Practical Issues in Geriatrics
Series Editor: Stefania Maggi

Giuseppe Guglielmi
Mario Maas *Editors*

Imaging in Geriatrics

Springer

Practical Issues in Geriatrics

Series Editor
Stefania Maggi, Aging Branch
CNR-Neuroscience Institute, Padua, Italy

This practically oriented series presents state of the art knowledge on the principal diseases encountered in older persons and addresses all aspects of management, including current multidisciplinary diagnostic and therapeutic approaches. It is intended as an educational tool that will enhance the everyday clinical practice of both young geriatricians and residents and also assist other specialists who deal with aged patients. Each volume is designed to provide comprehensive information on the topic that it covers, and whenever appropriate the text is complemented by additional material of high educational and practical value, including informative video-clips, standardized diagnostic flow charts and descriptive clinical cases. Practical Issues in Geriatrics will be of value to the scientific and professional community worldwide, improving understanding of the many clinical and social issues in Geriatrics and assisting in the delivery of optimal clinical care.

Giuseppe Guglielmi • Mario Maas
Editors

Imaging in Geriatrics

Springer

Editors
Giuseppe Guglielmi
Clinical and Experimental Medicine
University of Foggia
Foggia, Italy

Mario Maas
Department of Radiology and Nuclear Medicine
University of Amsterdam
Amsterdam, Noord-Holland
The Netherlands

ISSN 2509-6060 ISSN 2509-6079 (electronic)
Practical Issues in Geriatrics
ISBN 978-3-031-14876-7 ISBN 978-3-031-14877-4 (eBook)
https://doi.org/10.1007/978-3-031-14877-4

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Demographic changes, due to the longer lifespan and the improvement of the quality of life, led to an aging society, where developing high-quality healthcare for older people becomes increasingly important.

Nowadays the elderly population is more informed and more demanding of better care through cutting-edge technology and treatment. Specifically, radiologists play an increasingly important role and occupy a frontline position in the evaluation of this cohort of patients, who necessitate definitive imaging.

In this perspective, the complex relationship between geriatrics and radiology must be redefined. *Imaging in Geriatrics* is the result of a teamwork of radiologists, experts in the field, with the aim to provide guidance for the appropriate use of imaging in modern geriatric care, describing how to recognize pathology from para-physiological findings in the elderly population.

The study of diagnostic imaging in geriatrics, enriched by traditional and modern imaging methods, is primarily oriented to the clinical and radiological analysis most frequently encountered in these patients and, above all, to the not easy distinction between "normal" and "pathological," especially in situations in which para-physiological changes resulting from aging processes are associated with alterations related to comorbidity and chronicity.

This volume includes a multidisciplinary approach, and it covers all major medical issues related to aging, divided by apparatus. In particular, it encloses the main pathologies in the neurological, cardiovascular, pulmonary, gastrointestinal, urogenital, hematologic, and musculoskeletal field.

This book considers all imaging techniques that have been the cornerstones of radiology, but also modern innovations. Conventional radiography is still the first approach in the diagnosis of a frequent variety of pathological conditions of elderly patients, such as fractures, often due to osteoporosis, pneumothorax, or heart failure. On the other hand, Computer Tomography (CT), with its intrinsic resolution power, allows radiologists to detect a possible ischemic or hemorrhagic cerebral focus, as well as neoplastic metastases for the staging of the primary pathology. Spinal cord injuries are best identified with Magnetic Resonance Imaging (MRI). But nowadays, and therefore modern "tailored" medicine, is changing, going towards Artificial Intelligence (AI), a technological evolution that brings with it the limits related to the training and updating of the healthcare personnel involved. For this reason, a section about the role of AI in the management of geriatric patients could not be missed at the end of this volume.

Finally, the aim of this book is to simplify the approach and the diagnostic imaging process of geriatric diseases, bringing out the potential and limitations of each imaging technique.

We recommend the reading of this book not only to radiologists for their daily clinical practice but also to all physicians who require a basic knowledge of imaging concerning the main geriatric pathologies, because of their complex clinical presentations.

Foggia, Italy — Giuseppe Guglielmi
Amsterdam, The Netherlands — Mario Maas

Contents

Osteoarthritis in Appendicular Skeleton in Geriatric Patients

13

Antonio Barile, Riccardo Monti, Federico Bruno, Julia Daffinà, Francesco Arrigoni, and Carlo Masciocchi

13.1 Introduction

Osteoarthritis (OA) is the most common form of arthritis and is the third leading cause of disease burden in developed countries with significant social and health impact. As the average age and life expectancy are increasing, this form of arthritis is expected to increase in the incoming decades. OA commonly affects weight-bearing joints such as the knee, which is most commonly affected, and the main clinical features are pain and stiffness. The gravity of this disease leads to a progressive decline in physical functioning. Imaging plays a vital role in initial diagnosis, staging, and monitoring of longitudinal progression and provides indications for conservative, minimally invasive, or surgical treatment. Although the primary focus of imaging lies in bone alterations, osteoarthritis should be framed as a whole organ disease, and multimodal instrumental evaluation is essential to highlight the various joint components involved and their alterations.

13.2 Shoulder Osteoarthritis

Compared to other appendicular joints, the glenohumeral joint is one of the least commonly affected by osteoarthritis. The estimated radiographic prevalence is in the range of 16–20% in an elderly population. The main risk factor for glenohumeral osteoarthritis is age. Other factors that increase the likelihood risk of developing shoulder osteoarthritis include female gender, obesity, Caucasians, previous trauma, rotator cuff tears, glenohumeral instability, and crystalline arthropathy. In

A. Barile (✉) · R. Monti · F. Bruno · J. Daffinà · F. Arrigoni · C. Masciocchi
Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila, L'Aquila, Italy
e-mail: antonio.barile@univaq.it; carlo.masciocchi@univaq.it

G. Guglielmi, M. Maas (eds.), *Imaging in Geriatrics*, Practical Issues in Geriatrics, https://doi.org/10.1007/978-3-031-14877-4_13

addition to idiopathic origin, further causes of glenohumeral osteoarthritis are the presence of prior trauma, glenohumeral dislocation, proximal humeral fractures, shoulder osteonecrosis, inflammatory arthritis, septic arthritis, hemochromatosis, hemophilia, and iatrogenic causes such as multiple injections of intra-articular steroids [1].

Symptoms are usually slowly progressive, characterized by posterior or deep localized shoulder pain associated with limited range of motion and stiffness. Other symptoms include blockage, grinding, and joint instability. As in other diarthrodial joints, glenohumeral osteoarthritis is associated with the thickening of the subchondral bone plate and the formation of marginal osteophytes, which can usually be seen both on the posterior glenoid rim and on the central part of the humeral head. The soft tissue changes associated with this condition are the capsular thickening and contraction, potentially leading to a deficit of internal rotation, and the further eccentric erosion of the posterior glenoid [2].

As with other joint OA involvements, general imaging hallmarks comprehend osteophyte formation, joint space narrowing, and subchondral bone plate sclerosis, whereas subchondral cyst formation and joint surface remodeling or deformity are seen in later stages.

13.2.1 Conventional Radiography (CR)

To assess the presence and degree of arthritis in the glenohumeral joint the first step is conventional radiography. Standard projections include an anteroposterior view, a Grashey view (AP oblique internal rotation), and a further axillary view. These views allow grant the assessment of the presence, type, and degree of arthritis and rule out other conditions, including fractures, dislocations, and bone injuries [3].

To determine the extent of osteoarthritis of the glenohumeral joint various radiographic classifications were established. The most widely adopted is the Samilson-Prieto classification. This classification acknowledges grade 0 is normal, grade 1 is mild with osteophytes smaller than 3 mm on the humeral head, grade 2 is moderate with osteophytes between 3 and 7 mm on the humeral head or glenoid rim, and grade 3 is severe with osteophytes over 7 mm, with or without contextual joint incongruity. The state of the rotator cuff can be inferred from the radiographic evaluation of Grashey's view. This view is accessed from a lateral oblique projection at 30°, tangential to the glenohumeral joint, to obtain an image parallel to the glenoid face in order to reveal any degenerative modifications [4].

