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Review

Osteoarthritis Year in Review 2014: imaging

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SUMMARY

Purpose: This narrative review covers original publications related to imaging in osteoarthritis (OA) published in English between April 2013 and March 2014. *In vitro* data, animal studies and studies with less than 20 observations were not included.

Methods: To extract relevant studies, an extensive PubMed database search was performed based on, but not limited to the query terms "Osteoarthritis" in combination with "MRI", "Imaging", "Radiography", "Ultrasound", "Computed Tomography" and "Nuclear Medicine". Publications were sorted according to relevance based on potential impact to the OA research community with the overarching goal of a balanced overview covering all aspects of imaging. Focus was on publications in high impact special interest journals. The literature will be presented in a methodological fashion covering radiography, ultrasound, compositional and morphologic Magnetic resonance imaging (MRI), and from an anatomic perspective including bone, muscle, meniscus and synovitis.

Results and conclusions: Imaging research in OA in the last year was characterized by a strong focus on MRI-based studies dealing with epidemiological and methodological aspects of the disease. Ultrastructural tissue assessment specifically of cartilage and meniscus using compositional MRI is evolving further. Additional subsets of the large publicly available Osteoarthritis Initiative (OAI) MRI dataset are being analyzed at present and have been published with muscle analyses coming increasingly into the focus of the community. Bone parameters were evaluated using varying technology and a persistent interest in inflammatory disease manifestations has been noted. Other modalities than MRI have been less explored. To date most OA imaging research is still focused on the knee joint.

Introduction and methods

The osteoarthritis (OA) imaging field has seen a multitude of publications of potential relevance to the community since the last Osteoarthritis Research Society International (OARSI) meeting. Magnetic resonance imaging (MRI) has seen broadened applications especially in bone and muscle research and is still the key modality in OA morphologic assessment, but compositional MRI methodology is also evolving rapidly and is being validated taking advantage of large public datasets.

This narrative review on published original research on imaging in OA covers the period from the first of April 2013 until the thirty-first of March 2014. Basis of this overview was a comprehensive literature search in the PubMed database based on but not limited to the terms "Osteoarthritis", "MRI", "Ultrasound", "Radiography", "Computed Tomography" and "Nuclear Medicine". In regard to imaging trends covering the periods from April first to January thirty-first over the last 5 years a steady increase of overall publications dealing with MRI (using query terms "MRI" and "osteoarthritis") from 153 in 2009 to 243 in 2013 has been observed. During the same periods the number for articles focusing on "radiography" and "osteoarthritis" (PubMed search terms) was more or less stable from 438 articles in 2009 to 462 articles in 2013. When interpreting these numbers for the last year one has to keep in mind that "Osteoarthritis and Cartilage" (OAC) announced publication of a Special OAC issue focusing on imaging with a deadline of February first, 2014, which might have been reason for some authors to submit their original work rather to this special issue than during the course of the second half year in 2013.

The selection of the presented articles is based on potential relevance to the interdisciplinary readership of OAC and focus was on imaging methodology or application of imaging in OA research

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published in high-impact special interest journals. Only original articles were included excluding animal studies or *in vitro* data. Presentations from the OARSI conference 2014 are not part of the present overview. No review articles, no publications focusing on cartilage repair or other surgical therapy were included, and only publications with a minimum number of 20 observations (usually patients or joints) were included. The overarching aim of this review is to give a balanced and comprehensive overview, but due to the multitude of articles published, selection for inclusion was based on the subjective expert opinion of the authors in regard to relevance to the research field. Only two studies were isolated that focused on applications of nuclear medicine to clinical OA and few studies using computed tomography (CT) as their primary tool of investigation.

Focus of this review will be the knee joint discussing new insights into radiographic applications, morphologic MRI assessment, compositional and quantitative MRI assessment. Studies that used imaging markers as an outcome measure in therapeutic evaluation will be summarized and in addition a more anatomical approach will specifically focus on other joints than the knee, and on advances in muscle, bone, synovitis and meniscus.

