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Ultrasound of the joints

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Abstract High-frequency ultrasound is now considered an excellent modality to image normal tendons, muscles, and peripheral nerves as well as to diagnose a wide variety of pathological conditions affecting these structures. Although US is limited in the visualisation of some intra-articular structures, it can be a useful tool in joint disease assessment. Ultrasound has some advantages over other imaging modalities including time- and cost-effectiveness, superior spatial resolution, dynamic examination and the possibility to perform the examination in a comfortable position for the patient. The aims of this review are twofold: firstly, to present the normal US appearance of the joint structures that are susceptible to US examination, including the joint surfaces, intra-articular structures such as menisci and other fibrocartilages, capsule and ligaments; and secondly, to show the US appearance of the most commonly encountered joint disorders and discuss the role of US in the imaging strategy of joint disorders.

Keywords Ultrasound · Joint disorders · Sonography · Joint · Tendons

Introduction

Ultrasound provides useful information in assessing a wide range of joint disorders. Although US is not capable of visualizing some intra-articular structures due to shadowing of the overlying bone, it has some advantages over other imaging modalities in this field including time- and cost-effectiveness, superior spatial resolution, dynamic examination and the possibility to perform the examination in a comfortable position for the patient.

In this paper we review the normal US appearance of the anatomic structures located in and around the joints that are amenable to US examination, and discuss the US appearance of the most commonly encountered joint disorders.

Normal US anatomy

Ultrasound can evaluate the joint surfaces only in part, depending on the individual joint examined. Tight joints are most difficult to evaluate. The assessment of the articular surfaces of the hip, for example, is limited to the anterior portion of the femoral head. The posterior head and the acetabular surface are not visible at US due to a too deep location and posterior shadowing of the inter-

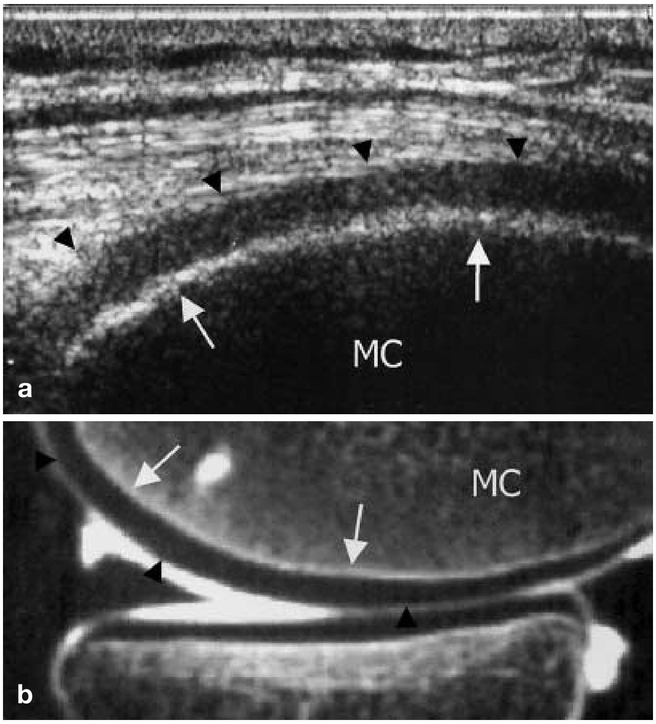

Fig. 1 **a** Longitudinal sonogram obtained over the medial aspect of the posterior knee shows the subchondral bone (*arrows*) as a regular continuous hyperechoic line underlying the hypoechoic hyaline cartilage (*arrowheads*). *MC* medial femoral condyle. **b** Corresponding CT arthrography image

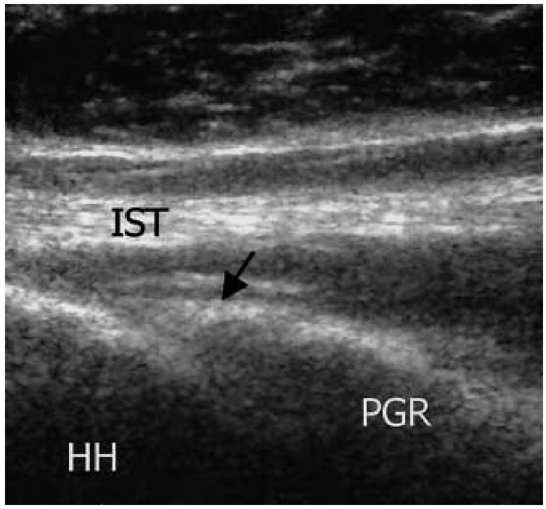

Fig. 2 Transverse sonogram obtained at the posterior aspect of the shoulder (internal rotation) demonstrates the posterior labrum (*arrows*) as a hyperechoic triangular structure adherent to the posterior glenoid rim (PGR). *HH* humeral head; *IST* infraspinatus tendon