For the rotator cuff the radiographic classification used integrity is the Hamada–Fukuda classification, a radiographic morphological description of the natural course of massive rotator cuff tear assessing the height of the acromiohumeral space. There are five distinctions within this classification:

- Type 1: Normal joint morphology and acromiohumeral distance bigger than 6 mm
- Type 2: Acromiohumeral distance smaller than 5 mm

- Type 3: Type 2 plus the acetabularization (i.e., exaggerated undersurface concavity) of the acromion
- Type 4: Types 2 and 3 plus the narrowing of the glenohumeral joint space
- Type 5: Types 2, 3, and 4 plus the humeral head collapse

Finally, an axillary view is essential in preoperative planning. It allows the assessment of the posterior glenoid wear and deficiency, which has ramifications on the glenoid preparation (concentric reaming) necessary to center the glenoid-based implant [5].

13.2.2 Computed Tomography (CT)

For an effective preoperative planning and to assess the humeral and glenoid bone condition, computed tomography (CT) provides greater bony detail compared to radiographs. If there are concerns regarding the glenoid's bone loss, the presence of cyst, or retroversion on standard radiographs, CT should be suggested as it may influence both the type of arthroplasty choice and the location of the glenoid component. The CT study of the affected shoulder is necessary to estimate the glenoid bone loss, which may require preoperative planning before eccentric reaming, augmentation of bone graft, use of augmented glenoid components, or consideration of total reverse shoulder arthroplasty. Therefore, CT evaluation should be considered mandatory in all patients undergoing an arthroplasty procedure that requires glenoid resurfacing (e.g., total shoulder arthroplasty and total reverse shoulder arthroplasty) as it allows the quantification of the glenoid border and recognition of different forms of glenoid bone loss such as cyst that can alter implant fixation and placement [6].

13.2.3 Magnetic Resonance Imaging (MRI)

Besides visualizing the glenoid and humeral head morphology, MRI can help detect the underlying etiology. Thanks to MRI, the evaluation of various tissue abnormalities, regarding cartilage, labrum, and glenohumeral ligaments can be assessed. However, the capacity of detecting cartilage lesions is limited by the comparison with to other joints. Additionally, magnetic imaging provides valuable information for the rotator cuff evaluation, which forms an integral part of surgical planning. Shoulder MRI is suggested in patients with rotator cuff deficiency doubts on clinical examination. Indeed, an intact rotator cuff is required for both hemiarthroplasty and total shoulder arthroplasty. Therefore, the integrity of the rotator cuff is a crucial factor in determining whether the patient is a candidate for total anatomical shoulder arthroplasty, hemiarthroplasty, or conversely to total reverse shoulder arthroplasty [7, 8]. MRI shows soft tissues with an excellent detail, it can also add information on rotator cuff tears and on the presence and degree of muscle atrophy.

The Goutallier Grading Scale of Fat Infiltration of Rotator Cuff Muscles was initially described using CT to assess the degree of fat infiltration of individual rotator cuff muscles. Goutallier's classification consists of: grade 0 is normal muscle, grade 1 is some fat streaks, grade 2 is less than 50% fat muscle atrophy, grade 3 is 50% fat muscle atrophy, and grade 4 is greater than 50% of fat muscle atrophy. The importance of this classification scale is its implication in the reparability of the rotator cuff: a degree of Goutallier fat infiltration of 3 or greater (i.e., fat infiltration equal to or greater than 50% of muscle mass) has a 50–70% tear rate [9].

13.3 Acromioclavicular Osteoarthritis

Although AC osteoarthritis is less common than other locations such as the knee or the hip, it is differently much more frequent than glenohumeral osteoarthritis. Around 54–57% of elderly patients have an X-ray evidence of degenerative changes in the AC joint. On the other hand, clinically relevant AC osteoarthritis is uncommon, although it is more frequently related to other pathologies, such as the CR upper impingement syndrome [10]. Primary osteoarthritis is strongly age-related, as a matter of fact the degenerative process begins in early adulthood. Secondary osteoarthritis, mainly following trauma such as joint sprains or distal clavicular fractures, appears to be even more prevailing than primary osteoarthritis. The clinical picture is pain in the anterior/superior aspect of the shoulder, sometimes radiating to the base of the neck/trapezius muscle. Daily movements or activities that involve overhead or transverse movements increment pain. Local tenderness can be caused by AC joint palpation. This range of symptoms is not specific and is also reported in cervical spine disease and CR impingement syndromes, which, as aforementioned, are predominant causes of shoulder pain. The direct intra-articular injection of anesthetics can grant a differential diagnosis. The imaging evaluation of the AC joint begins with an X-ray. This joint can be studied with average AP views of the shoulder. However, the best option according to literature is the Zanca view (a cephalad inclination of 10–15° with a 50% reduction in exposure compared to standard AP view shoulder). Imaging findings are typical of degenerative diseases: sclerosis, osteophytes, subchondral cysts, and joint space narrowing [11]. Bone modifications seen on X-rays are evidenced more precisely on CT scan. At the same time, MRI is more useful for evaluating changes in capsuloligamentous structures, bone edema, and abnormalities in surrounding soft tissues (e.g., effusion of bursal or tendon pathology) [12]. The AC joint can only be partially evaluated with US. Still, it should be a part of routine shoulder examination, as AC joint osteoarthritis can sometimes mimic rotator cuff tendinopathy and may cause anterosuperior impingement. AC osteophytes are found in 50% of patients with rotator cuff tears but also in 14% of patients without rotator cuff tears. By placing the high-frequency linear probe on a coronal plane at the level of the joint, the evaluation of the two articular ends of the acromion and clavicle is possible. The superior AC ligament is clearly seen as a banded arch echo structure that overstays the bones; below it, the joint space can vary in size and echogenicity with movements. In case

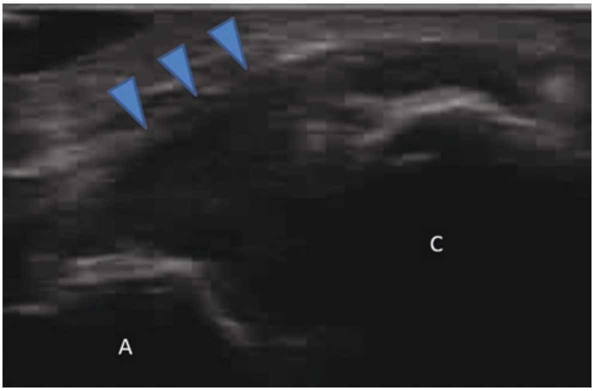

Fig. 13.1 US scan of the acromioclavicular joint showing capsular distension with effusion (arrowheads). A: acromion; C: clavicle

of AC joint osteoarthritis, US can help evaluate superficial bone irregularities and osteophytes, capsular hypertrophy, joint space narrowing, and joint effusion or synovial hypertrophy (Fig. 13.1). Bilateral evaluation of the AC joint is always suggested to evaluate capsular hypertrophy and joint space narrowing with increased sensitivity. US AC joint findings should always be correlated with rotator cuff and bursa findings and clinical picture. AC joint arthrosis-related shoulder pain can only be diagnosed in the absence of RC abnormalities and with radiological proof showing this condition. Besides, US signs of acromioclavicular osteoarthritis and rotator cuff or bursal pathology are frequently connected; in this case, the joint injection test can be a valuable diagnostic tool. Another frequent finding in US is an AC joint cyst whose pathogenesis is still debated. They are however more commonly related to full-thickness RC tears. Tendon tears cause the cranial migration of the humeral head and damage the inferior AC joint capsule, creating a connection between the glenohumeral joint and the AC joint [13].

13.4 Hand Osteoarthritis

Despite the high prevalence, hand OA generally receives less attention compared to OA of the weight-bearing joints. It typically affects the distal interphalangeal (DIP) joints and the thumb base and, less frequently, the proximal interphalangeal (PIP) joints. Patients with hand OA can experience considerable pain, stiffness, and disability with a high impact on health-related quality of life. Outcome measures in OA usually include evaluation of pain and disability and structural changes in the joint can be studied with outcome [14].

