The usefulness of ultrasonography in synovial disease

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Abstract
Synovial disease is common in clinical practice and can have different causes. The development of high resolution ultrasonography (US) has led to greater use of US in the study of synovial disease. In this context, US is useful because (1) it can detect not only synovial disease, but also its consequences as tissue damage (erosions); (2) it can guide arthrocentesis when clinical attempts to obtain joint fluid have been unsuccessful, especially in joints that are difficult to access (hips), or sometimes when joint infections are clinically suspected; (3) it enables the efficacy of treatment for synovitis to be evaluated; and (4) it makes it possible to distinguish benign cystic lesions from other tumors. The overall evaluation of synovial disease is based on semiologic criteria that enables these alterations to be classified into four main groups: (a) joint effusion, (b) cystic synovial lesions, (c) intra-articular free bodies, and (d) synovial thickening.

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Keywords
Synovial membrane; Synovial disease; Sonography; Ultrasound; Synovial joint; Musculoskeletal system

Utilidad de la ecografía en el estudio de la enfermedad sinovial

Resumen
La enfermedad sinovial es frecuente en la práctica clínica y puede tener diferentes etiologías. La introducción de la ecografía de alta resolución se ha traducido en una mayor utilización de esta técnica para explorar esta enfermedad. La utilidad de la ecografía consiste en los siguientes aspectos: a) detectar no sólo la enfermedad sinovial, sino también sus consecuencias en forma de daño tisular (erosiones); b) obtener líquido articular guiando la artrocentesis, especialmente en articulaciones poco accesibles (caderas), cuando clínicamente sea infructuoso o en algunos casos de sospecha de infección articular; c) evaluar la eficacia del tratamiento en la sinovitis, y d) distinguir lesiones quísticas benignas de otros tumores. Para realizar una aproximación global a esta enfermedad utilizamos un criterio semiológico que nos permite clasificar estas alteraciones en 4 grupos principales: derrame articular, lesiones quísticas sinoviales, cuerpos libres intraarticulares y engrosamiento sinovial.

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Introduction

The synovial membrane, which lines all surfaces of the articular space except for the articular cartilage, also forms part of the tendon sheaths and bursas. This membrane ensures a rapid and extensive reaction to any foreign agent. It also synthesizes proteins that are part of the synovial fluid, a high-viscosity plasma dialyse that lubricates the articular structures. The synovial membrane is composed of two or three layers of synoviocytes and is too thin to be assessed by ultrasound. However, ultrasound is an excellent technique for the detection and assessment of synovial disease when using high-resolution equipment with high frequency broadband (7-13 MHz) linear transducers, Doppler (and power Doppler), good lateral definition, and tissue harmonic. For exploring the musculoskeletal system, ultrasound has some advantages over other imaging techniques; these include superior spatial resolution and the possibilities of dynamic exploration, applying pressure with the transducer, a comparative study with the contralateral joint and obtaining clinical data thanks to a direct contact with the patient. However, under certain conditions, ultrasound images require correlation with other imaging techniques. Magnetic resonance imaging (MRI) is presently considered the gold standard for the assessment of the synovial membrane. Because many conditions can lead to synovial disease, it is essential to consider the findings of imaging studies as well as the clinical signs to make a correct diagnosis.

The following is a review of synovial disease that includes descriptions of its usual ultrasound findings. In this review, we use a semiotic approach that allows us to classify synovial diseases into four main groups: joint effusion, synovial cystic lesions, intraarticular loose bodies and synovial thickening.

Joint effusion

Under normal conditions, a thin layer of synovial fluid separates opposing joint surfaces. Joint effusion, which occurs when the volume of this joint fluid increases, indicates the existence of articular disease. The causes of joint effusion can be traumatic, mechanical, inflammatory or infectious and, rarely, neoplastic. Ultrasound is a technique with high sensitivity for the detection of synovial fluid, although depending on the amount of fluid and the type and size of the affected joint. There have been several studies in which the physiological volume of the synovial fluid in large articulations (hip, shoulder, knee, ankle) has been determined by MRI or ultrasound. In general, when the amount of joint fluid is small, evaluation of the contralateral joint and obtaining clinical data thanks to a direct contact with the patient. However, under certain conditions, ultrasound images require correlation with other imaging techniques. Magnetic resonance imaging (MRI) is presently considered the gold standard for the assessment of the synovial membrane. Because many conditions can lead to synovial disease, it is essential to consider the findings of imaging studies as well as the clinical signs to make a correct diagnosis.