Radiography

The last year has seen increasing validation of existing methods using radiographic technologies. Evaluating baseline tibial trabecular bone texture from anterior–posterior tibiofemoral radiographs to assess longitudinal risk of knee joint replacement 6 years later, Podsiadlo and co-workers found that with increasing mean fractal dimension, i.e., the general measure of bone texture roughness, the risk of knee replacement was reduced independent of other clinical predictors of knee replacement[1]. Another group evaluated bone trabecular integrity as a measure for OA progression defined as 12- and 24-month changes in radiographic medial compartment minimal joint space width (JSW) and area, and by medial tibial and femoral cartilage volume on MRI[2]. Bone trabecular integrity was able to predict progression based on 12- and 24-month changes in joint space area and 24-month change in tibial but not femoral cartilage volume. Authors concluded that the trabecular phenotype of patients with progressive OA is compatible with thinning of vertical trabeculae secondary to stress shielding from thickened horizontal trabeculae and apparent thinning as a result of hypomineralization due to high subchondral bone turnover. Bone texture analysis seems to be a promising tool as a screening test for progressive OA that is inexpensive and not burdensome for the patient. Currently however, the technique and especially interpretation of data acquired is challenging and lacks standardization, and additional validation and reliability studies are urgently needed.

Focusing on phenotypic characterization of early OA progression using radiography Kinds and colleagues defined five different morphologic phenotypes based on hierarchical clustering[3,4]. These were defined as “no”, “early”, “late”, “severe” and “bone density”. The defining features were medial JSW, varus angle, osteophyte area, eminence height, and bone density at baseline that were associated with the severe and bone density phenotypes. The authors suggested that these phenotypes might represent potential subgroups for the evaluation of preventive therapies in clinical trials, which needs to be shown in confirmatory studies using cohorts of pre-radiographic or early OA. In a longitudinal study design Cao *et al.* assessed the role of bone mineral density (BMD) using systemic and subchondral dual energy X-ray absorptiometry (DXA) in regard to cartilage thickness cross-sectionally and over a 2.7 year period[4]. Positive associations were observed for total body, total hip and/or spine BMD and increased cartilage thickness cross-sectionally and longitudinally in subjects with radiographic OA. A high medial tibial subchondral BMD predicted an increase in medial tibial cartilage thickness. Further studies are warranted to explore whether systemic and local BMD might play a protective role against cartilage loss in knee OA.

Another study looked at longitudinal change of JSW over a 3 year period and prediction of joint replacement over 8 years[5]. The authors found that each 0.1-mm narrowing of JSW over 3 years was associated with a 14% increased risk for knee replacement. They conclude that changes in structure as manifested by JSW change over 3 years reflect a clinically relevant progression of the disease. Paramount for any of such analyses is optimized image acquisition, which has been and still remains a challenge for all research activities involved in radiographic OA evaluation[6].

Ultrasound

Not many studies focused on ultrasound methodology in OA research in the last months but ultrasound has an established role in assessment of hand OA, which was reflected by two relatively small studies looking at inflammatory manifestations and at the differentiation between nodal and erosive OA. Kortekaas and colleagues evaluated evolution of inflammatory hand OA features and pain over a period of 3 months in 20 patients assessing 30 hand joints in each using power Doppler ultrasound[7]. Nearly all patients showed inflammatory features during those 3 months, but median number of joints per patient and median total score per patient did not change over this period. However, a change in the joints that showed inflammation was observed with 21% of joints showing inflammation only at one time point. The authors concluded that in hand OA inflammatory ultrasound features are stable over time at patient level, but vary on a joint level.

In an attempt to distinguish erosive hand OA from nodal hand OA using ultrasound and MRI in a small cohort, Vlychou *et al.* detected erosions in the large majority of nodal hand OA patients. Also inflammatory changes were frequently seen in both subgroups, which lead to the assumption that erosive OA may represent the severe end of the spectrum of nodal hand OA[8].

Ultrasound is excellently suited to assess meniscal extrusion in the knee joint as previously shown[9]. One study looked specifically at changes in the weight bearing and non-weight bearing positions in a cross-sectional study design comparing OA patients with controls[10]. It was observed that the medial meniscus undergoes significant subluxation in the OA knee compared with the control knees and that the degree of subluxation was significantly greater in the weight-bearing than in the non-weight-bearing supine position. Albeit a small sample, the study seems encouraging for other researchers to pursue meniscal assessment using ultrasound (Fig. 1). Application of ultrasound to large joints seems still challenging due to the inherent challenges of ultrasound to visualize deeper portions of the joint and based on the fact that sound is not able to pass through bony structures[11,12]. However, especially the application of ultrasound under dynamic and weight-bearing conditions is one of the method's inherent strengths and warrants further exploration.