vening bones. Large and lax joints can be better examined by means of different manoeuvres that increase the extension of the articular surfaces to be explored. The articular surface of the humeral head, for example, can almost completely be evaluated if US scanning includes different approaches (anterior, posterior, axillary) with the arm at different degrees of rotation (internal, neutral and external rotation) and abduction. Similarly, forceful flexion of the knee joint, when achievable, allows evaluation of the trochlear surface by sonograms obtained over the suprapatellar region [1]. The US analysis of the joint surfaces reveals the subchondral bone plate as a regular, continuous hyperechoic line, covered by a hypoanechoic smooth and regular linear structure relative to the hyaline cartilage (Fig. 1) [1, 2]. The variations in the cartilage thickness are well detected and can be measured with US.

Because of their deep location and close contact with the bone, the menisci and the glenoid labrum can be evaluated only in part with US. Both structures are made of fibrocartilage and appear as hyperechoic triangular images adherent to either the bone (labrum) or the peripheral joint capsule (menisci) [3]. Dynamic examination of the posterior glenoid labrum shows changes in shape of the fibrocartilage during different degrees of rotation of the arm. Because the joint capsule inserts into the labrum, this latter structure is stretched in internal rotation and appears pointed and triangular in shape, while it assumes a more globular appearance in external rotation (Fig. 2). Nevertheless, the portions of the labrum that are more commonly injured as a result of trauma or sport activities are barely assessed by US. The anterior labrum is commonly torn in anterior shoulder dislocations while the superior labrum is detached in SLAP (superior labrum anterior posterior) lesions. In shoulder dislocation, US is not so accurate to evaluate labral tears, because of the deep location of the labrum and oblique orientation of the tear. In addition, the superior labrum cannot be assessed due to the intervening shadowing of the coracoacromial arch. Although the knee menisci can be depicted with US, they are quite difficult to evaluate in certain areas, such as the anterior horn of the lateral meniscus. Menisci appear as triangular hyperechoic structures with their base located superficially and the apex directed towards the inner joint. Because of their deep location and shadowing from adjacent bones, the apex of the menisci is difficult to assess. Other fibrocartilaginous structures, such as the triangular fibrocartilage at wrist, can be hardly evaluated with US as well.

The joint capsule appears at US as a hyperechoic line bordering the joint cavity and merging with the para-articular tissues.

Ultrasound depicts the ligaments as hyperechoic lamellar structures (Fig. 3) [4, 5, 6]. Ligaments are anisotropic and, therefore, are subjected to changes in echogenicity depending on the angle of incidence of the US beam. The typical fibrillar echotexture is well demonstrated only if the incidental beam is perpendicular to the

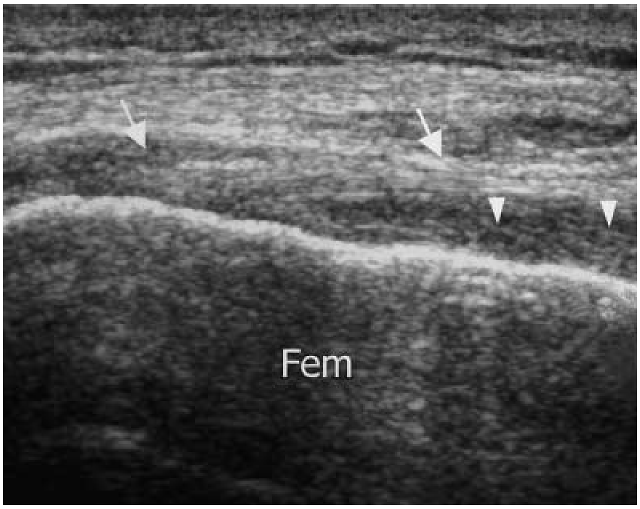

Fig. 3 Longitudinal sonogram obtained at the medial aspect of the knee shows the medial collateral ligament as a hyperechoic linear structure. The ligament is formed by a superficial (*arrows*) and deep (*arrowheads*) portion. *Fem* femur

