Ultrasound in osteoarthritis

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ABSTRACT

Ultrasound (US) is a valuable imaging modality in the evaluation of joint and periarticular abnormalities in osteoarthritis (OA). It is able to image structural lesions as well as inflammatory changes in early and late disease. US is a relatively inexpensive, safe and quick-to-perform tool that can be used as a bedside procedure in the assessment of patients with OA. US shows abnormalities at different peripheral joint sites that can be assessed for variable aspects during the same scanning session. The easy accessibility of equipment facilitates its use and applications in the clinical practice. US is helpful in guiding local procedures (i.e. aspirations of joint and periarticular fluid collections, drug injections, biopsy) that can be easily and safely performed with optimal patient's tolerance. In addition, US allows for a monitoring of the disease process and follow-up of local and systemic treatments.

Introduction

OA is the most common rheumatic disease. It affects large and small joints and represents a pathologic process which involves multiple joint tissues. Predominant lesions of the hyaline cartilage are present with concomitant bone abnormalities and inflammatory processes within the synovium (1, 2). All joint tissues have dysregulations of local turnover and repair processes with consequent joint failure (3). Progressively, focal cartilage degeneration and loss, bony hypertrophy and capsule fibrosis appear and lead to joint impairment (3, 4). Episodic synovitis also may be present during the disease course and it contributes to cartilage deterioration and worsening of symptoms. Synovitis is typically non-destructive and it is characterised by the presence of synovial hypertrophy, joint effusion and bursitis. However, it contributes to the appearance and aggravation of joint pain, swelling and stiffness which are the most relevant symptoms of the disease. In addition, with disease progression, deformity and loss of function appears with consequent disability and worsening of quality of life (5-9). These conditions frequently cause patients' complaints and relevant public health problems (3).

Conventional radiography is the gold standard modality for imaging OA and detecting bony abnormalities. However, it is unable to directly visualise hyaline cartilage as well as other joint and peri-articular soft tissues that may be affected in OA such as the synovial recesses and the bursae (2). In addition, it is loaded by radiation burden that limits it's widespread use for follow-up in the routine clinical practice. Among other imaging modalities, magnetic resonance imaging (MRI) is able to image the inflammatory process as well as the traditional structural radiographic findings in OA patients since early disease and allows for detection of cartilage abnormalities, bone structural changes and joint damage. During the last years MRI has been increasingly used mainly in research studies, demonstrating its accuracy and reliability; however, its high costs and low availability of MRI equipment limit its routine use (5, 10). Arthroscopy is a powerful tool for evaluating most osteoarthritic changes, particularly for direct visualisation of cartilage surface alterations and synovitis; but its invasiveness limits its use in daily clinical practice (1, 10). Scintigraphy has shown its predictive value in the assessment of progressive changes in OA; however, it is scarcely available, invasive and expensive for routine use (1, 4). Ultrasound (US) is a valuable imaging modality in the evaluation of joint and periarticular abnormalities in OA. It is able to image structural lesions as well as inflammatory changes in early and late disease, offering an overall assessment of the osteoarthritic peripheral joints. It provides useful information to the rheumatologist clinician as well

as to the rheumatologist ultrasonographer bridging the gap between the clinical and the radiologic evaluation (2). US is a relatively inexpensive, safe and quick-to-perform tool that can be used as a bedside procedure in the assessment of patients with OA. It can be used at different peripheral joint sites during the same scanning session and at the time of clinical consultation as often as necessary, thus reducing patient's discomfort. This allows rapid and useful correlations between imaging findings and clinical data facilitating diagnosis and management of patients with OA (1, 2).

This article aims to describe the principal indications and clinical applications of US in both clinical practice and research in OA, including also the most relevant technical aspects and the limitations of the technique.

Table I. Indications and clinical applications of US in OA.

Assessment of cartilage lesions
Detection of osteophytes
Detection of erosions (erosive hand OA)
Detection of joint effusion
Detection of synovial hypertrophy
Differentiation between active and inactive synovitis (Doppler modalities)
Assessment of periarticular soft tissues abnormalities in OA (bursitis)
Evaluation of mucous cysts (hand OA)
Execution of US guided procedures (aspiration of joint and periarticular effusion, injections, biopsy)
Monitoring of disease progression from early to late stages
Follow-up of the response to local and systemic therapies

Indications and clinical applications of US in OA

US is able to image a wide set of abnormalities in OA (Table I) (1, 5, 7, 11-25). Particularly, joint and periarticular soft tissue involvement as well as bony cortex abnormalities can be assessed at different peripheral joint sites since early disease (1, 7, 18, 23, 26, 27).

Thanks to technological improvements of US equipment, the sonographic visualisation of most joint and periarticular structures has been optimised with possibility to demonstrate different abnormalities which may characteristically be present in OA and which may be related to inflammation as well as to structural damage (1, 5, 10, 11, 22, 25, 28). Particularly in hand OA, the use of US has increased our knowledge about erosive disease as well as about the frequent associations between OA and local pain, and about the role of inflammation in the disease progression (29-33). US may also be used to study specific pathologic conditions such medial meniscus displacement and progression of knee OA, as well as to understand knee pain as being predicted by the presence of synovitis (35).

