Ultrasound imaging for the rheumatologist XLII. Assessment of hip pain in rheumatic patients: the radiologist's view

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ABSTRACT

Hip pain is a common complaint in daily practice and the identification of the underlying pathologic condition is the first step for an adequate treatment. In this review, we discuss the available evidence for the application of conventional radiography, computed tomography and magnetic resonance imaging in rheumatologic patients with painful hip, presenting the main imaging findings due to osteoarthritis, inflammatory arthritis (rheumatoid arthritis and spondyloarthritides), osteonecrosis and some other soft tissue involvement (bursitis and synovial cyst) that could be the cause of hip pain. Because different imaging techniques show different sensitivity and specificity, the choice of technique to use depends on the type and stage of the disease itself.

Introduction

Hip pain is a common complaint in rheumatologic daily practice and the identification of the underlying pathologic condition is the first step for the institution of the adequate treatment.

This review discusses the available evidence for the application of conventional radiography, computed tomography (CT) and magnetic resonance imaging (MRI) in patients with painful hip, presenting the main imaging findings due to the most common rheumatic diseases. Ultrasound was not included because its usefulness has been extensively described in the recent previous issues of this journal (1-6).

Osteoarthritis (OA)

Conventional radiology is widely used as a first-line imaging technique to confirm the clinical suspicion of OA, evaluate disease severity, assess disease progression and response to treatment (7). The typical findings are represented by joint space narrowing (JSN), osteosclerosis, osteophytosis and subcondral bone cysts.

Joint space narrowing is more evident in the joint areas stressed by the load. It determines a displacement of the femoral head toward the acetabulum and, in a frontal view (antero-posterior or AP), we can identify three different patterns of migration: superior (when it is more pronounced in the superior joint area, with a vertical femoral head migration), medial (when it is more pronounced in the internal joint area, with a medial femoral head migration) and axial (when it involves all of the joint, and the femoral head moves centrally along the femoral neck axis) (8-9). The lateral view and other imaging methods, which provide an axial plane view, can show a front-back migration of the femoral head; for instance, CT can show a front migration associated to a superior or a back migration associated to a medial one. Other patterns are extremely rare and caused by other pathologies (8, 9).

Osteosclerosis (secondary to the new bone deposition on the existing trabeculae and also to the compression and fracture of the trabeculae with formation of new callus) follows cartilage degeneration so, it can be seen in association with joint space narrowing, gradually becoming more marked with progressive obliteration of the joint space (10).

Osteophytosis is one of the most easily detectable and characteristic manifestations of OA. While central osteophytes are located inside the joint and

appear like flat or button-shaped bony protrusions causing irregularity of the articular surface, the marginal ones are bony projections located at the periphery of the femoral head and on the edge of the fovea. They are usually located on the medial side of the femoral neck, producing the thickening of the cortical bone or the buttressing (a line of intensely radiopaque bone). The latter alteration shows a modification of the weight discharge along the femoral neck, and is typical of OA (10, 11).

Subchondral cysts, also called geodes, can be detected in OA and are localized in the subchondral bone. They are not usually coated by a epithelium, nor uniformly cavitate and can be associated with areas of osteosclerosis in the close proximity of JSN. Radiographically they appear as areas more radiolucent than normal bone tissue and a communication between the geode and the joint space can be detected, sometimes. Subchondral cysts, derived from necrotic areas resulting from bruises, usually contain synovial fluid or myxoid tissue (10, 12).

The x-ray views used to assess hip OA are the AP and the "frog-leg" (with a 45° abduction of the lower limb) (Fig. 1-2).

To allow a better evaluation of the femoral neck, especially in the early stages of the disease, hip x-ray should be with a 10-20° joint intra-rotation, or with an angle of 25° between the feet.

In 1961 Lequesne and Laredo first proposed an oblique/lateral projection of the hip with the patient in an erect position (13). This so-called "false profile" view, has been shown to be more sensitive than conventional AP view for detecting early cartilage space narrowing (detecting changes in almost 75% of the cases with doubtful or no narrowing seen on the AP).