surfaces of the ligaments. If the US beam is oblique, the ligament appears diffusely hypoechoic. A good technique of examination is then necessary to avoid false hypoechogenicity that can mimic pathological changes. Ligaments that stabilize a joint are best evaluated while stretched. The external ligament of the ankle, for example, must be evaluated during application of eversion stress [7], whereas the medial collateral ligament of the knee can be imaged dynamically during valgus stress to evaluate its functional behaviour. Complex ligaments, such as the ankle deltoid ligament and the medial collateral ligament of the knee, are made of different components that can readily be distinguished and evaluated with US [7].

The articular fat pads appear at US as fibrofatty hyperechoic structures. Those most commonly recognized are located at the knee and elbow. At the knee, the Hoffa fat pad fills the space between the patellar tendon and the cruciate ligaments while the suprapatellar fat pad is located superior to the upper patellar pole, posterior to the distal quadriceps tendon and anterior to the suprapatellar bursa [8]. At the elbow, the anterior and posterior fat pads are located inside the coronoid and olecranon fossa, respectively [9, 10].

The normal synovial membrane is thin and cannot be detected at US in the absence of pathological conditions that lead to its thickening or hypertrophy. In normal conditions, the small amount of intra-articular fluid located in the articular cavity can be detected with high-resolution US in the majority of joints.

Para-articular tendons appear at US as linear hyperechoic structures with internal fibrillar echotexture [11, 12]. As for ligaments, tendons are strongly anisotropic and can show different echogenicity depending on the

Fig. 4 Transverse sonogram obtained at the posterior aspect of the shoulder shows a joint ostheophyte (*arrow*) as a beak-shaped structure that caused displacement of the infraspinatus tendon (IST). *HH* humeral head; *Del* deltoid muscle

different angles of the US incident beam [13]. For proper assessment, tendons must be kept with their longitudinal axis parallel to the probe since the artifactual hypoechogenicity due to their obliquity can lead to a false diagnosis of tendinopathy or partial rupture.

In normal conditions, the thin walls of and the small amount of fluid in the para-articular bursae explain why US can hardly detect them. Only high-frequency probes can image the most superficial bursae as hypoechoic linear structures.

Pathological changes

Ultrasound can detect joint surfaces and hyaline cartilage alterations. In osteoarthritis these include progressive thinning and irregularity of the cartilage up to complete absence as well as irregularity of the hyperechoic line corresponding to the subchondral bone [2]. In addition, osteophytes can be well demonstrated as beak-shaped joint surfaces projections covered by cartilage. Typical locations of the osteophytes are the posterior humeral head (Fig. 4), the internal femorotibial and the anterior tibiotalar joints. In rheumatoid arthritis, US can effectively show the marginal erosions, located at the level of the intra-articular bare areas, filled by the pannus. In crystal pyrophosphate deposition disease (CPDD), multiple hyperechoic images are found inside the hyaline cartilages, particularly at the level of the femoral condyles, thus reflecting aggregates of chondral calcium crystals [14, 15].

Osteochondrosis or osteochondral fractures can be detected only if they affect segments of the joint that can be assessed by US as surface irregularities or nidus formation [16]. A common alteration of the joint surface that, in almost all patients, can be clearly and accurately imaged is the Hill-Sachs (H-S) lesion of the humerus. This is a compression fracture at the posterosuperior aspect of the humeral head due to the impact on the antero-inferior rim of the glenoid following anterior dislocation of the shoulder. At US, the H-S lesion appears as a localized concavity of the articular surface usually filled by fluid and covered by the anterior portion of the infraspinatus tendon. The US data correlate well with CT in evaluating the presence and size of the lesion [17].