The following is a review of synovial disease that includes descriptions of its usual ultrasound findings. In this review, we use a semiotic approach that allows us to classify synovial diseases into four main groups: joint effusion, synovial cystic lesions, intraarticular loose bodies and synovial thickening.

Cystic lesions

Synovial cyst

The synovial cyst is defined as a collection of juxtaarticular fluid lined by a synovial membrane. It represents a herniation of the synovial membrane through the joint capsule. The main etiological factor is an increase in intra-joint pressure, irrespective of the underlying joint

Figure 1  Suprapatellar pouch lipohemarthrosis. The ultrasonic sagittal image (composite) of the suprapatellar recess shows a fat-fluid level; arrows indicate an upper hyperechoic layer of fat and a lower anechoic layer of serum in a patient with an external tibial plateau fracture.
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condition. On ultrasound, synovial cystic lesions may show floating echogenic material or septa. Color Doppler ultrasound does not show blood flow.

The prototype of the synovial cyst is the popliteal cyst. Characteristically, it communicates with the knee joint (fig. 2A) and follows the exit of joint fluid through a thinning of the articular capsule in the postero-medial region between the internal head of the medial gastrocnemius and the semimembranosus tendon towards the gastrocnemius semimembranosus bursa. In 80-90% of cases, popliteal cysts are associated with meniscal tears, usually in the posterior horn of medial meniscus. Ultrasound can detect a dissecting cyst into the calf (fig. 2B and 2C) or, less commonly, into the thigh; dissection is due to cyst rupture, which can clinically simulate thrombophlebitis.

Bursitis

There are many local and systemic processes, including overuse, trauma, infection, inflammatory arthropathy, and others that can lead to inflammation of a bursa, accumulation of fluid and, sometimes, thickening of the synovial membrane. When a bursa that does not communicate with a joint (non-communicating) becomes inflamed, an ultrasound scan can show the increase in the amount of fluid as an anechoic collection with posterior acoustic enhancement (fig. 3); in chronic bursitis, the bursa’s synovial walls are thickened and the liquid is usually more echogenic. On some occasions, it may be necessary to perform a diagnostic aspiration of the bursal fluid to establish a definitive diagnosis.

Differential diagnosis of synovial cystic lesions includes ganglions and parameniscal or paralabral cysts. A ganglion is a pseudotumoral cystic lesion of unknown origin, which originates in the periarticular soft tissues and is lined by synovial cells. There is no agreement regarding its pathogenesis, although most authors consider that these lesions result from mucinous cystic degeneration in a collagenous structure after repeated trauma in areas experiencing a continuous stress, such as a joint capsule or tendon. The ganglions may be located in extra-articular soft tissues but are also found intra-articular (fig. 4), in bones and, rarely, in the periosteum. Ultrasound usually shows a well-defined anechoic collection with posterior acoustic enhancement, although septae or more complex contents can occasionally be observed in longstanding ganglions (fig. 5). Parameniscal or paralabral cysts are polylobulated accumulations of synovial fluid that relate to the edge of the meniscus in the knee and the labrum in the shoulder, respectively, and indicate the presence of a meniscal or labral tear.

Another periartricular cystic lesion, which has been called juxta-articular myxoma, is now considered as a perilabral/meniscal cyst. 4

Intraarticular loose bodies

Intraarticular loose bodies are chondral, osteochondral or bone fragments that are located within the joint cavity. These fragments may be the result of an acute aggression that results in the removal of an osteochondral fragment or may result from chronic diseases such as arthritis, repetition injuries, synovial osteochondromatosis, some chronic inflammatory arthritis and osteochondritis dissecans.

The zones within each joint in which these loose bodies usually build up are detailed in table 1. 5 Detection of loose bodies by ultrasound depends on the demonstration of a focal echogenic image with posterior acoustic shadow; the structure is located within the articular space and is separate from other structures, mobilized and usually surrounded by joint fluid (fig. 6).