13.4.1 Conventional Radiography (CR)

Currently the cheapest, most feasible, and available imaging modality for morphological assessment of the structural features of the OA hand is conventional

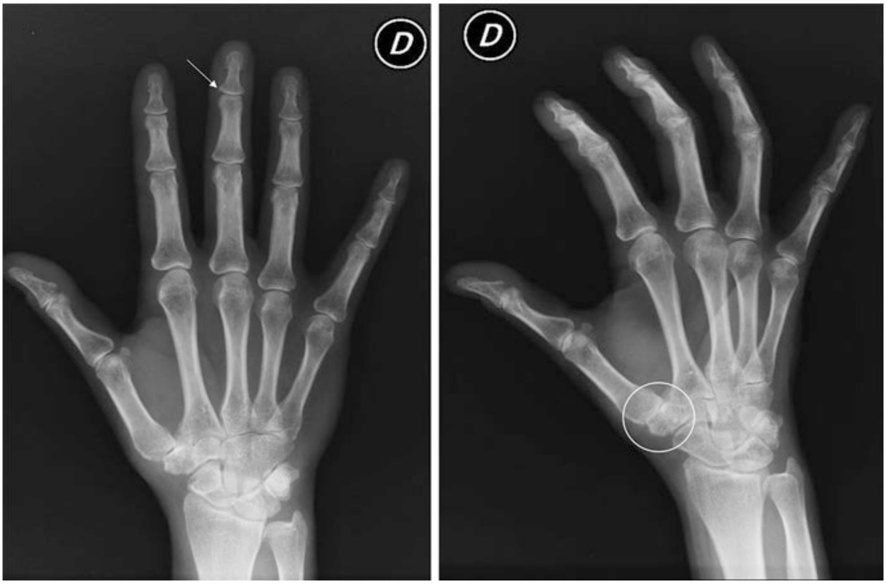

Fig. 13.2 AP and oblique radiographic view showing initial osteoarthritis changes at the level of the DIP with joint space narrowing and sclerosis (arrow). More advanced OA changes of the trapeziometacarpal joint (circle)

radiography (CR). At present, there is no established gold standard for the definition of radiographic hand OA. Studies also differ in classification systems most commonly used and in the radiographic definitions of radiographic.

CR provides a two-dimensional picture of bone modifications, such as osteophytes, erosions, cysts, and sclerosis and joint space narrowing (JSN) as an indirect measure of cartilage loss (Fig. 13.2). Osteophytes can be divided into "true" intra-articular osteophytes and traction spurs. "True" intra-articular osteophytes are found at joint margins and can be easily seen on CR with a traditional posteroanterior view. Traction spurs are differently located at the extensor tendon insertion or on the central shaft and are most easily seen on CR with an oblique or lateral view. Whether these enthesophytic changes are related to OA is not entirely clear, previous studies have suggested that they are mainly related to age and local biomechanical factors and not to systemic enthesopathy [15].

Since cartilage is indirectly evaluated by the inter-osseous distance, the radiographic measurement of JSN is currently recommended as an imaging endpoint for clinical trials of disease-modifying OA drugs. The radiological assessment may be affected by the hand positioning (e.g., flexion deformity) and is further complicated by erosive development in the fingers joints, which can lead to increased joint space width (JSW) (pseudo-enlargement) despite the worsening of the disease. Radiographic erosions in hands with OA are seen as bone damage in the central part of the joints with a typical gull-wing configuration. These erosions typically occur in the DIP and PIP joints, but they have been described in the joints of the base of the thumb as well. Longitudinal studies have shown that JSN precedes erosive development, suggesting that local biomechanical factors are important for erosive development. These findings may suggest that erosive hand OA represents severe hand OA rather than a different disease entity. Whereas cysts are identified by the loss of trabecular structure, sclerosis gives an increased density in the CR. Both features can be related to bone remodeling [16].

At present, there is no consensus on the preferred grading scale. The first proposed radiographic scoring system was the Kellgren and Lawrence (K&L) scale which is the most widely used so far. The K&L scale classifies OA over a range from 0 to 4 points (where grade of at least 2 is OA) based on different factors. These include: the presence/severity of osteophytes, JSN, sclerosis, pseudocystic areas, and altered shape of the bony ends. In spite of different grading descriptions for various joint groups and difference between publications, there is general confusion in the way of interpreting the various grades. Furthermore the K&L scale is criticized for the emphasis given to osteophytes; however, sclerotic joints cannot be classified as OA unless osteophytes are present. Therefore, several studies used modified K&L scales to overcome these limitations. The evaluation of individual characteristics instead of using a global score can optimize the joint assessment, hence the OARSI (Osteoarthritis Research Society International) atlas is more frequently used. With this atlas as a reference, the presence and severity of individual characteristics (osteophyte, JSN, malalignment, erosion, subchondral sclerosis, subchondral cysts) are assessed on semi-quantitative scales at the level of DIP, PIP, first CMC, thumb and trapezionavicular joint. However, scoring individual features can take longer [17].

Standard radiographs to characterize the basal thumb joint include PA, lateral and oblique views of the hand or wrist. Arthritis of the basal joint of the thumb is most commonly described using the Eaton-Littler classification which was first proposed in 1973 and modified in 1987 by Eaton and Glickel. In this classification, stage I is given by normal joint contours with mild joint widening (secondary to synovitis, ligamentous laxity, or effusion), while stage II shows mild joint space narrowing (<2 mm), mild sclerosis, subchondral cysts, and/or periarticular debris. Stage III follows with noticeable joint space narrowing, prominent sclerosis, subchondral cysts, and periarticular debris. Finally, stage IV concerns the scapho-trapezius joint, plus the narrowing's worsening, increased sclerosis, and the presence of subchondral cysts. In the clinical examination, CMC subluxation, metacarpal adduction, and MCP hyperextension are seen. However, the Eaton-Littler classification has its flaws, including only moderate compatibility with clinical presentations, morphological findings and therapeutic recommendations, and sub-optimal inter- and intra-observer variability. Although some authors underline the convenience of transverse imaging (e.g., MRI, ultrasound, CT) in basal thumb joint arthritis diagnosing, there is currently no recommended role for advanced imaging [18].

13.4.2 Ultrasonography (US)

In recent years, ultrasonography has been acknowledged as a useful tool for finger joints' inflammation evaluation in patients with rheumatoid arthritis. Recently, the prevalence, validity, and reliability of US characteristics have also been studied in patients with hand OA. By scanning the joint in both longitudinal and transverse projection we can obtain conditions regarding the dorsal appearance with the joint in full flexion, while volar aspects are studied with the joints in a neutral position. US allows visualization of a broad spectrum of OA features of the hand, including osteophytes, marginal erosions, and synovitis (Fig. 13.3). It may also be considered a feasible and prompt tool for visualizing inflammation in patients with hand OA. Conversely, one of the US disadvantages is the inability of the beam to penetrate the cortex. Because of joint anatomy, the visualization of the cartilage and bone damage is mainly limited to its peripheral parts. Overlying osteophytes, which interfere with the acoustic window, further complicate the assessment. In severely damaged joints, it may be difficult to determine where an erosion begins and an osteophyte ends. Most US studies of patients with hand OA reported a high prevalence of grayscale synovitis, while potency Doppler activity was less frequent. In erosive OA, often called "inflammatory" OA, a greater power Doppler activity, synovial hypertrophy, and joint effusion compared to patients with non-erosive radiographic OA joints can be found. Synovitis appears to be more prevalent in joints with active erosions, while the prevalence is lower in joints that have been remodeled [19, 20].

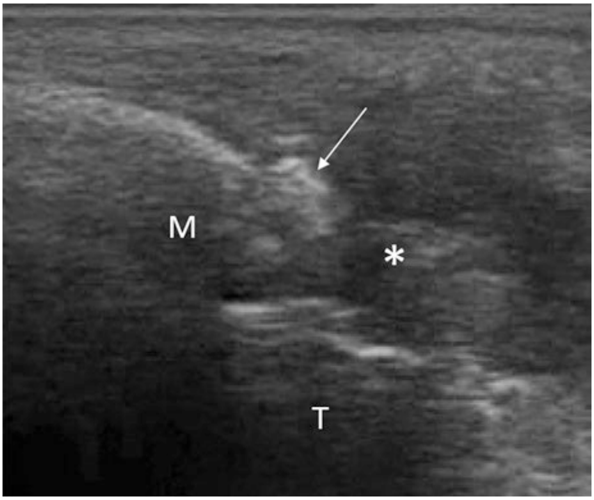

Fig. 13.3 US scan of the first carpometacarpal joint (M: metacarpal bone, T: trapezius) showing capsular distension with effusion (asterisk), osteophyte and periarticular calcifications (arrow)

13.4.3 Magnetic Resonance Imaging (MRI)

With the use of MRI, OA is now recognized as a disease that affects the entire joint. Currently, only limited research is available on the prevalence, reliability, and validity of pathology defined by MRI in hand OA. Common features of hand osteoarthritis MRI can provide a multiplane image of all joint components, including structural features such as osteophytes, cartilage, erosions/cysts, misalignment, and inflammatory features such as synovitis and tenosynovitis (Fig. 13.4). MRI is the only technique capable of showing bone marrow's injury, which is an important feature of structural progression and nonetheless, a source of pain. The prevalence of MRI pathology in patients with hand OA has been studied in several cohorts, founding a high prevalence of synovitis based on gadolinium enhancement. Synovitis was also widespread in joints without radiographic OA, and this is in line with previous observations in knee OA. However, minimal gadolinium enhancement can also occur in the population without OA, and therefore synovitis cannot be seen unless there is an accompanying thickness of the synovium. In the joints of the little fingers, it is also important to be aware of partial volume artifacts that can mimic BMLs [21].