The possibility to diagnose menisci tears with US is debated. Although different authors reported a high sensitivity and specificity of the modality in diagnosing meniscal rupture [3], there is general consensus that further experience and additional double-blinded studies are required to propose US as a routine imaging technique in meniscal tear evaluation. On the contrary, US is a well-recognised, effective modality in diagnosing meniscal cysts (MCs) [18, 19]. Being these cysts always associated with a meniscal tear, their detection allows diagnosis of a rupture of the meniscus. The MCs appear as expansible lesions located closely to the femoro-tibial joint space. The MCs typically show regular borders and mixed internal echostructure made by hypoechoic and anechoic areas. Attention must be made in evaluating internal MCs since they can expand at considerable distance from the joint space due to long pedicles connecting them with the meniscus. Recently, the US appearance of meniscle ossicle has been reported [20]. Meniscle ossicles are vestigial remnants that are usually located inside the posterior horn of the medial meniscus. Clinically, they can be symptomatic. Ultrasound shows ossicles as regular intrameniscal hyperechoic structures. In clinical practice, US may be useful since it can prove the intrameniscal location of the ossicle, easily imaged by standard radiographs, and helps in excluding the presence of a loose body.

Some articles have reported the usefulness of US in detecting labrum pathology in anterior shoulder instability [21, 22]. As for the knee menisci, degeneration of the glenoid labrum fibrocartilage can lead to cyst formation. Paraglenoid cysts usually derive from the superior (SLAP lesion) and posterior labrum. They are usually small in size but can be clinically evident because of compression on the suprascapular or infrascapular nerve at the glenoid notch [23, 24]. Since the clinical findings are not specific and can mimic tears of the rotator cuff, routine examination of the notch must be performed in every patients with shoulder pain. Some authors have reported US findings in tears of the triangular fibrocartilage of the wrist [25].

In normal conditions, the joint capsule merges with the surrounding para-articular tissues and cannot be detected with US. Ligament tears are well demonstrated at the level of the ankle and the knee [26]. A partial torn ligament appears as a swollen and hypoechoic structure. In acute complete ligament ruptures, the torn ends can be detected and surrounded by fluid collection related to haematoma [27]. Ligament calcifications are found mainly in chronic tears. A typical example is the Pellegrini-Stieda syndrome where a linear calcification is found at the proximal end of the medial collateral ligament of the knee and appears as a curvilinear hyperechoic structure. Other ligaments that can be assessed with US include the ulnar collateral ligament of the elbow and the ulnar collateral ligament of the metacarpophalangeal joint of the thumb [28]. The glenohumeral ligaments of the shoulder, commonly injured in shoulder instability, cannot be evaluated.

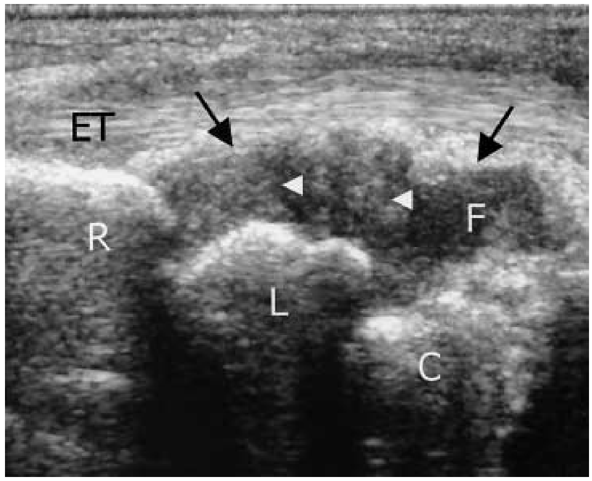

Fig. 5 Longitudinal sonogram obtained at the posterior aspect of the wrist reveals distended radiocarpal and midcarpal joint spaces associated with posterior bulging of the joint capsule (*arrows*). Note the intra-articular fluid (*F*) and the hypertrophy of the synovial membrane (*arrowheads*). *ET* extensor tendons; *R* radius; *L* lunate; *C* capitate

Although US allows demonstration of displacement of fat pads by intra-articular effusion, this sign has little clinical value since the effusion itself can readily be assessed also [9].