Figure 2 Baker’s cyst. A) Oblique sagittal plane on the back of the knee, showing the neck of the Baker cyst (arrows) communicating with the joint. B) Sagittal plane of the popliteal fossa showing a ruptured Baker’s cyst that dissects caudally towards the calf tissues (arrows). C) Characteristic sharp tip at the lower end of the cyst (arrow).

Figure 3 Retrocalcaneal bursitis. Ultrasound sagittal plane showing a distended bursa, synovial thickening and hyperemia (arrows) in a patient with pain in the back of the ankle. The green star indicates the Achilles tendon.
Radiography is the appropriate imaging technique for the initial evaluation. Ultrasound should be conducted when it is necessary to establish the exact location of the lesion within the articular space, even if the radiographic examination is positive, and when the clinical symptoms are highly suggestive of the presence of a loose body and the radiography is negative. However, ultrasound cannot always establish the exact number of loose bodies present, nor can it, in many cases, establish where the fragment came off. Furthermore, this technique cannot scan the entire joint. In some cases, it may therefore be necessary to perform a CT scan or a MRI.

**Synovial thickening**

The thickening of the synovial membrane encompasses a wide spectrum of findings depending on size and morphology (diffuse, nodular, villous); these parameters are usually related. Included in this section are synovitis, amyloidosis, gout, chondrocalcinosis, adhesive capsulitis, arborescent lipoma, PVNS and related benign proliferative disorders, synovial osteochondromatosis and synovial masses.

**Synovitis**

Inflammation of the synovial membrane is presented in a wide range of diseases, including traumatic synovitis, septic or non-septic inflammatory arthritis and osteoarthritis; with these entities, ultrasound findings can be very similar. However, ultrasound is more sensitive than physical examination and is particularly useful in cases of clinical suspicion of synovitis with an equivocal physical examination. Synovitis may reveal a variety of aspects in the ultrasound examination including smooth and regular, nodular or villous thickenings. In the tendon sheaths, synovitis usually appears as a hypoechoic ring around the affected tendon, while in joint and bursal synovitis, it tends to appear either as a diffuse and nodular thickening or as thickening of the synovial folds and effusion. Synovial thickening may be hypoechoic (fig. 7A and 7B) or hyperechoic (fig. 7C). The detection of flow with color Doppler and power Doppler is variable and depends on the degree of congestion. Such imaging can help differentiate a synovitis from a joint effusion, although MRI is more useful for this purpose.

**Table 1**

<table>
<thead>
<tr>
<th>Joint</th>
<th>Location</th>
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<tbody>
<tr>
<td>Ankle</td>
<td>Anterior recess of the tibiotalar joint</td>
</tr>
<tr>
<td>Elbow</td>
<td>Coronoid fossa and olecranon</td>
</tr>
<tr>
<td>Knee</td>
<td>Suprapatellar bursa, Baker’s cyst</td>
</tr>
<tr>
<td>Shoulder</td>
<td>Subscapular recess, axillary and long biceps tendon sheath</td>
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</table>
Pannus is a term designating synovitis associated with rheumatoid arthritis (RA) and is usually associated with a disease in evolution. Pannus is defined as a membrane of granulation tissue composed of mesenchymal cells and derived from bone marrow. Pannus formation stimulates the macrophages release of IL-1, growth factors derived from platelets, prostaglandins and substance P that ultimately lead to cartilage destruction and bone erosion. Its sonographic aspect has been described as a hypoechoic (fig. 8A) or hyperechoic (fig. 8B) pseudotumoral proliferation located inside the synovial cavity. Synovial inflammation is the key manifestation of the disease activity in RA and precedes the development of bone erosions. Ultrasound can detect joint effusion and synovial thickening and can reliably detect changes in synovial thickness. With its greater sensitivity in exploring low-speed blood flow at the microvascular level than that provided by color Doppler, ultrasound with power Doppler can help assess synovial hyperemia and allow distinction between an active inflammatory phase and an avascular fibrous pannus. The use of contrast agents is under investigation and its value in the diagnosis of inflammatory arthritis remains to be demonstrated.