Nuclear medicine

Not many studies focused on nuclear medicine methods and the role of the more recent technologies such as ^{18}F-fluorodeoxyglucose (FDG) positron emission tomography (PET) in rheumatology in general and specifically OA research still needs to be defined[13]. Kobayashi and colleagues evaluated associations between glucose uptake using ^{18}F-FDG PET and radiographic and clinical findings[14]. ^{18}F-FDG PET showed a significantly higher

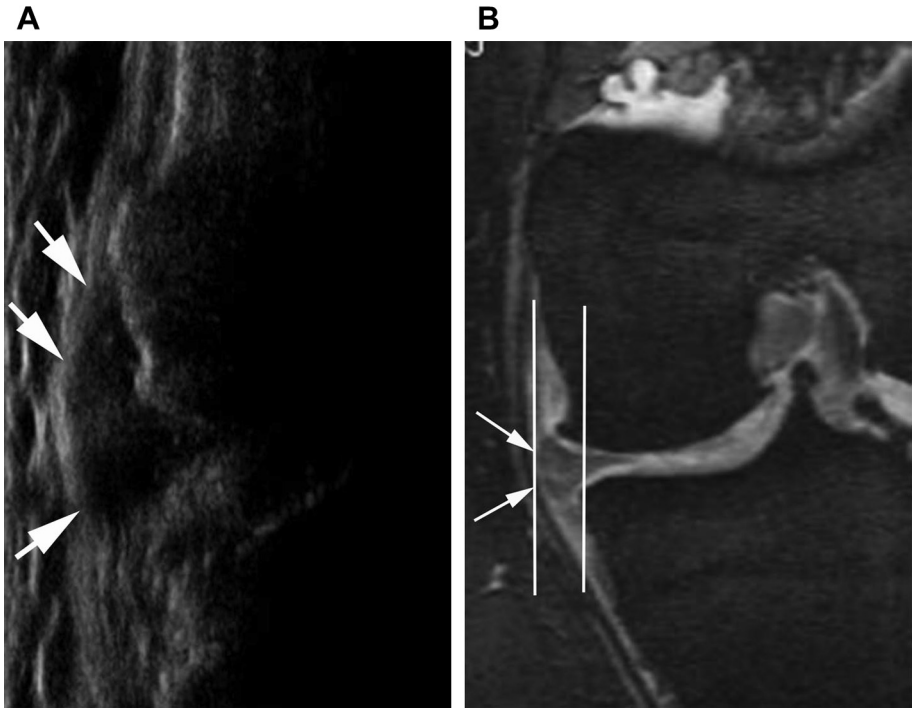

Fig. 1. Imaging assessment of meniscal extrusion. A. Ultrasound screenshot shows moderate medial meniscal extrusion (arrows). Note sound extinction beyond the cortical bone and inability to assess the bone marrow (right side of image). B. Coronal DESS MR image shows medial meniscal extrusion (arrows and vertical lines) in the same patient. The tomographic viewing perspective of the MRI allows for assessment of all joint tissues in a given imaging plane.

uptake value for late stage OA cases than in early OA and authors found a higher uptake value in cases with severe pain. Even in early-OA-stage patients who did not show joint space narrowing (JSN) on a plain X-ray, cases with severe pain exhibited a significantly higher uptake value. Another study looking at ankle joint abnormalities in a cohort of patients with knee OA and found frequent ankle scintigraphic abnormalities on technetium-99m methylene diphosphonate bone scan, and observed that these were strongly associated with presence of tibiotalar radiographic OA[15]. Whether interventions targeting mechanical factors may be needed to prevent ankle OA in the setting of knee OA will need to be explored.

Compositional MRI

Multiple studies were published using compositional MRI techniques, which is a rapidly evolving field especially as the publicly available Osteoarthritis Initiative (OAI) T2 mapping datasets are being increasingly explored. In the following section the focus will be on potential clinical application and feasibility. A concise overview of currently available compositional techniques including strengths and inherent challenges in the implementation of the different methods was presented by Mosher and colleagues in the 2013 summary of "OARSI Year in Review"[16].

