicity: (1) anechoic homogeneous widening indicating joint effusion. Findings from US allow accurate and rapid evaluation of even small amount of synovial fluid within a joint. Moreover, joint effusion can be easily aspirated under sonographic guidance; (2) homogeneous echoic widening indicating synovial proliferation. Irregular clusters of soft echoes are a typical appearance of the proliferative synovium (high concentration of proteinaceous material may mimic the sonographic pattern of synovial hyperthrophy); (3) irregularly echoic widening with small anechoic areas. This pattern can be interpreted as caused by the combined presence of both effusion and synovial proliferation.

Cartilage

Diagnosing early cartilage damage remains a challenge in daily rheumatological practice. At present, US provides a quick, reliable, albeit imperfect information about the characteristic of articular cartilage without risk and discomfort for the patient.

The sonographic features of articular cartilage have been described in only few papers.[8 9 22–24] The normal hyaline cartilage appears as a well defined hypoechoic layer with four main distinguishing features (fig 1A): (1) the high degree of transparence of the cartilage (relative lack of echoes), because of its high water content; (2) the clear, continuous and sharp cartilage-soft tissue interface (a careful examination is required for an adequate depiction of this subtle hyperechoic rim); (3) the sharp echoic profile of the subchondral bone (the pronounced difference in chemical structure between articular cartilage and subchondral bone allows an easy detection of the bone-cartilage interface that appears as a highly hyperechoic band); (4) the homogeneous width of the cartilagineous band (the precision of quantifying cartilage thickness depends on the ability of the sonographer to detect the cartilage-synovial space interface).

The integrity of the "synovial space-cartilage" interface is the main distinguishing feature of healthy subjects, when compared with patients with osteoarthritis.

Indistinctness of the cartilage margins and/or more severe signs of cartilage and bone involvement corresponding to inflammatory arthritic damage can be detected even in small joints (fig 1E).[6]

Cartilage involvement in osteoarthritis ranges from extensive, easily detectable abnormalities to small subtle findings.[8 22–24]

Loss of the clarity of the cartilage and loss of sharpness of the cartilage-soft tissue interface are clearly evident features even in absence of other sonographic signs of cartilage damage.[8] Loss of cartilage transparency could reflect pathological changes such as fibrillation of cartilage and cleft formation. Blurred and/or irregular margins are the most common sonographic findings in advanced osteoarthritis.

Although standard criteria for assessing ultrasonographic changes of condylar cartilage in osteoarthritis are not yet widely accepted, McCune *et al*[9] reported four main abnormalities in patients with osteoarthritis of the knee that can be regarded as ultrasonographic distinguishing features of the disease at different stages. They include loss of cartilage transparency, reduced sharpness of the anterior cartilage margins, increased intensity of the posterior bone cartilage interface, and cartilage thinning.

The ability of US to non-invasively detect hyaline cartilage defects is clinically important because no other technique allows a cost effective assessment of chondral lesions in rheumatic diseases. Measurement of cartilage thickness is possible. Greater clinical experience will be necessary to understand the significance of the spectrum of sonographic changes in patients with osteoarthritis.

Magnetic resonance with specialised techniques, such as saturation transfer subtraction or fat suppressed T1 weighted imaging, is the only other non-invasive method capable of directly visualising articular cartilage. However, spatial resolution of magnetic resonance is lower than high frequency US and unacceptable error occurs in measuring cartilage thickness in small joints (such as metacarpal cartilage).

Fluid collections

Early work on US in rheumatology mainly focused on identification and localisation of popliteal cysts because of the easy identification of fluid by ultrasounds even with low frequency transducers. The role of US for detecting popliteal cysts is now well established and continues to be an area of considerable interest, with several papers in the medical literature.[12 25] US provides structural details about the content of the cyst (fig 1D, 1F), its communication with the joint space, and the possible compression of adjacent vascular structures. In patients with ruptured cyst, the leakage of contents into fascial planes can be demonstrated by US.

US can be helpful in differentiating cysts from other masses in the popliteal space including vascular lesions (popliteal artery aneurysms), and soft tissue tumours (that is, lymphoma, liposarcoma, neurofibrosarcoma).