Ultrasound can also show bone erosions and is more sensitive than simple radiography for their detection. Bone erosion has been defined as a discontinuity of the intraarticular bone surface that is visible in two perpendicular planes. Acute erosions usually present an irregular margin and a poorly-defined base that leads to increased transmission of sound and is associated with active synovitis. They are initially typically observed in intracapsular bone surfaces that are not covered by cartilage. The radiovolar side of the proximal epiphysis of the metacarpal bones and the proximal epiphysis of the metatarsal bones on the medial side (except the fifth metatarsal, which initially affects the lateral border) are the joints that tend to be more prominently affected. Bone erosions are an important finding because they are indicative of structural damage, often irreversible and associated with a worse prognosis and may determine the choice of treatment. Erosions are characteristic of septic or non-septic inflammatory arthritis, RA, spondyloarthropathy with peripheral involvement, etc.). Ultrasound can supplement simple radiography in the initial assessment of RA, especially when negative.

In inflammatory arthritis, ultrasound is thus a very useful tool in diagnosis, evaluating the response to treatment, and monitoring disease conditions. It can assist the practitioner in making therapeutic decisions and is especially valuable because the early detection of a failing treatment with subsequent therapeutic adjustment is important to prevent permanent damage and a worsening of function.

**Amyloidosis**

Amyloidosis is a common complication of chronic hemodialysis that occurs because beta-2 microglobulin is
Gout

Gout is a metabolic disorder characterized by an increase in the blood concentration of urate; elevated blood urate can cause episodes of acute arthritis, deposition of monosodium urate crystals (tophus) in or around the joints, urolithiasis by uric acid and renal disease. Articular manifestations occur in any stage of the disease and include acute arthritis, an intercritical phase and chronic tophaceous gout. Simple radiography shows preservation of the articular space and bone density with well-defined erosions with elevated borders, and soft tissue nodules.

Ultrasound in acute arthritis shows the characteristic findings of synovitis including joint effusion, synovial thickening and hypoechoic or heterogeneous masses in which the hypoechoic component is associated with hypervascularity with color Doppler, indicating inflammation. The latent period between the first symptom and the appearance of specific signs of gout on simple radiography ranges from 5 to 10 years. It seems logical that ultrasound can detect findings earlier, mainly in soft tissues (bright punctate spots and hyperechoic areas) in relation to the deposit of urates and also the early appearance of erosions. It has been shown that ultrasound has a higher sensitivity but a lower specificity than simple radiography in the detection of signs related to gout. Most tophi are deposited in the periarticular soft tissue; however, they may be intraosseous or intraarticular. Chronic tophaceous arthritis is the result of a delayed diagnosis or an inadequate treatment. In ultrasound, the tophi have been described as heterogeneous masses that occasionally show calcifications; erosion of the adjacent bone cortex can also be observed (fig. 9). Some authors have shown that an irregular echogenic line on the surface of the articular cartilage appears characteristically in patients with gout, unlike chondrocalcinosis, in which the echogenic line is located inside the cartilage.

In typical cases of gout, clinical and laboratory diagnosis does not require the performance of imaging techniques. However, the existence of atypical cases is common, and ultrasound can provide additional information in patients with clinical suspicion of gout but negative or inconclusive laboratory and radiological data, and guide a puncture when necessary.

Chondrocalcinosis

Chondrocalcinosis is the term used for conditions in which there is radiological or pathological evidence of calcification in the cartilage. In most cases, this calcification reflects deposition of calcium pyrophosphate dihydrate crystals, although there may be other causes. Most cases are asymptomatic. As ultrasound has a high sensitivity for detection of such deposits in cartilage, the detection of signs of chondrocalcinosis is usually an incidental finding that occurs when scanning for another reason. Chondrocalcinosis calcifications appear as ill-defined hyperechoic lines parallel to the surface of the cartilage. There may also be a significant thickening of the synovial membrane (fig. 10). The high sensitivity of simple radiography should not lead to the underestimation of the importance of ultrasound. There are published reports in which ultrasonographic demonstration of cartilaginous calcifications and negative radiography were used to finally diagnose chondrocalcinosis after synovial fluid examination.

Adhesive capsulitis

Adhesive capsulitis is a clinical syndrome characterized by an insidious onset of pain and restriction in the elevation and external rotation of the shoulder. In such patients, the main alterations seem to be extra-articular tissue inflammation in the rotator interval region (limited in its upper part by the anterior margin of the supraspinatus tendon and on the bottom by the top edge of the subscapularis tendon), synovitis in the anterior superior portion of the glenohumeral joint and coracohumeral ligament thickening. Some authors have used ultrasound
to evaluate the rotator interval, which appears hypoechoic and vascular in cases of early adhesive capsulitis (symptoms less than a year of evolution); such evaluation can provide an accurate and early diagnosis. Assessment of the coracohumeral ligament by ultrasound has also been proposed as strongly indicative of adhesive capsulitis in cases in which this structure appears to be thickened. The coracohumeral ligament can be visualized from its insertion on the coracoid to its entry into the rotator interval, although this is not possible in all patients.