Newbould and co-workers evaluated T1-weighted (w) sodium MRI at 3 Tesla (T) for OA patients and controls and also looked at change at 3 and 6 months[17]. While OA subjects had higher sodium concentrations in the lateral tibial, lateral femoral and medial patella regions of interest, no significant changes in sodium concentration over 6 months was observed. Authors concluded that 3 T systems might be an alternative to higher field systems and propose potential application in clinical trials. As the application of sodium MRI is challenging future studies will have to confirm these findings and compare sodium measurements to more established methods like delayed gadolinium-enhanced MRI of cartilage (dGEMRIC) or other compositional techniques that are specific to glycosaminoglycan (GAG) assessment[18,19]. Several studies used dGEMRIC to evaluate long-term prediction of structural changes in the knee joint. Although the technique is rather complex in application and requires intravenous administration of a Gadolinium compound, long standing experience and previous validation makes this technique an important instrument especially in cartilage research. Owman and colleagues performed dGEMRIC one to 5 years after meniscal surgery and assessed radiographic outcome after 11 years[20]. They found that ipsi-compartmental low dGEMRIC indices (T1Gd) were associated with higher grades of JSN and medially with more osteophytosis. The same research group evaluated patients that had an anterior cruciate ligament (ACL) disruption, no surgical therapy and no radiographic changes at 16 years post injury[21]. No differences were found in the medial and lateral compartments in regard to T1Gd when compared to a healthy reference group. Authors concluded that patients who were able to cope with ACL injury over long periods and have sustained good knee function also exhibit persistent good cartilage quality. Another group investigated the relationship between medial meniscal pathology and medial cartilage status in middle aged women at baseline and 1 year later[22]. Significantly lower T1Gd in the medial compartment were found for patients exhibiting high-grade meniscal damage (Fig. 2). Whether these ultrastructural cartilage changes that are observed together with concomitant meniscal damage are potentially amenable to treatment without restoring meniscal integrity remains to be shown in future work. The same team of researchers assessed in the same study population of 148 women change in T1Gd between baseline and 1 year with concomitant changes in cartilage thickness at one and 2 years and found that a decrease in T1Gd significantly predicted an increase in cartilage thickness in knees without or early radiographic OA, which appears to represent GAG depletion and consequent