Haugen et al. recently proposed an extensive preliminary MRI scoring system with an accompanying atlas for hand OA, validated with good intra- and inter-reader reliability. Their system includes osteophytes evaluation, JSN, erosions, cysts, misalignment, synovitis, flexor tenosynovitis, BML, and collateral ligament pathology such as absence/discontinuity at insertion sites. The scoring was developed for the DIP and PIP joints, and future studies need to confirm whether it can be further applied to the metacarpophalangeal (MCP) and base of the thumb joints [22].

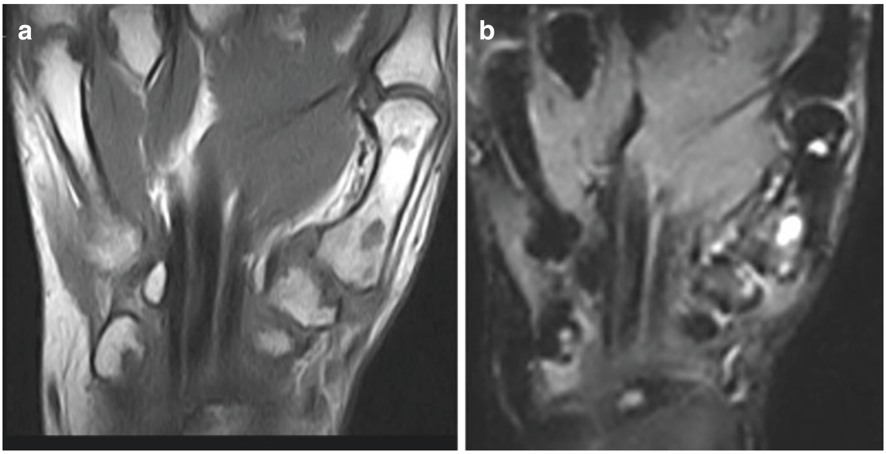

Fig. 13.4 Coronal T1 (**a**) and STIR (**b**) slices of the hand showing advanced trapeziometacarpal joint osteoarthritis changes with joint space narrowing, joint capsule thickening, and reactive bone marrow edema

13.5 Knee Osteoarthritis

Knee OA is the most common joint disease in the elderly and, overall, is very common. It is estimated to affect ~12.5% of patients >45 years. The medial femorotibial joint district is more commonly affected and is usually more severe than the lateral one.

13.5.1 Conventional Radiography (CR)

The hallmarks of knee OA are like the aforementioned for other joints, This includes joint space narrowing which is usually asymmetric, typically regarding the medial tibiofemoral and/or the patellofemoral region. JSN <3 mm on weight-bearing knee radiographs is considered a finding of absolute joint space narrowing with a normal joint space >5 mm (Fig. 13.5). Compared to non-weight-bearing radiographs, weight-bearing radiographs evidence a bigger joint space narrowing, hence affecting the radiographic severity.

Plain radiographs are the imaging flagships including follow-up, although there is a poor correlation between radiographic findings and clinical symptoms. The initial study of a patient with knee OA suspect should include a Rosenberg view, a PA radiograph with weight-bearing, and 45° flexion, which is more sensitive in detecting joint space narrowing [23].

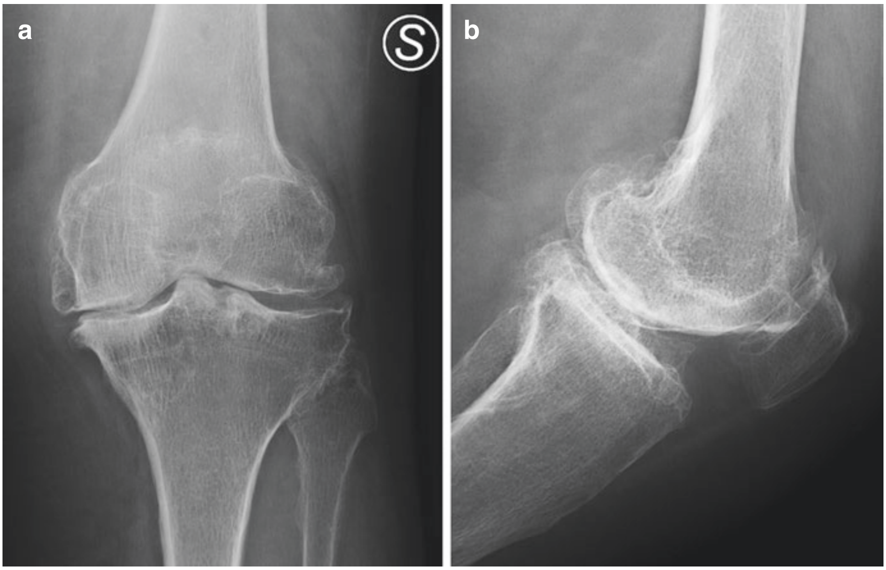

Fig. 13.5 Frontal (**a**) and lateral (**b**) plain film view in a patient with knee osteoarthritis showing marked medial joint space narrowing, subchondral bone sclerosis, and osteophytes

Kellgren and Lawrence first described a grading system in 1957 which was later adopted as the standard measure for assessing radiographic OA by the World Health Organization in 1961. The original description was graded as follows:

- Grade 0 (none): absence of X-ray osteoarthritic changes
- Grade 1 (doubtful): doubtful joint space narrowing and possible osteophytic lipping
- Grade 2 (minimal): osteophytes and possible joint space narrowing
- Grade 3 (moderate): moderate multiple osteophytes, definite narrowing of joint space and some sclerosis, and possible deformity of bone ends
- Grade 4 (severe): large osteophytes, marked narrowing of joint space, severe sclerosis, and definite deformity of bone ends

Subsequently, methods were used to classify OA individual aspects, such as osteophytes, JSN, and subchondral sclerosis. However, there are several limitations associated with both these classifications. Firstly, they predominantly include ordinal measures, with only a limited number of categories. Secondly, the osteophytes' role is unclear, although their presence is crucial in the classification systems. For example, despite being related to the presence of pain, osteophytes are not related to severity and do not seem associated with disease progression. The underlying use of JSN is the hypothesis that longitudinal joint space reduction is a valid measure of a reduction in joint cartilage volume [24].

13.5.2 Magnetic Resonance Imaging (MRI)

For OA assessment, standard MR sequences allow morphological and qualitative evaluation of articular cartilage and other joint structures. In the last years, several advanced MR imaging sequences and techniques were developed to provide a global, sensitive, and specific assessment of the joint degenerative processes with semi-quantitative, quantitative, and compositional analysis methods [25].