X-rays can be used to assess the disease severity using semi-quantitative methods based on the findings shown on radiography. The most common and known score was developed by Kellgren and Lawrence (14) in 1957 and, according to the findings detected, it ranges from 1 to 5 (Table I). The main drawback of this score arises from the impossibility to use it in the absence of osteophytosis (even in presence of a significant joint space narrowing); secondly, the measurement of some features such as osteosclerosis and cyst has a low reproducibility (15, 16).

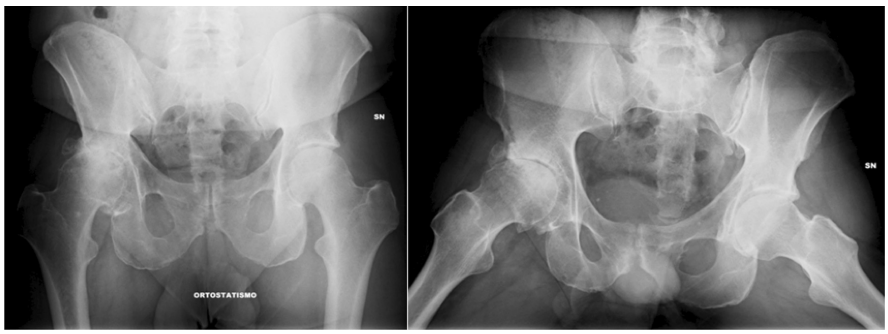

Fig. 1. A-P and "Frog-leg" x-ray views; Joint space narrowing particularly marked on the right where there are also acetabulum sclerosis and coarse osteophytes. Remodeling of the right femoral head with oval appearance. Subchondral sclerosis of the left acetabulum.

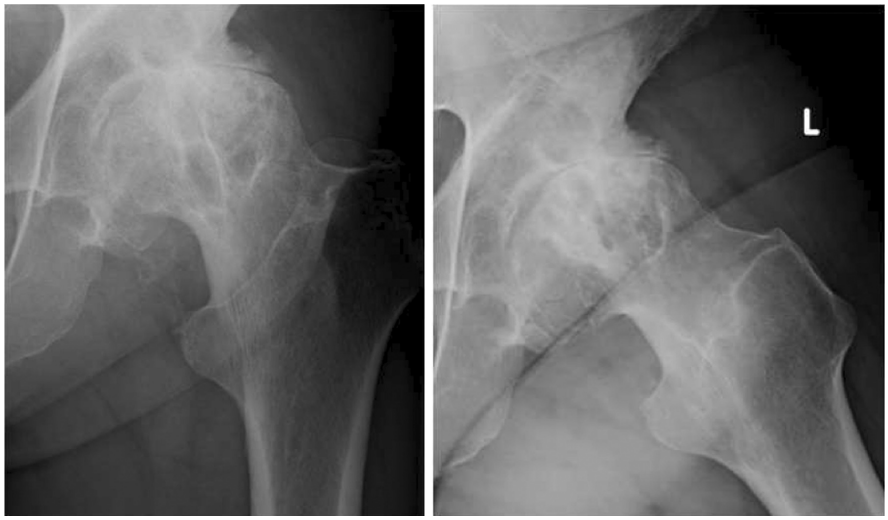

Fig 2. AP and "Frog-leg" x-ray views: Disappearance of joint space, osteophytes, and sclerosis of the acetabular roof. Deformation of the femoral head with multiple geodes.

More recently, cartilage thickness (evaluated through the joint space width on x-ray) has become more important because it is one of the first and most sensitive indexes of disease.

The two most common scoring systems which evaluate joint space are:

- OARSI (Osteoarthritis Research Society International) atlas score (Table I), which attributes a different score according to the lesions found (16);
- Quantitative measurement of the joint space width (JSW) which provides a non standardised continuous variable of joint cartilage loss (17).

These three different scoring systems were compared in 2008 by Gossec *et al*. (15), who showed a greater sensitivity of the JSW score in identifying OA early structural changes.

CT and MRI are the two imaging modalities that allow a direct evaluation of the cartilage thickness, but given the lower availability, higher cost and ionising rays exposure (for CT) with respect to conventional radiography, are not routinely used in established disease patients, while they are useful when a clinical suspect of early stage OA is given or an accurate assessment of joint cartilage is needed.