Arborescent lipoma

Arborescent lipoma is a benign lesion of the synovial membrane that is characterized by subsynovial tissue replacement by mature fat cells; it can lead to villous proliferation that is occasionally associated with chronically inflamed synovial membrane. It occurs most often between the fifth and seventh decades of life. Although its etiology is unknown, arborescent lipoma is considered to be a nonspecific synovial reaction because most reported cases have been associated with trauma, inflammatory arthritis or osteoarthritis. The knee is the joint that is most frequently affected, although cases have been reported in the shoulder, the subacromial subdeltoid bursa, hip, elbow, ankle, or even involving several joints.

The ultrasound findings of arborescent lipoma have been described as hyperechoic villous synovial proliferations that curve and wave in real time during joint manipulation, in addition to observation of synovial thickening and effusion. Doppler ultrasound evaluation of the synovial alteration shows no vascular flow (fig. 11). MRI allows for an accurate diagnosis because the fat signal in the lesion on all sequences.

Diffuse and nodular pigmented villonodular synovitis and giant cell tumor of the tendon sheath

This group includes several benign proliferative disorders of the synovial membrane that can affect joints, tendon sheaths and bursae. These disorders have similar histological characteristics and are considered related entities that differ in their clinical diagnosis, radiological manifestations, treatment and prognosis.

PVNS is a proliferative disorder of the synovial lining of the joints resulting in villous and nodular thickening of the synovial membrane that may be localized or diffused. It usually affects both men and women between the second and fourth decades. The knee is the most commonly affected joint (80%), although PVNS can occur, in decreasing order, in the hip, ankle, shoulder and elbow. Simple radiography of the affected joint may be normal or may show increased periarticular soft tissue or bone erosion in joints with a little distensible capsule. The articular spaces and bone mineralization are characteristically preserved in the later stages of this disease. Ultrasound reveals joint effusion, hypoechoic synovial thickening with nodular and villous projections and increase in vascularization when color Doppler is applied (fig. 12). When available, this technique can also be used to show bone erosions and to guide arthrocentesis, which usually shows a hemorrhagic fluid. These findings are nonspecific and usually require an MRI scan. The typical MRI presentation includes low signal intensity intraarticular nodular thickening in T1, T2 and proton density weighted sequences; the low signal intensity is secondary to hemosiderin deposits and can be enhanced with higher magnetic fields and gradient echo sequences.

Intraarticular localized nodular synovitis, also known as synovial giant cell tumor, is a benign focal intraarticular mass. The most typical location of this rare entity is the knee joint. Intraarticular localized nodular synovitis originates in a small area of the synovial membrane and usually affects the infrapatellar fat pad. The nodular aspect and the smooth surface of the lesion, as well as the presence of a small amount of hemosiderin in the tumor and the absence of hemorrhagic effusion, are factors that help to differentiate localized nodular synovitis from PVNS (fig. 13).

Giant cell tumor of the tendon sheaths (GCTTS) or nodular tenosynovitis. Histologically, GCTTS and pigmented villonodular bursitis are two entities virtually identical to PVNP and represent its extra-articular analog. Unlike PVNS, GCTTS is exclusively nodular and generally
involves less hemosiderin deposition than PVNS. GCTTS can arise in any synovial sheath, although the tendon sheaths of the hands are most often affected; GCTTS is the second most common tumor of soft tissue in the hands, after the ganglion. It is also common in the feet. Ultrasound shows a solid, hypoechoic or hyperechoic mass with defined borders that is often adjacent to the flexor tendons of the fingers. These injuries do not move with the tendon because the tumor arises from the sheath and not the tendon. GCTTS shows flow on color Doppler (fig. 14). MRI can also identify and characterize GCTTS. Middleton et al. consider that both ultrasound and MRI may suggest the diagnosis with high reliability. As they differ in cost and availability, these authors propose that ultrasound should be the first-line imaging procedure, reserving MRI for difficult cases.