Semi-quantitative MR scoring systems are based on the global morphological evaluation of pathological changes (e.g., alterations of articular cartilage, subchondral bone, fibrocartilages) that affect the functional and structural integrity of the joint and determine the severity of the disease. These scoring systems are used with standard morphological MR sequences, especially T2 and PD fat saturated sequences. Four scoring systems were established for the knee: the Whole Organ Magnetic Resonance Score (WORMS), the Knee Osteoarthritis Scoring System (KOSS), the Boston-Leeds Osteoarthritis Knee Scoring (BLOKS), and the MOAKS (MRI Osteoarthritis Knee Score). Equivalent scores were also created for other peripheral joints, such as the Oslo Hand OA MRI Score (OHOA-MRI), the Hip Osteoarthritis MRI Scoring System (HOAMS), and the Scoring Hip Osteoarthritis with MRI (SHOMRI). Concerning the methodology, in brief, the joint is divided into several articular compartments/subregions (e.g., medial and lateral tibia, medial

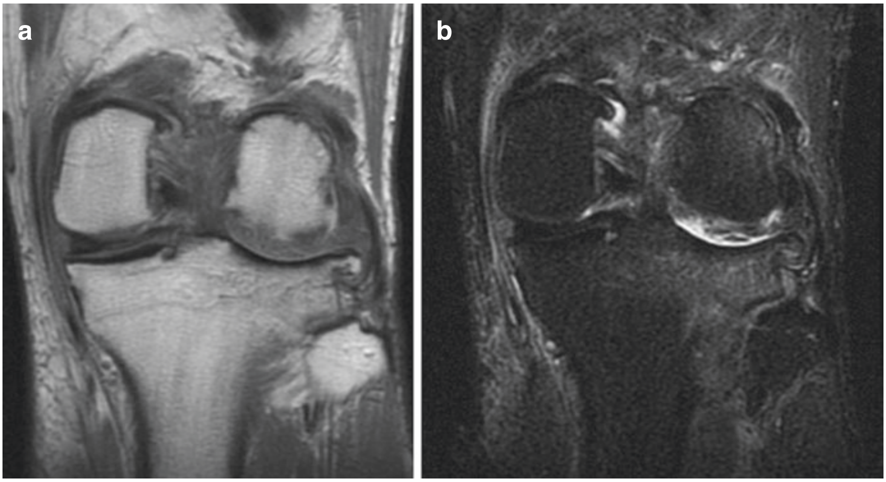

Fig. 13.6 Coronal T1 (**a**) and STIR (**b**) knee MR images depicting high-grade lateral femoral condyle and tibial plateau chondropathy

and lateral femoral condyle), and several joint features (e.g., cartilage signal and morphology, synovitis, subchondral bone) are analyzed and scored according to the severity of the involvement (Fig. 13.6). Numerous studies validated the reproducibility of these scoring systems; the MOAKS is currently the most used one for the knee, bringing together the advantages of these scoring systems. The clinical assessment of semi-quantitative analysis was demonstrated by the presence of some specific alterations (such as Hoffa synovitis, joint effusion, medial meniscus lesions) associated with an increased risk of OA radiographic progression. Other studies, using these transversal and longitudinal comparisons methods of disease evolution, highlighted how the presence of cartilage damage and the presence of subchondral edema correlate with an increased risk of prosthetic surgery necessity.

Quantitative MRI assessment provides a more sensitive and specific evaluation of cartilage's degeneration degree and it is superior to semi-quantitative techniques in evaluating structural changes. Three-dimensional (3D), high-resolution sequences are required to image the bone–cartilage interface and the cartilage surface with adequate contrast. After image acquisition, the post-processing analysis involves automatic or manual segmentation of the articular cartilage (that is, the separation of the cartilage from the underlying bone and adjacent tissues). This data sets and image reconstructions allow the evaluation of several quantitative features (e.g., cartilage thickness, area, volume) as continuous variables. Studies on quantitative cartilage evaluation showed good inter-operator reproducibility at different degrees of cartilage degeneration and excellent correlation with the surgical and histological findings. Quantitative methods have a good correlation with semi-quantitative results, even if more sensitive and specific in predicting cartilage loss (especially in small widespread defects using regional analysis); therefore, some authors suggest a combined use of these techniques. Modifications in the cartilage's volume and thickness were used as an outcome parameter in observational studies regarding pharmacological treatments (e.g., chondroitin sulfate), physical therapy and rehabilitation, and surgical treatment trials. These assessments have become new quantitative metric parameters that can be considered as biomarkers, to improve the prognostic value of conventional disease progression assessments. The necessity of a dedicated software and the tedious analysis can be considered as a major disadvantage to ordinary clinical application.

Articular cartilage is made of chondrocytes which spread within a matrix composed of water and a highly organized reticulum of collagen proteoglycans (PGs) and glycosaminoglycans (GAGs). Collagen fibers orientation varies from the surface to the deepest calcified zone. In OA, before cartilage fissuration, there is a progressive disruption of the matrix's architecture with GAGs and collagen loss and a consequent increase of water content. Noticeably, these matrix modifications in the early stages of OA development are not discernible in standard morphological MRI sequences. Based on the known pathogenesis of joint degenerative processes, we can appreciate the histological level of biochemical changes in cartilage ultrastructure, including the reduction of proteoglycans (PGs) and glycosaminoglycans (GAGs) and the increase in water content, anticipate morphological changes. Advanced imaging technologies provide information on the ultrastructural and biochemical composition of cartilage to detect and monitor the initial stages of the joint degenerative processes. MR imaging techniques are in fact based on the cartilaginous ultrastructural components modification (e.g., GAG, PG). In particular, we consider relaxation times measurements (T2 and T1ρ mapping), sodium imaging, delayed gadolinium enhancement MRI of cartilage (dGEMRIC) imaging, chemical exchange saturation transfer imaging of GAG (gagCEST), and imaging and diffusion imaging (DWI and DTI).

T2 and T1ρ mapping: These sequences measure the T1 and T2 relaxation times (expressed in ms) of molecules present in the tissue. Briefly, T2 relaxation time reflects the ease of protonic water molecules movement within the matrix. In the articular cartilage, T2 relaxation times mainly depend on the collagen content of the extracellular matrix and the orientation of collagen fibers, and higher relaxation times are correlated with an increased deterioration of the cartilage matrix. The T2 relaxation time is measured as a function of the signal measured in multi-echo SE and FSE T2-weighted images with mono- or multi-exponential decay curve at the different echo times (TE). T1ρ mapping is a compositional approach which is sensitive to regional changes in cartilage matrix proteoglycans characterized by continuous resonance RF pulse. Water molecules protons associated with different macromolecules such as PGs dissipate energy faster than protons of free water molecules, therefore long T1ρ relaxation times correlate with GAG depletion. The main disadvantages are given by issues related to the high SAR (due to the application of long-lasting RF pulses) and long acquisition times. A fundamental advantage of relaxation mapping sequences is that contrast medium administration is not necessary. Both T1ρ and T2 mapping can be assessed both qualitatively with colorimetric scale and quantitatively by ROI positioning. Fibrocartilages (e.g., menisci) can be studied using T1ρ and T2 mapping since they are composed of collagen, proteoglycans, and water as well. Ultrashort time echo (UTE) T1 and T2 mapping sequences can be used to analyze low intrinsic relaxation time tissues such as menisci, tendons, deep layers of cartilage, deep cartilage areas where non-UTE imaging is not sensitive enough.

Sodium imaging (23Na): This compositional imaging technique is based on the detection of sodium, the positive cation linked to the negatively charged glycosaminoglycan (GAG) of the cartilage's matrix. More specifically, the sodium concentration within the cartilage matrix is directly correlated to the concentration of GAG and hence to proteoglycans. The main strength of sodium (23Na) MRI is in fact the high specificity to proteoglycan. As in relaxometry and diffusion imaging, exogenous contrast medium administration is not required to obtain sufficient tissue contrast. However, in vivo sodium imaging of cartilage limits includes low intrinsic SNR, caused by the low 23Na MRI signal compared to the one from protons.

Delayed gadolinium enhancement MRI of cartilage (dGEMRIC): Contrast medium (gadolinium), injected intravenously is necessary for this imaging method. The scan is performed 60–90 min after injection, to allow diffusion of the contrast medium into the cartilage matrix. Gadolinium is negatively charged and is rejected by positively charged GAGs in cartilage, while in case of cartilage matrix degradation, the amount of contrast in cartilage tissue will be increased in an inversely related manner. The dGEMRIC technique showed high sensitivity and specificity; the routine clinical use is limited by the need for high doses of gadolinium.

Chemical exchange saturation transfer imaging of GAG (gagCEST): This sequence is based on the constant labile protons transfer between solutes (in the case of cartilage, GAGs) and water. The difference between water–water transfer and water–GAG transfer is measured as the magnetic transfer ratio. The signal obtained from the energy transferred after radiofrequency proton saturation is proportional to the concentration of GAG in the tissue. Unfortunately, strong magnetic fields (7 T scanners) are required to obtain sufficient signal, thus widespread use, even in the research field, is currently limited.