CT provides a three-dimensional joint view and, after the administration of an intravenous iodinated contrast agent, it allows the evaluation of cartilage thickness; it also identifies morphological changes which facilitate the onset of OA (*i.e*. femoro-acetabulum impingement and post-traumatic changes). CT is useful for a correct prosthesis surgery

Table I. The "Kellgren and Lawrence" and the "OARSI Atlas" scores.

Kellgren and Lawrence	OARSI Atlas		
grade 1 (None)	Marginal osteophytes	Joint space narrowing	Other
grade 2 (Doubtful)	Superior acetabular (0–3)	Superior (0–3)	Acetabular subchondral cyst (absent/present)
grade 3 (Minimal)	Superior femoral (0–3)	Medial (0–3)	Acetabular subchondral cyst (absent/present)
grade 4 (Moderate)	Inferior femoral (0–3)		Femoral subchondral sclerosis (absent/present)
grade 5 (Severe)	Inferior acetabular (absent/present)		Flattening of the femoral head (absent/present)
			Buttressing (absent/present)

Table II. Hip osteoarthritis MRI scoring system.

HOAMS					
Joint Feature	Score				
Cartilage	0	1	2	3	-
BML	0	1	2	3	-
Cysts	0	1	2	3	-
Osteophytes	0	1	2	3	4
Labrum	0	1	2	3	-
Synovitis	0	1	2	-	-
Effusion	0	1	2	-	-
Loose bodies	0	1	-	-	-
Attrition	0	1	-	-	-
Dysplasia	0	1	-	-	-
Greater trochanter tendonitis/bursitis	0	1	-	-	-
Labral hypertrophy	0	1	-	-	-
Paralabral cysts	0	1	-	-	-
Herniation pits	0	1	-	-	-

planning, to identify intra-articular calcific fragments, to evaluate the femoral antiversion angle and to replace MRI when it cannot be performed (*i.e.* presence of metallic devices not compatible with a magnetic field) (18).

MRI examination can be used to diagnose initial hip OA, to evaluate predisposing conditions and to stage the disease (Fig. 3). A specific MRI score for hip OA, the HOAMS (Hip Osteoarthritis MRI Scoring System), was introduced by Roemer *et al*. (19) in 2011. It is a semi-quantitative score considering the whole hip joint and evaluating both early and late features (Table II), some of them detectable only using MRI, providing a more complete assessment. The need of a standard MRI equipment and the usual sequences, makes the HOAMS widely used (19).

Recently, new MRI protocols were proposed to assess the cartilage qualitative changes that precedes macroscopic alterations (20). These procedures, not yet routinely used, are: dGEMRIC (delayed gadolinium-enhanced MR imaging of cartilage), T2 maps, T2* maps and T1ϱ imaging:

- dGEMRIC is performed to assess, indirectly, cartilage degeneration by the estimation of the glycosaminoclycan decrease (early characteristic of cartilage degeneration). It is a T1 mapping sequence that is performed a short time after iv injection of a negatively charged gadolinium-based contrast agent (gadopentetate dimeglumine) or, alternatively, after intra-articular injection of contrast material. Therefore, shortening of T1 values due to the increased content of contrast agent molecules correlates with cartilage glycosaminoglycan loss (21).
- T2 mapping is a quantitative assessment of changes of the T2 value that take place when changes in water content and arrangement of the collagen structure of cartilage occur in cartilage degeneration (22).
- T2* mapping has the advantage of a faster acquisition time than T2 mapping, allowing the acquisition of a 3D volume. As the T2* technique is more sensitive to susceptibility artifacts than T2 mapping, local magnetic inhomogeneities at the bone-cartilage interface may be a limitation of this technique (23).
- T1ϱ-weighted MR imaging allows estimation of the loss of proteoglycans on the basis of the effect of low-frequency physicochemical interactions between water and extracellular matrix molecules when a spin-lock pulse is applied (24).