Sonography is based on direct and multiplanar evaluation of different musculoskeletal regions including most of the peripheral joints involved by the disease (35). It allows imaging of several tissues including hyaline cartilage, synovial membrane and fluid, joint capsule, tendons, ligaments bursae, external areas of menisci (5, 11, 23). US can detect cortical bone alterations and demonstrate the typical structural abnormalities of the disease (5, 9, 23, 25). Both joint effusion and synovitis may be shown at different peripheral joint sites and the use of Doppler modalities allows for the differentiation between active and non-active disease. In addition, by using sonography, it is possible to directly monitor the progression of pathology and evaluate the response to local and systemic therapy (1, 5, 11, 36). US can be successfully used as a guide for fluid aspirations, injections (hyaluronic acid, corticosteroid), biopsies and other diagnostic procedures, improving the reliability and safety of those tools and resulting in an excellent patient tolerance and absence of radiation burden (1, 37-39).

Equipment

US assessment of the osteoarthritic joint requires the use of high-end equipment. This concept should include not only the use of high-level machines but needs to be extended also to the availability of high resolution transducers which are mandatory devices for appropriate imaging of anatomic structures involved in OA and for demonstrating abnormalities since early disease (5, 11, 35). Particularly, the use of high-frequency probes is indicated for assessing small joints and superficial areas, while the evaluation of large joints and deep tissues requires lower-frequency tranducers (11, 35).

In addition, the choice of the opportune probe size and shape may help mostly in the evaluation of patients with functional disability and deformities or when assessing wide areas. Small-size or hockey stick transducers are suitable for the study of small joints and large footprint probes are appropriate for the assessment of large joints and wide districts, as they offer a more complete and extended visualisation of the areas of interest (1, 40).

Both B-mode US and Doppler modalities represent fundamental tools for the correct joint evaluation in OA.

After B-mode assessment, colour or power Doppler are used to study synovial vascularity, which may be increased in case of active inflammation within the joint and other synovial periarticular structures (1, 5, 35, 41). The use of correct machine settings optimises the visualisation of the target areas and the detection of local pathology (11).

Particularly, this requires the adjustment of B-mode (correct frequency, image size and depth, gain, focus positioning) and Doppler (appropriate frequency; the lowest pulse repetition frequency; optimal colour gain; positioning of the focus at the level of the area of interest; modification of the size of the color box according to the extent of the area that is studied) settings according to the target area both before and during scanning. In fact, modifications and adjustments are needed also during real time scanning for optimising the imaging of local structures and the analysis of their pathologies (41-43).

US scanning technique

An appropriate scanning protocol should always include multiplanar, dynamic, and bilateral evaluation. This

recommendation allows complete assessment of the various anatomic structures of the examined joint (1, 36).
Guidelines for US in rheumatology represent the reference standard in the sonographic assessment of the joints also in OA (44). An adequate knowledge of the scanning technique for the various anatomic areas to be examined is mandatory to correctly evaluate the different joints.
The use of generous amounts of gel is recommended for optimising the visualisation of the joint structures and reducing the presence of artifacts.
A correct patient and probe positioning is fundamental to allow the US beam to penetrate through the most suitable acoustic windows to visualise the joint structures. Particularly, for hyaline cartilage assessment, all joints should be optimally positioned to expose it to US evaluation (44). If the patient is correctly positioned, the cartilage is visualised in many peripheral joints. Usually, the appropriate patient position for the assessment of the cartilage consists of keeping the joint either in maximal flexion (hand and knee) or in extension (elbow, wrist, ankle and foot) or in intra-/extra-rotation (hip and shoulder) (1). In some articular sites lacking appropriate acoustic windows, hyaline cartilage cannot be imaged by US, except in limited portions. To optimally visualise the cartilage and avoid artifacts, a correct, perpendicular insonation of the US beam is mandatory (1, 40).
A tailored protocol for the study of osteoarthritic joints should include the assessments of cartilaginous lesions, osteophytes, joint effusion and synovitis (5). In some areas, such as the knee, foot and shoulder, the presence of bursitis should be investigated (11). In hand OA, cortical erosions should be evaluated. All lesions should always be documented in two perpendicular planes (5).