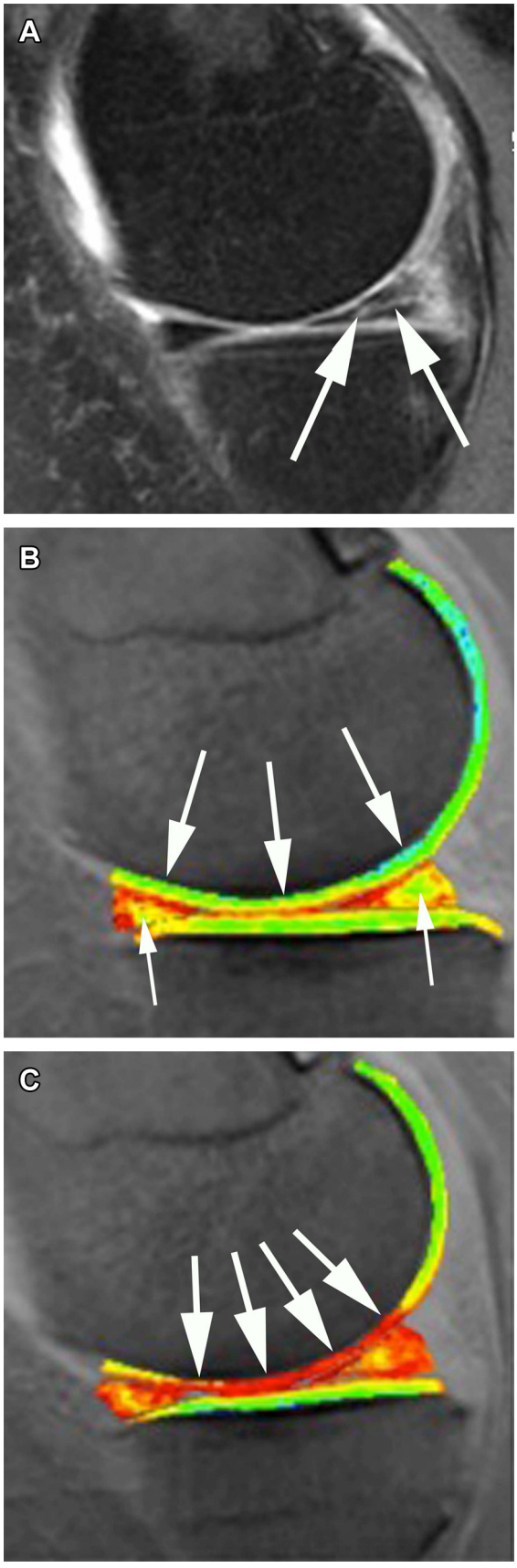

Fig. 2. Compositional MRI of cartilage and meniscus over a 2-year period. A. Morphologic proton density-weighted fat suppressed image shows a horizontal-oblique tear of the posterior horn of the medial meniscus (arrows). B. Corresponding color map shows intact articular femoral cartilage of the weight bearing region (large arrows). Intrameniscal composition is normal with the central parts of the meniscus showing higher dGEMRIC indices reflecting higher GAG concentration centrally (small arrows). C. After 2 years there is a marked decrease in the dGEMRIC index in the central weight bearing region of the medial femur reflecting a decrease in GAG concentration and early cartilage degeneration. In addition there is a decrease in the dGEMRIC index in the central parts of the menisci.

cartilage swelling[23]. The authors concluded that ideally morphological and compositional techniques should be combined to monitor cartilage status over time in a clinical trial setting. A small short term study looking at the effect of intraarticular hyaluronic acid injections found clinical improvement on KOOS but no changes in T1Gd, which adds to the ongoing debate concerning structural effects of these compounds[24,25].

Several analyses using the OAI T2 dataset are worth mentioning. Lin *et al.* assessed 205 subjects without pain and no radiographic OA longitudinally over 5 years and reported that high and very low activity scores measured with the Physical Activity Scale for the Elderly questionnaire were associated with greater progression of cartilage T2 suggesting accelerated cartilage matrix biochemical degeneration over time in these subjects[26]. In a case–control design the same group evaluated whether T2 relaxation time measurements obtained at 3 T MRI predict the onset of radiographic knee OA over a 4-year period and found that baseline T2 values in all compartments except the medial tibia were significantly higher in knees that developed OA compared with controls and were particularly elevated in the superficial cartilage layers in all compartments[27]. The same research group assessed 245 knees with various degrees of cartilage abnormalities at baseline and at 2 years and found an inverse correlation of longitudinal T2 changes vs baseline T2 values and morphological cartilage abnormalities suggesting that once morphological cartilage defects occur T2 values may be limited for evaluating further cartilage degradation[28]. Additional studies investigated spatial variation of T2 predicting symptoms[29], one study used T1ρ to evaluate patients with anterior knee pain[30], and another group focused on dGEMRIC of hip pathology using arthroscopy as a reference to detect cartilage lesions[31].

Summarizing these multiple promising studies, the feasibility of application of these methods into a daily clinical routine setting using standard MRI systems will be crucial before biochemical MRI techniques will have a place in the broader context of a clinical environment.

Morphologic MRI

Several studies have focused on morphologic MRI using semi-quantitative data based on expert grading of MRI features. Subchondral sclerosis, one of the disease defining features using imaging methodology has rarely been the subject of investigation using MRI. Crema and co-workers evaluated baseline subchondral sclerosis onT1w MRI in 163 subjects with knee pain and did not find an increased risk for cartilage loss in the same knee region at 3 years when compared to subjects without sclerosis after adjustment for confounders[32]. Authors concluded as both, sclerosis and bone marrow lesions (BMLs), are probably related to mechanical loading, it is possible that sclerosis might represent a different phase of bone trabecular changes and remodeling during the disease process when compared to edema-like BMLs. In another population-based study Stefanik and colleagues described prevalence of different compartmental OA phenotypes and found that isolated patello-femoral damage was more common than isolated tibio-femoral damage using MRI[33]. In addition, when mixed disease was the most common pattern, the patello-femoral joint had more

severe damage. Authors emphasized that any intervention studies should focus on subgroups of knee OA patterns as these groups may respond differently to the same treatment regimen, which has also been postulated by others[34,35] The same cohort was subject of an additional study evaluating which subregions of the knee joint have a high prevalence of pre-radiographic osteoarthritic changes. In 696 participants without OA authors found that cartilage damage and osteophytes are highly prevalent in the medial patellofemoral and medial posterior tibiofemoral joints in radiographically normal knees in persons aged 50 to 79, which is of potential relevance for additional studies focusing on early or pre-radiographic disease[36]. A novel semiquantitative scoring system for cartilage assessment was introduced that was compared to the established Whole-Organ Magnetic Resonance Imaging Score (WORMS) and BLOKS systems[37]. The novel Cartilage Lesion Score (CaLS) enabled higher detection of cartilage lesion progression in the 25 subjects without radiographic OA that were analyzed but was not considering within-grade changes[38]. Additional validation on larger datasets including subjects with manifest disease using comparative methodology including established systems and within-grade scoring will have to investigate the potential application of this score further.