Compositional MRI sequences were widely explored in literature for the assessment of cartilage, menisci, and tendons in degenerative osteoarthropathies of peripheral joint, mostly the results concerning the use of T2 mapping on knee articular cartilage. The most important results were obtained by longitudinal studies on disease progression, demonstrating the association and the predictive value of compositional cartilage changes with potential risk factors such as age, sex, BMI, sport, injuries, surgery. Imaging with advanced MRI sequences is becoming increasingly important in cartilage's degeneration studies. Because of the recent widespread development of disease-modifying drugs and regenerative therapies (e.g., platelet-rich plasma, hyaluronic acid, chondrocyte implantation), MRI is also crucial in assessing new therapies for OA prevention or for approaches to avoid progression. As the efficacy is closely connected with early treatment, their use requires suitable biomarkers to provide an early diagnosis and detect signs of progression during treatment. Advanced MRI findings can represent, in this scenario, a powerful tool to understand how to better treat and manage OA and this will possibly allow the creation of a "target-based therapy" for every single component of the cartilage matrix [26].

13.6 Hip Osteoarthritis

The hip is the third most common joint affected by osteoarthritis after the knee and the hand. Women are more commonly affected than men. The reported prevalence varies in different studies and is also subject to geographic distribution. The risk of symptomatic hip osteoarthritis in people reaching the age of 85 is estimated up to 25% in some regions. Attributes, characteristics, or exposures that increase the likelihood of developing hip osteoarthritis are advanced age, obesity, genetics, repetitive stress and mechanical overload, acetabular dysplasia, femoroacetabular impingement, epiphysis capital femoral slip, Perthes disease, and trauma.

Patients usually experience slowly progressive hip pain or hip-related groin pain that radiates into the thigh, gluteus, or knee. Pain can be worse at night, during rest, or after strenuous activity, reducing motion and limiting the walking distance. It can be associated with morning stiffness or after rest. Other symptoms include joint locking, grinding and instability, fatigue, and pain-related psychological distress. Occasionally, a striking discrepancy is observed between radiological findings and clinical symptoms, in fact, patients with pronounced radiological changes have only mild symptoms, while patients with minor radiographic findings complain of acute pain. Therefore, OA diagnosis and, above all, the therapeutic indication, should be made only after both radiological and clinical evaluation [27].

13.6.1 Conventional Radiography (CR)

Plain hip radiographs are inexpensive, widely available, and readily obtainable, and they allow a prompt OA assessment.

For hip osteoarthritis definition, an anteroposterior radiograph of the hip and a lateral cross or lateral view of the frog leg are crucial. As for other joints, reliable radiological indicators are joint space narrowing, subchondral sclerosis, subchondral cysts, and the formation of osteophytes. Narrowing of the hip joint space $\leq$2 mm or <2.5 mm or the combination of joint space narrowing and the presence of osteophytes, especially in the absence of elevated inflammatory markers (e.g., ESR < 20 mm/h), can be used as an indicator of osteoarthritis [28]. In addition, loose bodies (<10), joint deformities, and subluxations can be observed. In advanced stages of OA, the head of the femur is deformed assuming a cylindrical or mushroom-shaped form. The classic radiological sign of osteoarthritis is the joint space narrowing, particularly seen on anteroposterior radiographs taken while the patient is standing (Fig. 13.7). When joint space and cartilage narrowing occurs, the femoral head changes its position relatively to the socket. Femoral head migration is primarily cranial (combined with anterolateral or anteromedial motion) but occasionally axial or medial. This description of the migration is based on what can be observed in the anteroposterior X-ray image. Radiographic signs of medial-caudal migration of the femoral head are the joint space narrowing in the medial joint with subchondral sclerosis and the osteophytes formation in case of laterocranial joint space enlargement. The orthopedic surgeon gives joint replacement indication without

Fig. 13.7 Radiographic findings in a patient with bilateral hip osteoarthritis, with joint space narrowing, subchondral sclerosis, and acetabular osteophytes

regard to the migration's direction. However, as various types of migration lead to leverage ratios modifications, geometric hip joint reconstruction using endoprosthetics goals include center of rotation normalization, anatomical offset reconstruction, and equalization of the leg length [29].

The radiological classification systems most commonly used for hip osteoarthritis assessment are: the Kellgren and Lawrence score, the Croft score, and the Tönnis classification. Although they are all affected by subjectivity, the Kellgren and Lawrence score is apparently the most reliable.

Another semi-quantitative method, which does not provide a grade definition of OA, but classifies several features such as the formation of femoral and acetabular osteophytes and the narrowing of the superior and medial joint space is the OARSI atlas. According to this atlas, a score from 0 to 3 is attributed to the presence and quantity of marginal osteophytes at the level of the upper acetabular side, upper femur, and lower femur, and to the presence or absence of osteophytes on the lower acetabular side.

The narrowing of the joint space is marked 0–3 points on both the superior and medial side. Additional scores (presence/absence) are used for the evaluation of acetabular subchondral cysts, subchondral femoral cysts, femoral subchondral sclerosis, flattening of the femoral head, and thickening of the medial femoral calcar (buttress).

13.6.2 Computed Tomography (CT)

CT exams with multiplane and three-dimensional reconstructions have now replaced most of X-ray views and can easily be used even in patients with limited range of motion. The representation of subchondral sclerosis, cyst formation, and small osteophytes or also the evidence of loose bodies is more accurate than projection

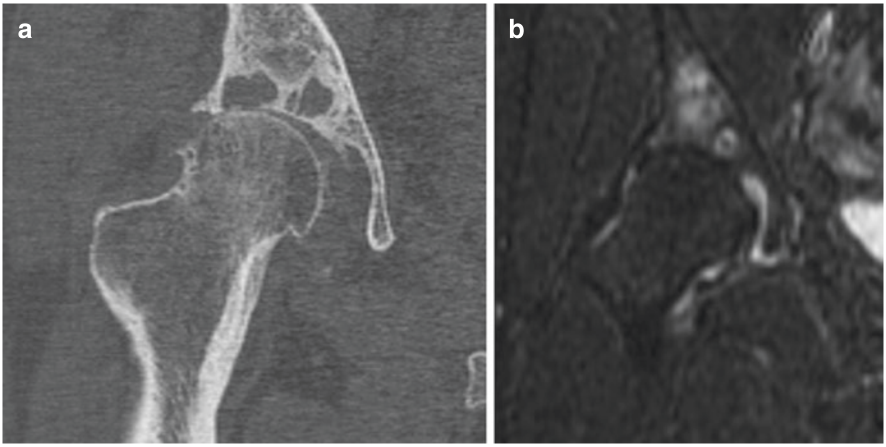

Fig. 13.8 CT (**a**) and STIR MRI (**b**) of the hip joint showing osteoarthritis changes with subchondral geodes, bone marrow edema, and joint effusion

radiography (Fig. 13.8). Another common CT indication is the preoperative diagnosis of hip socket abnormalities or post-traumatic conditions in presence of metal devices which is done by assessing the amount of acetabular bone stock and checking for misalignment or deformity of the proximal femur. The orthopedic surgeon requests the available bone stock localization which allows a safe endoprosthetic anchoring of the implant components. For example, for dysplastic osteoarthritis with high femoral head dislocation and neo-joint, the question will be how large the original acetabulum is and whether there is enough sized bone stock available to firmly anchor the planned socket. In case of axial misalignment and deformity of the proximal femur (e.g., after corrective osteotomy on the proximal femur), three-dimensional CT imaging is essential in planning the multiplane corrective osteotomy if needed. The objective of this procedure is to anchor the shaft components in the femur with a correct alignment and with a sufficient anchoring surface [30].