Inflammatory arthritis (rheumatoid arthritis, spondyloarthritides and juvenile idiopathic arthritis)

Hip involvement can occur quite frequently, especially in ankylosing spondylitis (AS) and plain radiography is considered the first-line imaging technique to be used. Unfortunately, early stages of disease (joint inflammation and synovial proliferation) cannot be shown by plain x-ray, so MRI and ultrasound (US) will be of crucial importance.

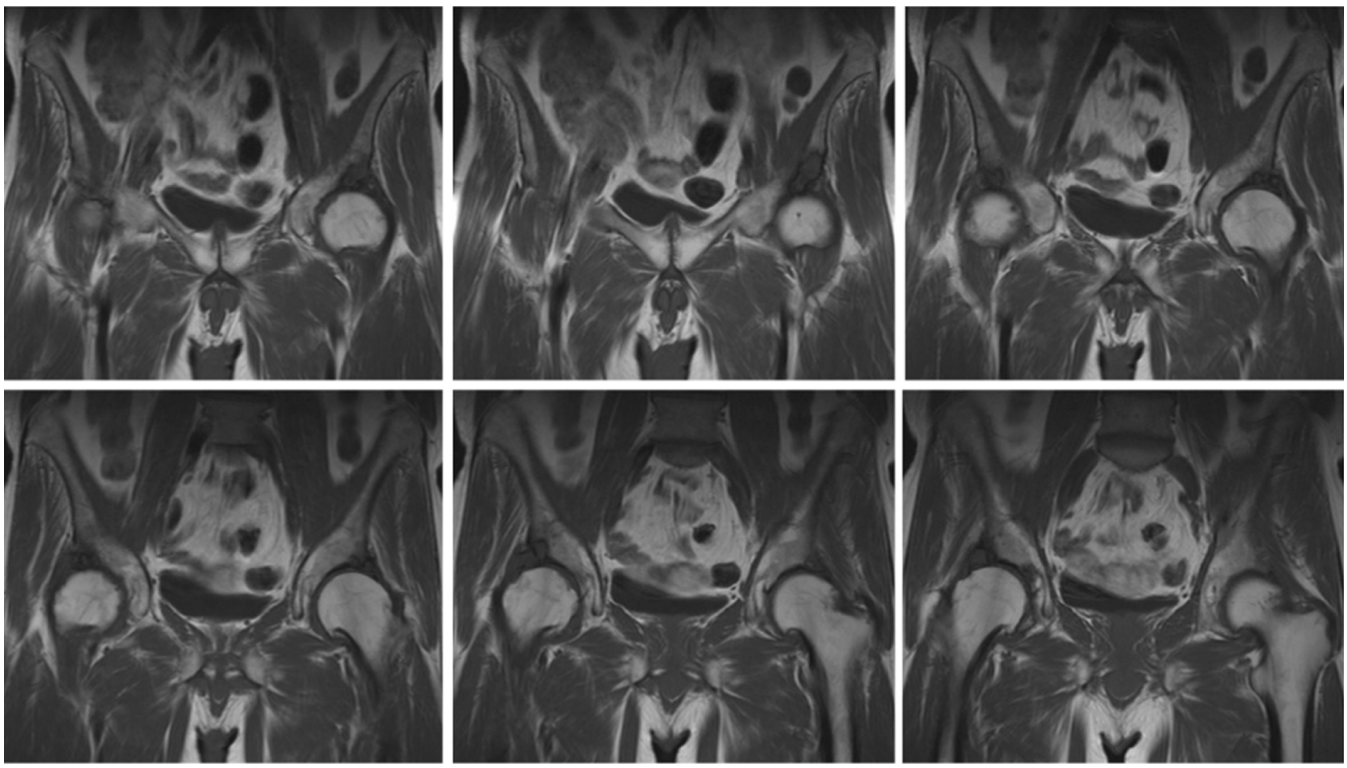

Fig. 3. Coronal T1-weighted images; Osteoarthritis of both hips with marginal osteophytes of the acetabular roof, of the front and rear acetabular pillars and of the femoral neck. Multiple subchondral geodes on the anterolateral side of the acetabular roof. Bilateral reduction of the front, top and medial joint space with moderate joint effusion on the right.