An MRI definition of OA was published several years ago but only few validation studies have been forwarded[39]. Schiphof and colleagues used 1766 knees from the population-based Rotterdam study comparing radiographic and MRI definitions and found a higher rate of OA (7% vs 4%) using the MRI definition[40]. Higher associations with knee pain and body mass index (BMI) were also found for the MRI definition. Authors conclude that together with a better content validity and at least equal construct validity, the MRI definition for knee OA is more sensitive than radiography in detecting structural knee OA.

Quantitative MRI

Several studies evaluated the effect of different parameters on three-dimensional (3D) quantitative outcome measures determined by MRI. Teichtahl and colleagues recruited 112 obese subjects and followed these 2 years later measuring baseline and follow-up tibial cartilage volume[41]. Percentage weight change was associated with change in medial tibial cartilage volume but not at the lateral tibia or patella. No data was forwarded regarding femoral cartilage parameters. Wirth and co-workers compared knees with and without baseline JSN and found accelerated cartilage loss for the narrowed but not the non-narrowed compartment[42]. Another group evaluated the effect of weight-bearing on X-ray- and MRI-determined JSW and found significant differences for both, an OA group and a control group, and found larger absolute differences for the OA knees[43]. In a matched within-person case–control design of subjects with radiographic OA in one knee but absent OA in the other knee over a 1 year period, Cotofana and colleagues did not find evidence of cartilage thickening or loss in the OA knees but greater variability in cartilage changes when compared to the non OA control knees[44]. To determine reproducibility of femoral condyle cartilage volume in cross-sectional and longitudinal studies, Fujinaga and co-workers compared four 3D sequences at 3 T that are commonly used for cartilage segmentation, i.e., fat-suppressed fast low angle shot (FLASH), water-excitation dual echo steady state (DESS), spoiled gradient recalled echo (SPGR) and water-excitation multiecho data image combination (MEDIC) that were acquired at baseline and 1 year later[45]. Although there was no statistical significance, volumes segmented on the FLASH and DESS sequences tended to be larger than those on SPGR or MEDIC (Fig. 3).