13.6.3 Magnetic Resonance Imaging (MRI)

MRI is most commonly indicated for the evaluation for surgery where there is a large discrepancy between clinical symptoms and osteoarthritis degree of severity in X-ray images. The orthopedic surgeon examines the MRI to judge the labral and cartilage damage, the presence of effusion/synovitis, and of subchondral and paralabral cysts. When there is hip joint OA, the primary significance of MRI is to show both early signs of arthritis (joint cartilage, labrum) and active signs of osteoarthritis. Additionally, MRI is also capable of showing any associated muscle atrophy. Further indications are to evidence active osteoarthritis (bone marrow edema, synovitis, effusion), as well as assessing the cartilage prior to hip arthroscopy (or the use of endoprostheses). On selected patients MRI is suggested for preoperative

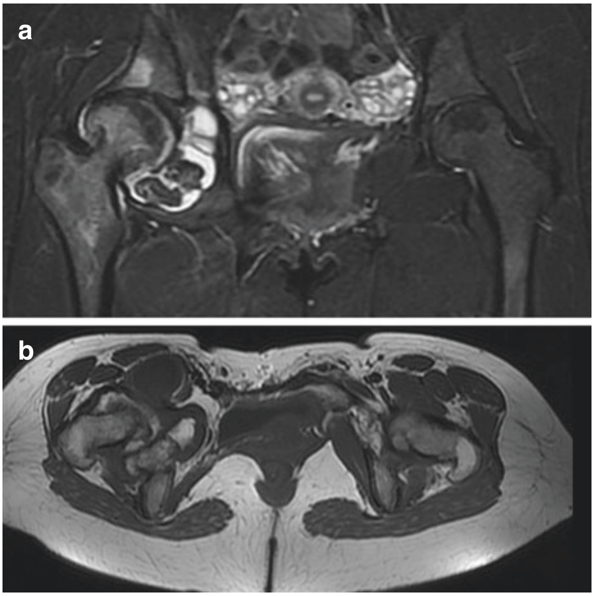

Fig. 13.9 STIR coronal (**a**) and T1-W axial (**b**) MRI images in a patient with right hip osteoarthritis showing the presence of fluid joint distension and synovial chondromatosis

evaluation of actual cartilage damage in joint-preserving periacetabular osteotomy. In addition to the 3D visualization of the acetabular and femoral head-neck morphology, MRI allows the evaluation of a large variety of tissue abnormalities not only of the cartilage and acetabular labrum but also of the bone marrow, ligaments, and synovium. Loose bodies in the form of cartilage and bone peeling are also a typical sign of osteoarthritis and are easier to detect with MRI than on X-rays (Fig. 13.9) [31].

Images should be acquired in sagittal and oblique coronal axial planes. Radial and axial images are of additional utility for femoral head-neck junction and acetabular anatomy evaluation in the case of femoroacetabular impingement associated with cam and/or pincer morphology. For simplified acquisition, 3D imaging and secondary oblique and radial reconstructions are recommended.

The semi-quantitative scoring systems based on MRI most commonly used are the HOAMS, HIMRISS, and SHOMRI scores. The HOAMS evaluates a variety of hip joint characteristics such as condral lesions, bone marrow lesions, subchondral cysts, osteophytes, labral lesions, synovitis, and joint effusion, as well as friction, dysplasia, intra-articular bodies, labral hypertrophy, paralabral cysts, femoral hernia fossa, insertional tendonitis, and/or bursitis. The SHOMRI score evaluates fewer features including: condral loss, bone marrow edema pattern, subchondral cysts, labral anomalies and cysts, intra-articular loose bodies, joint effusion or synovitis, and ligament abnormalities. For the evaluation of active disease, HIMRISS (hip inflammation MRI scoring system) was described, which focuses on the active inflammatory aspects of osteoarthritis and measures only three characteristics of the disease, namely bone marrow injury, effusion, and synovitis [32].

13.7 Foot and Ankle Osteoarthritis

About 1% of the world's adult population is affected by OA of the ankle, which results in pain, dysfunction, and reduced mobility. The mental and physical disability associated with end-stage ankle OA is at least as severe as that associated with end-stage hip OA. While the etiology of OA of the hip and knee is well understood and highlighted in numerous clinical studies, research relating to OA of the ankle is limited. Knowledge and analysis of the underlying etiology are important in selecting the best treatment strategy and are critical to achieving long-term satisfactory results and avoiding postoperative complications. Unlike the hip and knee, the ankle joint is rarely affected by primary OA. Numerous clinical and epidemiological studies have identified prior trauma as the most common cause of OA in the ankle instead. Patients with post-traumatic OA are generally younger patients than the ones with the primary form. An epidemiological study of patients with disabling OA of the hip, knee, and ankle showed that 1.6% of patients with hip OA, 9.8% of patients with knee OA, and 79.5% of patients with ankle OA had a verified history of 1 or more joint injuries. Saltzman and his colleagues evaluated 639 patients with end-stage painful OA in the ankle (Kellgren grade 3 or 4), founding that 70% of patients had post-traumatic OA, 12% had rheumatoid OA, and 7% had primary OA. While rotational ankle fractures were identified as the most common reason for post-traumatic ankle OA, previous ligament injuries have also been found to be a cause of ankle OA. Secondary OA has also been associated with a variety of underlying diseases or disorders, such as rheumatoid disease, hemochromatosis, hemophilia, gout, neuropathic diseases, avascular talus necrosis, osteochondral lesions, and postinfectious arthritis [33, 34].

A 4-film series of conventional radiographs including anteroposterior and lateral views of the foot, mortise view of the ankle, and Saltzman view of the hindfoot can be routinely performed for radiographic evaluation of the ankle and foot OA. Only foot and ankle X-rays are acceptable because non-weight bearing X-rays are often misleading. Additionally, standing views can help standardize radiographic techniques, allowing for more reliable comparison of inter and intra-individual radiographs. Ankle alignment must be analyzed on all 3 levels: supra-malleolar, intra-articular, and infra-malleolar. Supra-malleolar alignment of the ankle should be assessed in the coronal and sagittal planes by measuring the distal medial tibial angle and the anterior distal tibial angle, respectively. Measurement of the distal medial tibial angle depends on the radiographic technique. Saltzman's view should be used to assess infra-malleolar alignment. Several measurement techniques can be applied to quantify the infra-malleolar hindfoot alignment. Firstly, the angle between the longitudinal axis of the tibia and the heel axis can be measured as suggested by Cobey and Reilingh. Takakura and colleagues used weight-bearing radiographs to classify OA of the ankle into four stages. For clinical use, investigators simplified this classification, describing stage 1 as early, stages 2 and 3 as intermediate, and stage 4 as late [35].

13.8 Interventional Radiology in Osteoarthritis

Interventional radiology can offer a wide range of therapeutic procedures also in musculoskeletal pathology through ultrasound, CT, and MRI guidance. Based on the above evidence, the synovium—that is synovial inflammation—has become one of the main therapeutic targets not only for inflammatory arthropathies but also in degenerative arthrosis. Corticosteroids are arguably the most widely used anti-inflammatory drugs. The possibility, through image guidance, of direct intra-articular injection of drugs is the key to maximizing therapeutic effects while minimizing known systemic side effects. In addition to intra-articular administration, ultrasound imaging guidance is useful for intra-bursal and peri-tendinous assessment, where corticosteroids may have an anti-inflammatory action on synovial tissue. The imaging guide also helps minimize other risks of unguided corticosteroid infiltration, such as tendon ruptures. Injection of hyaluronic acid (HA) is another interventional procedure that can be suggested for degenerative joint disease (i.e., osteoarthritis) but mainly for the synovium. Hyaluronic acid is a glycosaminoglycan consisting of highly hydrophilic chains of D-glucuronic acid and *N*-acetylglucosamine. There are numerous types of hyaluronic acid on the market, which are distinguished mainly by their molecular weight. Hyaluronic acid with low molecular weight, able to bind to binding proteins (hyaladerin) and to the CD44 receptor, acts mainly with a biological effect of viscoinduction (i.e., by stimulating the endogenous production of HA). Those with high molecular weight, however, have a lower biological effect while carrying out a powerful viscous supplementation action, thanks to their rheological properties. Although the meta-analysis highlights the available studies heterogeneity, intra-articular injections of HA appear to be effective in the treatment of arthritic pain (mild to moderate OA) in both the knee and the hip. The size of the results on pain resolution varies between studies, peaking at 8 weeks (superior to corticosteroids). Cross-linked (high molecular weight) products have greater pain efficacy than linear HA and there is evidence to support the efficacy of HA also regarding functional improvement (level 1B). In all guidelines, use is recommended for osteoarthritis management of second-line treatment in symptomatic patients after conservative therapy (NSAIDs). Injection of platelet-rich plasma is another therapeutic tool that we can consider. This product, consisting of a platelet ultrafiltrate, carries out its action through various growth factors (PDGF, TGF-B, EGF, CTGF) released with their anti-inflammatory and trophic action on various joint tissues. There are several in vitro and clinical evidence that intra-articular injection of PRP can exert a positive influence in patients with knee cartilage degeneration and OA and that it may have greater and longer efficacy than HA in improving pain and joint function [36, 37].