US of the normal and osteoarthritis joint

The joints of healthy subjects are imaged by US as having regular and hyperechoic bony margins; homogeneously echoic and thin joint capsule; minimal amounts of hypoechoic or anechoic fluid; anechoic and homogeneous hyaline cartilage lining the bony profile and having two sharp, continuous, and regular hyperechoic margins (5, 11, 35). The thickness of the cartilage is different in the various sites according to the size of the joint where it is measured, ranging between 0.1-0.5 mm in the small hand joints to 3 mm in the knee (1, 40, 45).
A wide set of abnormalities can be demonstrated in OA. These include inflammatory and structural changes. In patients with synovitis, B-mode US shows the presence of joint effusion and/or synovial hypertrophy. In the presence of active inflammation, Doppler modalities are able to show increased local vascularisation within the synovium (41, 46, 48, 49). The Outcome Measures in Rheumatology (OMERACT) definitions for synovial fluid and synovial hypertrophy in rheumatoid arthritis can be applied in OA as well (5, 50). In OA joint effusion can be either anechoic or inhomogeneously hypoechoic, depending on its composition and presence of intra-articular debris and proteinaceous or calcified material (11, 50).
Synovial hypertrophy, defined by OMERACT as a non-displaceable and poorly compressible tissue, is a frequent finding in inflamed osteoarthritic joints.
A large set of changes involving the hyaline cartilage are imaged and are represented by loss of anechoic structure, thinning of cartilage layer, irregularities and loss of sharpness of cartilage margins (51). From early to late disease, initially blurring of the edges appear with evidence of irregularities and loss of normal sharpness (1, 5, 10, 11). These findings usually involve the superficial cartilaginous margin at first and correspond to the micro-cleft formation due to tissue deterioration (52). Later on, abnormalities in the echotexture appear, with evidence of loss of anechoic structure (52-55). With disease progression, focal and asymmetric thinning is imaged which then becomes more evident, up to the complete absence of the cartilaginous layer that corresponds to cartilage breakdown and bony denudation (56-60).
Osteophytes are imaged as step-up bony prominences at the end of the normal bone contour or at the margin of the joint seen in two perpendicular planes (5, 35). They may have a posterior acoustic shadow (35). US has been found to be more sensitive for detection of osteophytes than conventional radiography (8).
In erosive hand OA, erosions are imaged as a cortical breakdown with a step-down contour defect seen in two perpendicular planes within the joint space (1, 9, 11). Sensitivity in their detection can be decreased due to the interposition of osteophytes, which may be responsible for narrowing of the acoustic window (11, 19).
In hand OA, mucous cysts are shown as characteristic hypoechoic formations, located over the supero-lateral aspect of the distal interphalangeal joints (11, 25).
In knee OA, protrusion of the medial meniscus with displacement of the medial collateral ligaments are frequently demonstrated. This finding seems to be correlated with joint space narrowing (8).
Finally, periarticular abnormalities may also be found and they are usually represented by the involvement of local bursae and evidence of Baker's cysts and anserine bursitis at the knee, and bursitis over the medial aspect of the first metatarsophalangeal joint at the foot (5, 11).

Advantages and limits of US in OA

US is able to evaluate most of the pathologic conditions present in OA, both in terms of inflammatory abnormalities and structural damage lesions. In addition, it offers the possibility to easily and safely monitor disease progression and response to treatments. Moreover, it represents a useful, precise, well-tolerated and reliable guide for local procedures such as fluid aspirations, injections and biopsies (25, 61, 62). Particularly, it has been successfully used for guiding local treatments with corticosteroids and hyaluronic acid (38, 39, 63, 64).
OA is the most common and diffuse rheumatic disease and US allows for a quick and non-invasive assessment of joint abnormalities during clinical prac-

tice, being equipment widely available in most hospitals and outpatient clinic units. It is very well tolerated and accepted by patients, who usually appreciate being examined during the course of the clinical evaluation (65). In addition, US allows a multiregional evaluation of the musculoskeletal system during the same scanning session.

On the other hand, US has partial accessibility to the inner joint structures, resulting in incomplete visualisation of the articular cartilage in many peripheral joint sites (1). This is a relevant limitation particularly respect to MRI which has become crucial in understanding the natural history of the disease and in guiding future therapies because of its ability to image the joint as a whole organ and to assess cartilage morphology and composition directly and in a three-dimensional manner (66-68).

In addition, similarly to other imaging modalities, US is considered an operator-dependent technique. This is related both to image acquisition and interpretation (35). This problem has been partially solved by the use of high-end equipment, which has improved the visualisation of musculoskeletal structures and optimised the demonstration of abnormalities. Thanks to the applications of standardised scanning technique, accepted definitions of normal and pathologic findings and reference atlases, reliability of US in the assessment of a wide set of abnormalities in osteoarthritis joints has markedly improved over the last years, including the assessments between sonographers with different levels of experience (1, 51, 69-72).

Conclusions

US is a valuable imaging modality for the assessment of a range of pathologic findings related to OA (5, 11). It is able to detect most structural abnormalities involving the hyaline cartilage and the bony cortex as well. In addition, during the disease course, the presence of joint and periarticular inflammation may be demonstrated with the detection of joint effusion, synovial hypertrophy and bursitis. In the presence of active synovitis, Doppler modalities are able to show pathological vascularisation within the synovium (9, 11, 40, 47, 49, 73). US has the capability to evaluate several joints during the same scanning session, facilitate the diagnosis of OA and the assessment of the severity of joint involvement from early to late disease (35).

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