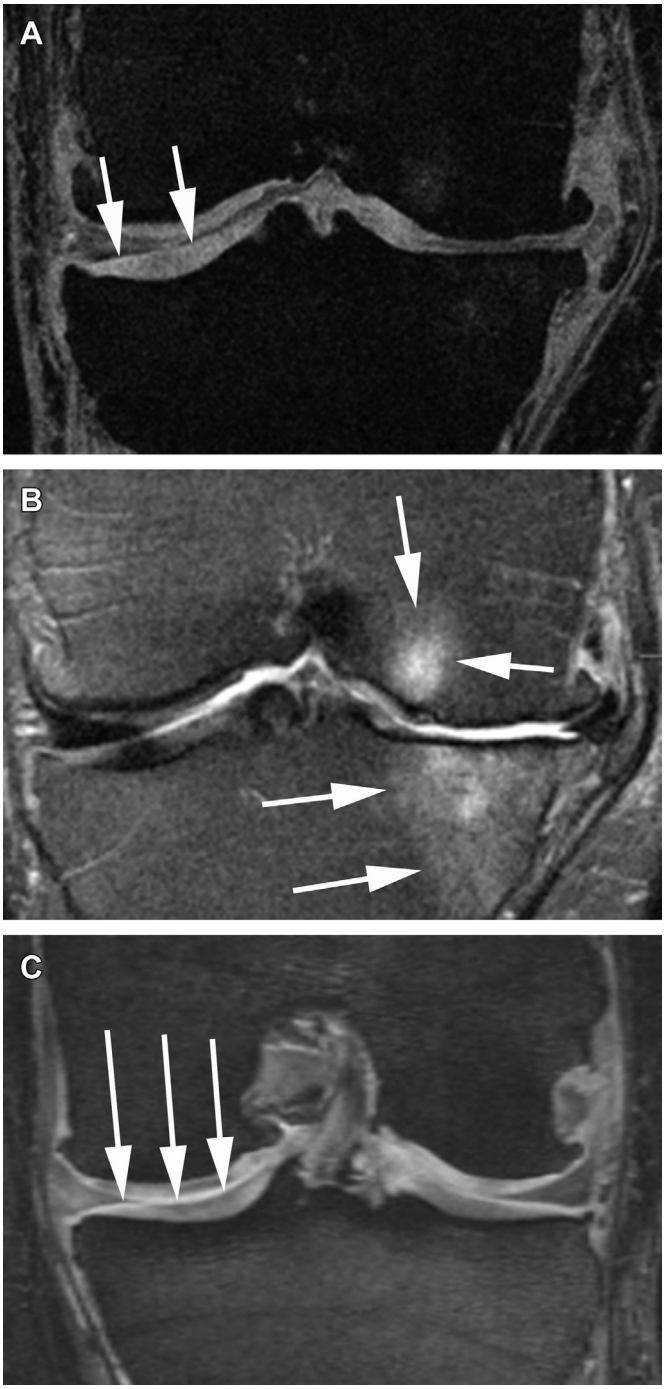

Fig. 3. Comparison of different MRI sequences for assessment of cartilage. A. Coronal 3D FLASH image depicts the articular cartilage with high signal. Medial tibial cartilage coverage is preserved in this patient (arrows). B. Corresponding proton density-weighted fat suppressed image shows mixed signal intensity in the preserved cartilage medially. Note, in addition subchondral BMLs are superiorly depicted when compared to the FLASH sequence (arrows). C. Example of the DESS sequence, which depicts cartilage also with high signal intensity and is commonly used for cartilage segmentation (arrows).

Not many studies looked at 3D datasets evaluating the hip joint likely due to the complexity of the hip anatomy and inherent thin articular cartilage. Khan *et al.* compared radiographic measures (i.e., JSW) between the hip and knee in the same persons and found consistent associations between hip and knee MRI volume but not for hip and knee radiographic parameters[46].

Other joints

Few studies were published on joints other than the knee and these include spine, hip and hand OA focusing on prevalence, assessment approaches and structural change over time. In the Wakayama spine study researchers provided data on prevalence of degenerative disk disease and found evidence of any disk disease in around 70% of subjects younger than 50 years and in more than 90% older than 50 years. The anatomic locations with the highest prevalence were the levels C5/6, Th6/7 and L4/5. Age and obesity were associated with presence of disease at all levels and low back pain was associated with disease in the lumbar spine[47]. In another population-based study authors described associations between severe facet joint OA in older adults and back pain independent of socio-demographic and health factors and disk height narrowing[48]. In a population-based study of young females undergoing MRI Leunig and co-workers found no cases of cam-deformities and only 10% of participants with increased acetabular depth, which was not associated with labral damage. Authors conclude a difference in prevalence of cam-deformities between young males and females[49]. The overall prevalence of low-grade cam-type deformities, which are of doubtful clinical relevance, was 22% in the studied female population. Conversely, the same group of authors found a prevalence of 24% of definite (grades 2 or 3) cam-type deformities in males, and an association of these deformities with signs of hip joint damage. The authors hypothesize that morphologic configurations of the hip joint differ between males and females as a result of the different maturation of the pelvis and hips in males and females with earlier closure of the growth plates in girls than boys. Also, cam-type deformities have been discussed as a consequence of high-impact sports activities that are more commonly pursued by males. In a longitudinal study over 2.6 years Ahedi and colleagues found that presence of acetabular BMLs was associated with lower local BMD but not systemic BMD and that resolving BMLs were associated with decrease and incident BMLs with increase in local BMD[50]. In a multi-reader reliability exercise comparing two semiquantitative scoring instruments for hip OA, adequate reliability for assessment especially of BML and synovitis could be shown and positive associations of MRI findings with clinical manifestations of disease were reported[51]. In another multi-reader exercise on hand OA good reliability could be shown using six and four readers assessing synovitis, erosive damage, cysts, osteophytes, cartilage loss, malalignment, BMLs using the OMERACT Hand Osteoarthritis Magnetic Resonance Scoring System (HOAMRIS) system[52].