Rheumatoid arthritis (RA)

Hip involvement in patients with RA is quite frequent (2, 25) and the main radiographic findings include JSN, erosions and iuxta-articular osteoporosis. Joint space narrowing is diffuse or located in the supero-medial area of the joint with axial or cranial migration (26). Erosion are typically ill-defined and marginally located, especially in bare areas. Usually there are no osteophytes, which are more typically present in seronegative spondyloarthropathies (SpA) (27).

Radiolucent areas appear earlier in the osteochondral margin of the femoral head, close to the femoral neck while surface irregularities appear on the entire surface of the femoral head and in the acetabulum. Finally, periarticular osteoporosis is characteristically found in RA. A peculiar pattern, called "cystic RA" or "robust RA" (27), can be shown in a small number of patients (mostly in men practicing intense physical activity) and it is characterised by the presence of large cystic lesions without periarticular osteoporosis.

As disease progresses, the pathological findings become more pronounced with erosions involving the central joint surfaces and in patients with a long-standing disease, plain radiographs could reveal complete obliteration of the joint space, fragmentation of the acetabular roof and massive erosion of the femoral head.

Secondary acetabular protrusion (a characteristic but non-pathognomonic finding) (26) frequently occurs in RA hip involvement (14% of patients with longstanding disease (28), especially in elderly women (26), and results from axial migration of the femoral head. It usually progresses slowly but in some patients it could be rapid (29).

Other findings can be present, especially during corticosteroid treatment, like osteoporosis, spontaneous acetabular medial wall fractures (which may both play a role in the development of acetabular protrusion) and avascular necrosis of the femoral head. All of these may lead to a secondary OA.

MRI may be used in the diagnostic path but also to evaluate disease activity (both at an articular and periarticular level), treatment response and complications (Fig. 4).

Allowing a direct view of synovial proliferative tissue, MRI has a fundamental role in the early stage of the disease. Synovitis (joint synovial thickening) and effusion are both characterised by a low-signal intensity in T1-weighted images and high-signal intensity in T2-weighted images. Injection of a contrast agent (gadolinium), using T1-weighted fat sat sequence, allows the differentiation between the synovitis (enhanced active destructive synovial proliferation with an high signal intensity) and the non-enhanced inactive fibrotic synovial proliferation or joint effusion (low-signal intensity) (30).

Finally, a better distinction between synovial tissue and cartilage (by the acquisition of very thin sections) is allowed by the use of three-dimensional gradient-echo imaging with fat-suppression techniques.

Bone marrow oedema is a finding that can be identified only on MRI and it appears as a lesion with ill-defined margins exhibiting high signal intensity on STIR or fat-suppressed T2-weighted MR images (31). It is thought to precede the development of bone erosions