The hypertrophy of the synovial membrane (pannus) can be found in chronic arthritis and appears at US as a bulk of hypoechoic vegetations located inside the synovial cavity [29]. The pannus can be seen protruding inside the synovial fluid up to fill completely the articular space. Differences in flow signal at color Doppler can differentiate between active acute and fibrous pannus and can be helpful in monitoring the response to therapy. In osteochondromatosis,US can detect the hypertrophy of the synovial membrane as well as the intrasynovial chondroid and osseous foci as hypoechoic and hyperechoic structures with posterior acoustic shadowing, respectively [30]. Pathological increase of the intra-articular synovial fluid can be accurately demonstrated (Fig. 5). Depending on the constitution of the fluid, US

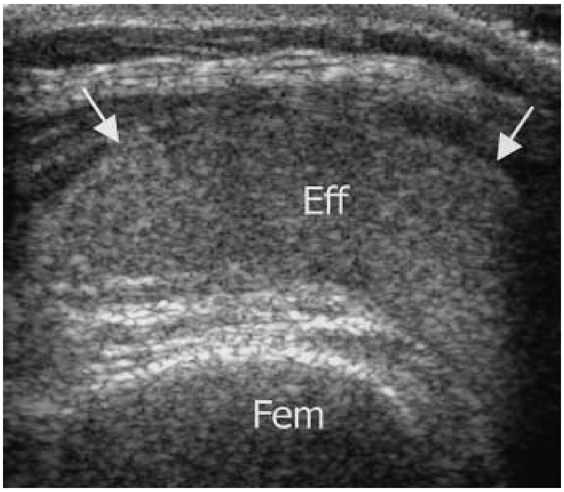

Fig. 6 Transverse sonogram obtained at the lateral aspect of the knee demonstrates the suprapatellar pouch (*arrows*) distended by hyperechoic effusion (*Eff*) due to an intra-articular posttraumatic blood collection. *Fem* femur

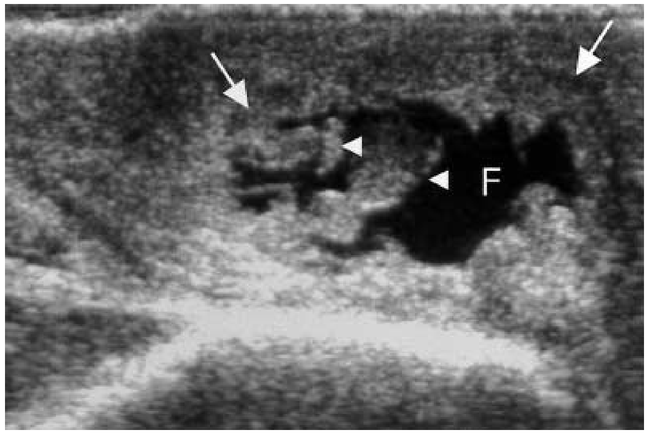

Fig. 7 Longitudinal sonogram obtained at the posterior aspect of the elbow shows the enlargement of the olecranon bursa (*arrows*) in a patient with acute bursitis. The bursa contains both fluid (*F*) and hypertrophied synovium (*arrowheads*)

can depict it as anechoic ("mechanical" or "inflammatory" fluid) hyperechoic (Fig. 6; bloody effusion) or complex fluid containing grossly hyperechoic spots and debris (infective fluid); however, it must be stressed that a reliable differentiation of the type of fluid cannot be achieved based on US findings alone. Demonstration of an intra-articular effusion in a single joint is a definite indication to joint puncture and fluid analysis and culture. Ultrasound can differentiate hypertrophy of the synovial membrane from fluid and can be useful to guide the needle puncture in real-time [31]. In lipohemarthrosis, a condition in which bone marrow fat is found in the synovial fluid because of an intra-articular fracture, US shows layering of the fat, serum, and red blood cells [32]. Intra-articular loose bodies (IALB) are chondral or osteochondral fragments located inside the joint cavity which can mainly derive from joint surfaces fractures, osteoarthritis, ostheochondromatosis or neuropathic joints disease. Intra-articular loose bodies can cause intermittent locking of the joint and early degenerative changes. Ultrasound shows IALB as hyperechoic fragments with variable posterior shadowing. Demonstration of fluid surrounding the fragments and of their intra-articular mobility induced by movements of the joint or pressure applied with the probe are definite diagnostic proofs. The main utility of US in this field is the possibility to prove the intra-articular location of a calcific structure demonstrated by standard radiographs and to exclude a para-articular calcification [33].

Disorders of para-articular tendons are the subject of a separate article. Ultrasound can show pathological changes of para-articular bursae. In acute bursitis, a variable amount of internal fluid can be associated or not with thickening of the bursal wall (Fig. 7). In chronic bursitis, the amount of fluid is reduced while the wall appears frequently thickened. As for articular effusions, needle puncture is often required to rule out infection.

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