The sonographic assessment of popliteal cysts may facilitate the treatment and allows a careful evaluation of the therapeutic response.

Bursae

Bursal involvement in rheumatic diseases is easily detected by US. Presence, distribution and amount of fluid and/or synovial hyperthrophy can be detected and regionally assessed. Synovial fluid can be detected in control healthy subjects and should not be regarded as a marker of disease even when unilateral or asymmetric.[11]

Peripheral nerves

A carefully executed US examination at frequencies higher than 10 MHZ can depict fine anatomic details of peripheral nerves. A typical fascicular appearance (hypoechoic areas separated by hyperechoic bands) that correlates with histological structure has been clearly described.[26] The fascicular pattern of the peripheral nerves can easily be distinguished from the fibrillar pattern of the tendons (fig 1C).

Skin

Sclerotic skin change in patients with systemic sclerosis can be assessed and quantitated. Increased skin thickness has been detected with US even in clinically uninvolved areas.[14]

Conclusions

US in rheumatology is still in its infancy. Although several applications have been successful and have made a contribution to physician education and patient care, much more effort is required to gain all the potential advantages of this elusive but fascinating and challenging technique.

At present, the use of sonographic imaging in rheumatology is generating much research, enthusiasm, disappointment, controversy, and confusion. The reluctance of many rheumatologists to engage in US is the major obstacle to its widespread clinical use. However, several factors indicate that use of US in rheumatological clinical practice is likely to increase dramatically. The advantages to the rheumatologist who can directly perform a sonographic examination are obvious.

The quick quality improvement of sonographic equipment and newer developments such as the use of contrast media will probably open new exciting opportunities for US in rheumatology. Thus, experienced ultrasonographers and standard criteria for US evaluation are urgently needed also to verify if US can be regarded as the right machine for rheumatologists.

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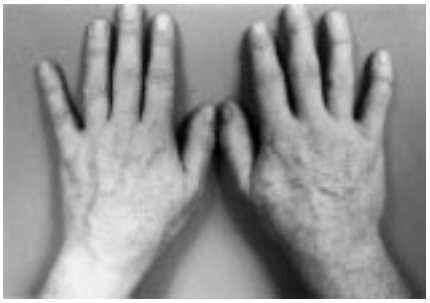
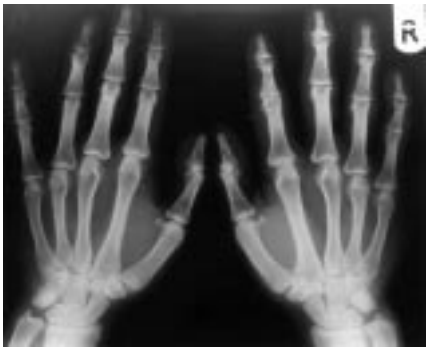
Unusual and memorable

Series editor: Gary D Wright

A 36 year old Royal Marine developed unilateral erosive nodal osteoarthritis after frostbite. In 1984 during winter military exercises while in Norway, inadvertently separated from his comrades, he lost his right hand inner glove suffering severe frostbite of his right (dominant) hand. Treated conservatively a slow recovery ensued with return of normal sensation. He first noticed discomfort in his right hand three months later. Fusiform deformities of the PIPJs associated with reduced flexion were noted and radiographs showed soft tissue changes only. In 1996, marked nodal osteoarthritis changes involving all the PIPJs and DIPJs of the right hand were noted (fig 1). Apart from mild arthralgia and slight diminution in the range of flexion he denied any specific problems and





continues to operate firearms without difficulty. Current radiographs (fig 2) demonstrate advanced osteodegenerative change, together with small punched out, well corticated, juxta-articular erosions involving all PIPJs and DIPJs of the right hand only.

Frostbite may result in localised osteoarthritis.[1 2] Early radiographic changes typical of erosive osteoarthritis may develop within six months of frostbite,[1] while a long latency between insult and clinical presentation is also described.[2] In this case the evidence for causality incriminating frostbite is compelling with no alternative explanation nor history of trauma. The pathophysiology remains obscure: although freezing insult to the hyaline cartilage may be causative, the radiographic defects described suggest that subchondral ischaemic bone changes may be more important.[3]

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