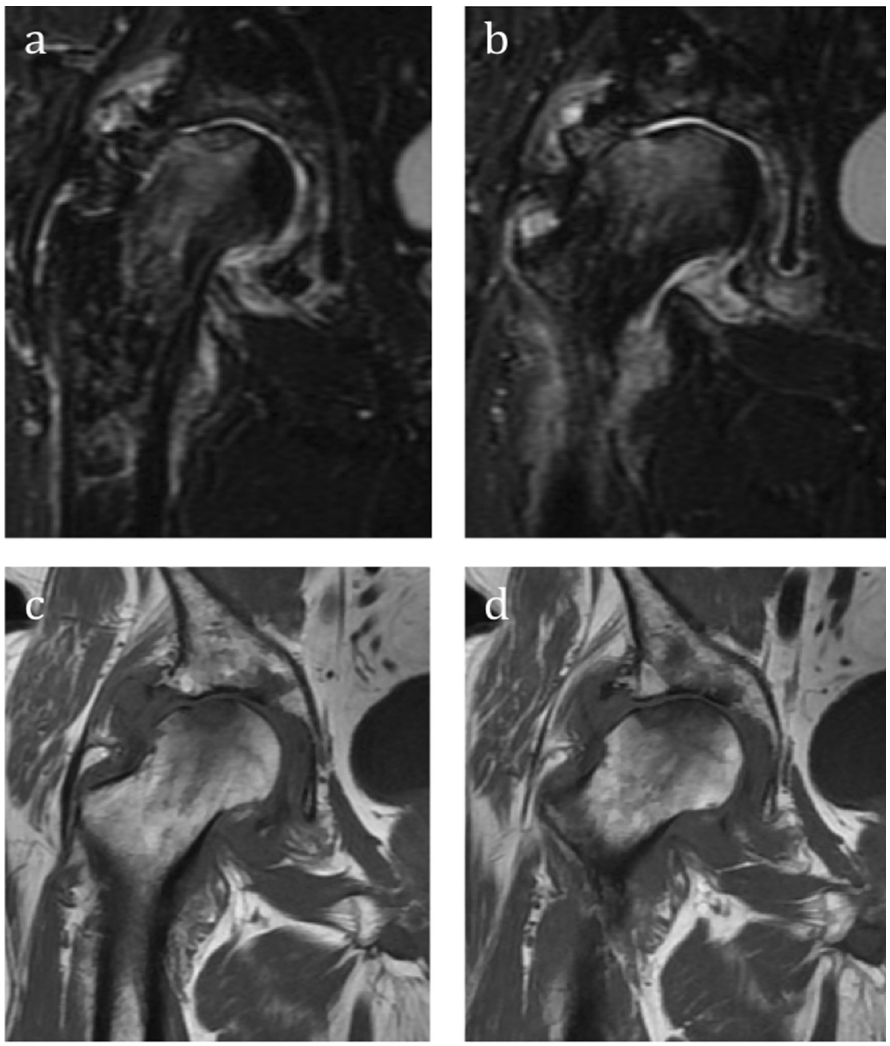

Fig. 4. Coronal STIR- (**a**,**b**) and T1-weighted (**c**,**d**) images; patient with inflammatory involvement (probably arthritic type) and osteonecrosis of the femoral head.

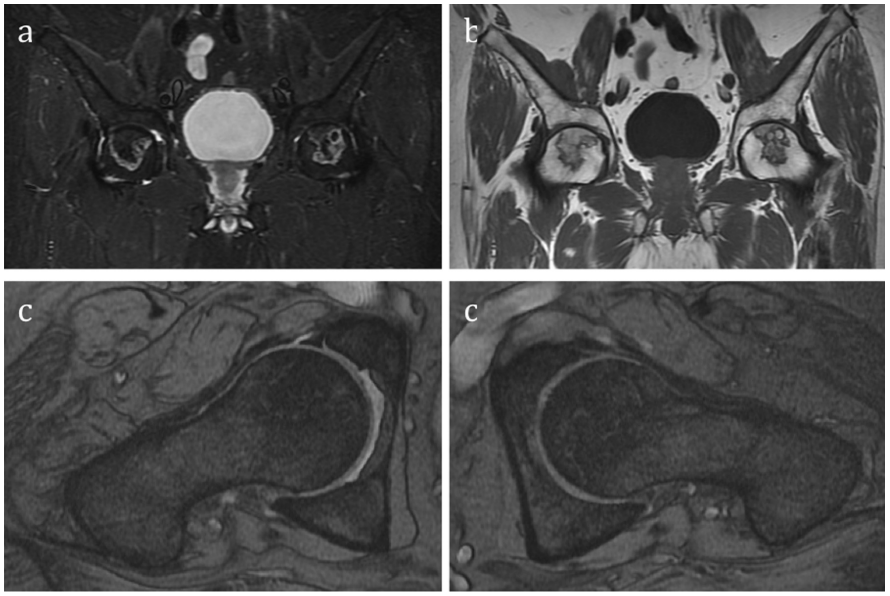

Fig. 5. Coronal STIR-, coronal T1- and axial T2-weighted images; bilateral osteonecrosis of the femoral head.

and it may occur alone, or it may surround osseous lesions resulting from synovial inflammation.