References

1. Kobayashi T, Takagishi K, Shitara H, Ichinose T, Shimoyama D, Yamamoto A, et al. Prevalence of and risk factors for shoulder osteoarthritis in Japanese middle-aged and elderly populations. J Shoulder Elb Surg. 2014;23(5):613–9.
2. Mehl J, Imhoff AB, Beitzel K. [Osteoarthritis of the shoulder: pathogenesis, diagnostics and conservative treatment options]. Orthopade. 2018;47(5):368–76.
3. Tauber M, Martetschlager F. [Shoulder Osteoarthritis-pathogenesis, classification, diagnostics and treatment]. Orthopade. 2019;48(9):795–808.
4. Thomas M, Bidwai A, Rangan A, Rees JL, Brownson P, Tennent D, et al. Glenohumeral osteoarthritis. Should Elb. 2016;8(3):203–14.
5. Dekker TJ, Steele JR, Vinson EV, Garrigues GE. Current peri-operative imaging concepts surrounding shoulder arthroplasty. Skelet Radiol. 2019;48(10):1485–97.
6. Bercik MJ, Kruse K II, Yalizis M, Gauci MO, Chaoui J, Walch G. A modification to the Walch classification of the glenoid in primary glenohumeral osteoarthritis using three-dimensional imaging. J Shoulder Elb Surg. 2016;25(10):1601–6.
7. Choate WS, Shanley E, Washburn R, Tolan SJ, Salim TI, Tadlock J, et al. The incidence and effect of fatty atrophy, positive tangent sign, and rotator cuff tears on outcomes after total shoulder arthroplasty. J Shoulder Elb Surg. 2017;26(12):2110–6.
8. Barreto RPG, Braman JP, Ludewig PM, Ribeiro LP, Camargo PR. Bilateral magnetic resonance imaging findings in individuals with unilateral shoulder pain. J Shoulder Elb Surg. 2019;28(9):1699–706.
9. Davis DL, Gilotra MN, Calderon R, Roberts A, Hasan SA. Reliability of supraspinatus intramuscular fatty infiltration estimates on T1-weighted MRI in potential candidates for rotator cuff repair surgery: full-thickness tear versus high-grade partial-thickness tear. Skelet Radiol. 2021;50(11):2233–43.
10. McDonald S, Hopper MA. Acromioclavicular joint disease. Semin Musculoskelet Radiol. 2015;19(3):300–6.
11. Krill MK, Rosas S, Kwon K, Dakkak A, Nwachukwu BU, McCormick F. A concise evidence-based physical examination for diagnosis of acromioclavicular joint pathology: a systematic review. Phys Sportsmed. 2018;46(1):98–104.
12. Veen EJD, Donders CM, Westerbeek RE, Derks RPH, Landman EBM, Koorevaar CT. Predictive findings on magnetic resonance imaging in patients with symptomatic acromioclavicular osteoarthritis. J Shoulder Elb Surg. 2018;27(8):e252–e8.
13. Precerutti M, Formica M, Bonardi M, Peroni C, Calciati F. Acromioclavicular osteoarthritis and shoulder pain: a review of the role of ultrasonography. J Ultrasound. 2020;23(3):317–25.
14. Kalichman L, Hernandez-Molina G. Hand osteoarthritis: an epidemiological perspective. Semin Arthritis Rheum. 2010;39(6):465–76.
15. Leung GJ, Rainsford KD, Kean WF. Osteoarthritis of the hand I: aetiology and pathogenesis, risk factors, investigation and diagnosis. J Pharm Pharmacol. 2014;66(3):339–46.
16. Haugen IK, Boyesen P. Imaging modalities in hand osteoarthritis--and perspectives of conventional radiography, magnetic resonance imaging, and ultrasonography. Arthritis Res Ther. 2011;13(6):248.
17. Marshall M, van der Windt D, Nicholls E, Myers H, Hay E, Dziedzic K. Radiographic hand osteoarthritis: patterns and associations with hand pain and function in a community-dwelling sample. Osteoarthr Cartil. 2009;17(11):1440–7.
18. Weiss AC, Goodman AD. Thumb basal joint arthritis. J Am Acad Orthop Surg. 2018;26(16):562–71.

19. Sivakumaran P, Hussain S, Ciurtin C. Comparison between several ultrasound hand joint scores and conventional radiography in diagnosing hand osteoarthritis. Ultrasound Med Biol. 2018;44(3):544–50.
20. Fjellstad CM, Mathiessen A, Slatkowsky-Christensen B, Kvien TK, Hammer HB, Haugen IK. Associations between ultrasound-detected synovitis, pain, and function in interphalangeal and thumb base osteoarthritis: data from the nor-hand cohort. Arthritis Care Res. 2020;72(11):1530–5.
21. Marshall M, Watt FE, Vincent TL, Dziedzic K. Hand osteoarthritis: clinical phenotypes, molecular mechanisms and disease management. Nat Rev Rheumatol. 2018;14(11):641–56.
22. Saltzherr MS, Muradin GSR, Haugen IK, Selles RW, van Neck JW, Coert JH, et al. Cartilage evaluation in finger joints in healthy controls and early hand osteoarthritis patients using high-resolution MRI. Osteoarthr Cartil. 2019;27(8):1148–51.
23. Teichtahl AJ, Wluka AE, Davies-Tuck ML, Cicuttini FM. Imaging of knee osteoarthritis. Best Pract Res Clin Rheumatol. 2008;22(6):1061–74.
24. Jacobson JA, Girish G, Jiang Y, Sabb BJ. Radiographic evaluation of arthritis: degenerative joint disease and variations. Radiology. 2008;248(3):737–47.
25. Kornaat PR, Bloem JL, Ceulemans RY, Riyazi N, Rosendaal FR, Nelissen RG, et al. Osteoarthritis of the knee: association between clinical features and MR imaging findings. Radiology. 2006;239(3):811–7.
26. Bruno F, Arrigoni F, Palumbo P, Natella R, Maggialetti N, Reginelli A, et al. New advances in MRI diagnosis of degenerative osteoarthropathy of the peripheral joints. Radiol Med. 2019;124(11):1121–7.
27. Aresti N, Kassam J, Nicholas N, Achan P. Hip osteoarthritis. BMJ. 2016;354:i3405.
28. Nilsdotter A, Bremander A. Measures of hip function and symptoms: Harris Hip Score (HHS), Hip Disability and Osteoarthritis Outcome Score (HOOS), Oxford Hip Score (OHS), Lequesne Index of Severity for Osteoarthritis of the Hip (LISOH), and American Academy of Orthopedic Surgeons (AAOS) Hip and Knee Questionnaire. Arthritis Care Res. 2011;63(Suppl 11):S200–7.
29. Weber MA, Merle C, Rehnitz C, Gotterbarm T. Modern radiological imaging of osteoarthritis of the hip joint with consideration of predisposing conditions. RöFo. 2016;188(7):635–51.
30. Gold GE, Cicuttini F, Crema MD, Eckstein F, Guermazi A, Kijowski R, et al. OARSI clinical trials recommendations: hip imaging in clinical trials in osteoarthritis. Osteoarthr Cartil. 2015;23(5):716–31.
31. Jaremko JL, Lambert RG, Zubler V, Weber U, Loeuille D, Roemer FW, et al. Methodologies for semiquantitative evaluation of hip osteoarthritis by magnetic resonance imaging: approaches based on the whole organ and focused on active lesions. J Rheumatol. 2014;41(2):359–69.
32. Huang BK, Tan W, Scherer KF, Rennie W, Chung CB, Bancroft LW. Standard and advanced imaging of hip osteoarthritis. What the radiologist should know. Semin Musculoskelet Radiol. 2019;23(3):289–303.
33. Barg A, Pagenstert GI, Hugle T, Gloyer M, Wiewiorski M, Henninger HB, et al. Ankle osteoarthritis: etiology, diagnostics, and classification. Foot Ankle Clin. 2013;18(3):411–26.
34. Kraus VB, Kilfoil TM, Hash TW II, McDaniel G, Renner JB, Carrino JA, et al. Atlas of radiographic features of osteoarthritis of the ankle and hindfoot. Osteoarthr Cartil. 2015;23(12):2059–85.
35. Wilkinson VH, Rowbotham EL, Grainger AJ. Imaging in foot and ankle arthritis. Semin Musculoskelet Radiol. 2016;20(2):167–74.
36. Acanfora C, Bruno F, Palumbo P, Arrigoni F, Natella R, Mazzei MA, et al. Diagnostic and interventional radiology fundamentals of synovial pathology. Acta Biomed. 2020;91(8-S):107–15.
37. Barile A, La Marra A, Arrigoni F, Mariani S, Zugaro L, Splendiani A, et al. Anaesthetics, steroids and platelet-rich plasma (PRP) in ultrasound-guided musculoskeletal procedures. Br J Radiol. 2016;89(1065):20150355.