**Synovial osteochondromatosis**

Synovial osteochondromatosis is a disorder of unknown origin characterized by the proliferation and metaplastic transformation of the synovial membrane with formation of multiple cartilaginous nodules in the joints. The disease progresses from an active initial phase with synovial proliferation and formation of intrasynovial cartilaginous nodules or masses, to a final phase characterized by inactive synovial disease and persistent nodules that fall into the joint space. The nodules may be unmineralized (synovial chondromatosis) or may contain cartilage and bone, or mature bone with marrow fat (synovial osteochondromatosis). Men in their fourth and fifth decades are more frequently affected (two to four times more frequent than in women). The knee is the most commonly affected joint, followed by the hip and elbow, although synovial osteochondromatosis may also less frequently affect the tendon sheaths and bursae. The radiographic findings are pathognomonic when calcified bodies are present. A simple X-ray shows abnormalities in 70% of cases, most of which show multiple calcified nodules of uniform size distributed along the joint or, less commonly, inside the bursae or tendons. Due to the pressure they exert, they cause bone erosion in over 30% of cases, especially in articulations with little distensible capsule. Ultrasound data vary according to the proportion of synovial proliferation or the formation of loose bodies and the extent of calcification. The synovial proliferation appears in the ultrasound examination as a periarticular hypoechoic mass with punctate or hyperechoic nodular images with posterior acoustic shadowing corresponding to
randomly distributed calcifications\textsuperscript{26} (fig. 15). The MRI appearance is also variable; the non-mineralized lesions tend to form a cluster of periarticular masses that is isointense or mildly hyperintense to the muscle on the T1-weighted images and hyperintense on T2-weighted images. When the chondral masses contain calcifications, we observe small areas of signal void on all the sequences. The intraarticular bodies with bone and bone marrow show a fat signal central area.\textsuperscript{12}

Synovial masses

This section describes synovial hemangioma, synovial chondrosarcomas and synovial metastases.

Synovial hemangioma is a rare benign lesion that usually involves the anterior compartment of the knee. It most often affects young people. When a hemangioma is completely intraarticular, it is usually well-defined and originates in the synovial membrane through a stalk of variable size. The normal ultrasonographic features of the synovial hemangioma include a hypoechoic and vascular mass that may occasionally show calcifications that appear as hyperechogenic structures with posterior acoustic shadowing. MRI is the technique of choice for evaluating hemangiomas and allows a presumptive diagnosis. They normally appear as polylobulated intraarticular masses with characteristic signal intensity; intermediate on T1-weighted images and markedly hyperintense on T2-enhanced images. Linear structures of low signal intensity within the lesion on T2-weighted images could represent fibrous septae or vascular channels.\textsuperscript{27}

Synovial chondrosarcomas are extremely rare neoplasms. The vast majority of cases (75\%) occur in the knee. These tumors may arise de novo or, most often, as a complication of a preexisting primary synovial chondromatosis. The clinical and radiological presentations both of synovial chondromatosis and synovial chondrosarcomas are similar and the distinction between the two can be difficult both for the radiologist and the pathologist. Chondrosarcomas usually present a larger size than synovial chondromatosis lesions and frequently appear as soft tissue masses. In chondromatosis, pressure erosions are typical, while in chondrosarcoma there is a permeation of the trabecular bone.

The synovial metastases are also extremely rare. The articulation most frequently affected is the knee. Neoplastic disease can cause arthritis due to malignant invasion or as a result of paraneoplastic syndromes including carcinomatous polyarthritis and pulmonary hypertrophic osteoarthropathy.

Conclusion

Synovial disease is common. Simple radiography is an important tool and is usually the first line examination. However, the ultrasound complements the assessment of patients with articular disease and provides much relevant information. Sonography not only detects synovial disease but also allows evaluation of its consequences in the form of joint damage (erosions); furthermore, it can assist in obtaining joint fluid by guiding arthrocentesis, especially in poorly accessible joints, such as the hips, where other techniques may be clinically unsuccessful and in some cases of joint infection. Sonography is also useful in evaluating the efficacy of treatment in synovitis and can distinguish benign cystic lesions from other tumors.

Conflict of interest

The author declares no conflict of interest.

References