Bone erosions that are initially located at the insertion of the synovial membrane (marginal erosions) and in a later stage in subchondral areas (central erosions), are defined as sharply marginated areas of trabecular bone loss with a visible cortical break (while cystic lesions do not show it). When joint fluid fills the erosions a fat-suppressed T2-weighted image can show them easily while, on those filled with hypervascularised synovial pannus, fat-suppressed gadolinium-enhanced T1-weighted images works better. So that, generally, MRI, as well as US, show erosions earlier than x-ray (27).

As has been previously stated, MRI may be used to assess disease activity, structural damage progression and treatment response, the latter by identifying the reduction in synovial volume, the decrease in the rate of synovial enhancement (32, 33) and, possibly, bone erosion healing.

Spondyloarthritides

Hip involvement in AS is quite frequent (34, 35) and is usually bilateral and symmetric (5, 26, 36) with concentric joint space narrowing, marginal osseous erosions and axial migrations which lead to acetabular protrusion. The presence of bony proliferation, with osteophytes and subchondral sclerosis, and the absence of osteoporosis are typical radiographic features which help to distinguish AS from RA. A typical AS finding is the "lump" osteophytes on the lateral side of the femoral head and, during disease progression, osteophytes form a collar around the femoral neck. Others radiographic findings are subchondral cysts, of variable size, in the acetabulum (37).

US hip involvement in the other seronegative spondyloarthropathies has been found with similar frequencies (27% and 24% in AS and PsA, respectively) (4-5). It is more often bilateral in psoriatic arthritis (PsA) and monolateral in post-infectious arthritis, with radiographic features similar to those of AS. Furthermore, during PsA, there is a rapid progression (36) leading to joint

destruction and secondary acetabular protrusion (38).
As for RA, MRI allows early detection of inflammatory changes in SpA, resulting in primarily importance not only in the hip but also in the assessment of the pelvic entheses. Once again, it can be used to evaluate treatment response, in fact bone marrow oedema and entheses inflammatory oedema (a fairly typical feature of SpA) are well demonstrated on STIR and T2-weighted with fat suppression sequences. Other inflammatory areas in bone marrow and joint space are well demonstrated in fat-suppressed gadolinium-enhanced T1-weighted images.
Structural changes (sclerosis, ankylosis) are well demonstrated on both T1- and T2-weighted MR images, and include low signal intensity on all sequences (sclerosis) and disappearance of the joint space on all sequences (ankylosis) (26), while erosions are better assessed using iv contrast agent.

Juvenile idiopathic arthritis
Hip joint involvement, in juvenile idiopathic arthritis, occurs in 35–63% of patients, especially in systemic arthritis and polyarthritis (26, 37). It may occur early in the disease course and in this case it is associated with poor outcome (27). Plain x-rays usually show bilateral and symmetric lesions (26, 39) including periarticular osteoporosis and enlargement of the femoral capital epiphysis. Unlike adults, concentric JSN and erosive changes are considered late findings (26). Hypoplasia of the iliac bones, coxa valga deformity, joint subluxation, severe joint destruction and acetabular protrusion (the latter sometimes being the predominant radiologic feature in patients with isolated hip disease) are other findings to consider (40).
As in other adult inflammatory arthropathies, MRI can provide information on synovial inflammation (39, 41-42), extent and progression of juvenile idiopathic arthritis (39, 43, 44), and response to treatment (37). Even in this case, MRI is the most sensitive modality to detect early articular damage, evaluate the extension of articular disease and identify complications and response to treatment. Bursitis and synovial cysts are not frequently reported in juvenile idiopathic arthritis.

Bursitis
Bursitis (the enlargement of a bursa due to synovial fluid or inflamed and hypertrophied synovium) is a commonly reported finding in patients with RA or SpA. X-ray is not of help in assessing bursitis and the first-line method is considered the US, showing a bursal wall (sometimes thickened) filled with a well-demarcated fluid collection and possibly, septa and proliferative synovial tissue, located anterior to the hip joint capsule (45, 46), which may exhibit colour or power Doppler signal.
MRI may be more effective than US in the detection of bursitis revealing also the communication between the bursa and the joint cavity, as well as the real size of the bursitis (46).
On T2-weighted MRI sequence, bursitis is shown as a uni- or multilocular high signal intensity collection. Chronic bursitis may occasionally contain multiple rice body formation (dense fibrinous material) that appear hyperechoic on US and hypointense on T2-weighted MR images. The iliopsoas bursa is located anterior to the hip joint, medial to the iliopsoas tendon and lateral to the femoral vessels (if an intrapelvic component is present, it is seen surrounding the iliopsoas tendon, medial to the ilium and lateral to the femoral vessels) (47). After contrast injection, peripheral and septal enhancement are seen (46). The trochanteric bursa is located superficial to the greater trochanter of the femur, beneath the gluteus maximus muscle and its involvement is present in 15% of RA patients (48). The ischiogluteal bursa is much less frequent and located between the ischial tuberosity and the gluteus maximus muscle (49).

Synovial cyst
A synovial cyst may be a cause of hip pain in patients with RA or SpA. It can stem from the articular synovial sheath (50) as well as from bursal cavities (50). Synovial cysts are well demonstrated by US and MRI (both of them detecting the communication with the hip joint or the adjacent bursitis) but, considering its deep location, MRI is more effective than US in its assessment (27).

Osteonecrosis
Osteonecrosis of the femoral head (ONFH) could be due to arthropathies and glucocorticoid therapy. It can be visualised using readiographs as a: crescent lucent subchondral line resulting from a subchondral fracture; sclerosis surrounding an osteopenic area (with the sclerotic rim being a reactive bone remodelling at the necrotic viable osseous junction); segmental flattening of the femoral head with or without JSN and secondary OA.
Even if plain x-ray is still considered the first step in a suspected ONFH, it shows high specificity for advanced disease, but low sensitivity for early phases of the disease, the visualisation of which is of the utmost importance since early diagnosis is directly associated with a better prognosis (51-53).
Due to their higher sensitivity, MRI and bone scintigraphy represent the preferred exams to perform in the suspicious of ONFH. In the case of a definite diagnosis, because of its ability to obtain multiplanar and three-dimensional images, CT could be useful to stage the disease showing collapsed or depressed areas. This could determine a change in the therapeutic approach.
Bone scintigraphy with 99mTc-methylene diphosphonate shows high sensitivity for early detection of ONFH, since the radionuclide activity reflects osteoblastic activity and blood flow which are absent in ONFH (54-55). The method can provide positive findings after only 2–3 days since the onset of symptoms (“cold within hot”) and, later, “hot lesion” reflecting revascularisation. Unfortunately, scintigraphy is not so specific and presents a few important limitations [*i.e.* high radiation dose, poor spatial resolution, inability to accurately discriminate the lesion from other disorders and inability to quantify the lesion and therefore contributes to prognosis estimation (54-55)].
The gold standard for ONFH diagnosis and staging is considered to be MRI (Fig. 5), which allows multiplanar imaging, superb soft tissue contrast and

discrimination between fat and other tissues in the bone marrow (53-55). Sclerosis and bone collapse determine a pathognomonic circumscribed subchondral "band-like" lesion with low signal intensity on T1-weighted images (54). The "double-line" sign is seen on T2-weighted Spin Echo or Turbo Spin Echo sequences and consists of a low signal intensity outer rim and a high signal intensity inner rim. This sign was introduced by Mitchell *et al*. (54) and was considered pathognomonic for ONFH since the outer rim represents the reactive bone and the inner rim the vascular and repair tissue at the necrotic-viable osseous interface. The extension of the necrotic area is well evaluated in the axial plane. Joint effusion is seen in about half the patients with ONFH regardless of the presence of articular surface collapse (51) and its extent is often directly correlated with the clinical severity. Femoral collapse, presence of osteophytes and JSN could provide additional information to stage the disease. Contrast enhancement provides increased signal to noise ratio which helps obtaining images with increased spatial resolution and in the absence of any other finding, it shows enhancement at the reparative interface (51).

Finally, since it is radiation free, MRI is useful in the follow-up of the disease and must be repeated at different times to detect the early onset of complications (51).

In conclusion, hip pain has a variety of causes that can be assessed using several different imaging techniques, showing different sensitivity and specificity. The choice of technique to use depends on the type and stage of the disease.

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