Treatment

Few studies focused on treatment effects using imaging data as the outcome. Results from the Strontium Ranelate Efficacy in Knee Osteoarthritis Trial (SEKOIA) assessing effects of Strontium Ranelate over 3 years, found effects for the 2 g/day subgroup on decreased cartilage volume loss in the tibial plateaus at 12 and 36 months[53]. Of note, in the medial femur and plateau, Strontium Ranelate 1 g/day, but not Strontium Ranelate 2 g/day, had more cartilage volume loss than placebo. In patients with BMLs in the medial compartment at baseline, the BML score at 36 months was decreased in both treatment groups compared with the placebo group.

Inconsistent data has been published on the effects of oral supplements and structural changes, which adds to the controversy in regard to the effect of nutraceuticals on joint structure[54]. While in a subanalysis of the OAI dataset focusing on subjects taking analgesics and oral supplements such as glucosamine and chondroitin sulfate authors found reduced loss of cartilage volume in subregions of the tibia[55], another group using semiquantitative methodology and assessing changes on cartilage and BMLs over 6 months did not find positive effects for an oral application of glucosamine[56]. In a non-pharmacologic observational study Wiegant and co-workers reported sustained structural and clinical benefit of 2 months of joint distraction therapy over 2 years[57].

Muscle and bone

More studies on muscle and bone changes have been published recently. Bone shape changes have come into the focus in recent years with 3D technology exploring large datasets such as the OAI and suggesting strong predictive evidence of progression in subjects with early bone shape alterations[58,59]. BMLs are important features to explain clinical manifestations of disease and also play a role in structural progression[60]. In the Hallym study a high proportion of knees with and without OA exhibited BMLs that were associated with knee pain severity[61]. The co-registration of MRI and CT data in the regions of BMLs by Lowitz *et al.* allowed for accurate determination of local BMD measures using quantitative CT, which suggested that local BMD is increased in areas of BMLs[62]. Using DXA Driban and co-workers found associations between BML change in both directions, and increase in periarticular BMD and sclerosis progression[63]. An additional study explored assessment technology for BMLs using automated algorithms[64]. In regard to muscle analyses, some studies suggested that intramuscular fat seems to be a potential important manifestation of disease[65,66], while the role of cross sectional muscle area is still being discussed by several authors[66,67].

Synovitis and meniscus

Using semiquantitative and quantitative technology several studies focused on the role of the meniscus and synovitis using MRI data. In the Multicenter Osteoarthritis (MOST) study authors reported on the role of root tears and risk of cartilage progression and found associations for incidence and progression of cartilage damage defined as worsening of the cartilage status using a semiquantitative MRI grading scheme[68]. As root tears are important destabilizers of knee integrity, timely detection of these tears is highly relevant for structural outcome[69]. In a case–control design in the OAI looking at incident OA, Badlani and colleagues reported that extrusion, complex tears and tears with large radial involvement were higher in the case group[70]. Using quantitative methodology Wenger *et al.* reported in a comparative design of OA vs non-OA knees that in OA knees commonly less meniscal coverage, more extrusion and more convex periphery are observed[71]. In 105 knees with OA authors showed in the Amsterdam OA cohort that reduced proprioceptive accuracy was associated with both, the number of regions with meniscal abnormalities and the extent of abnormality suggesting high relevance of meniscal preservation in regard to joint stability and subsequent integrity[72].

In regard to synovitis manifestations authors could show in a subset of the MOST study that were assessed with contrast-enhanced MRI that severity of synovitis was associated with radiographic OA, widespread cartilage damage and severe meniscal damage, confirming that synovitis seems to be mainly a manifestation of later disease[73]. In a histologic-MRI correlation study de Lange-Brokaar and colleagues reported that MRI-detected synovitis was associated with total histology grade, lining cell layer, stroma and inflammatory infiltrates summarizing that MRI correlated with both, macroscopic and microscopic features of synovitis supporting the validity of contrast-enhanced MRI for synovitis assessment[74].

Conclusions

The last 12 months since the 2013 OARSI conference were characterized by a strong focus on MRI-based studies dealing with epidemiologic and methodological aspects of disease. Bone parameters assessed using varying technologies are increasingly coming into the focus of the imaging community and a persistent interest in inflammatory disease manifestations has been noted. Ultrastructural assessment using compositional MRI is evolving further but the predictive value of these techniques in regard to structural and clinical outcomes still needs to be shown. Further subsets of the large publicly available OAI MRI dataset are being analyzed and have been published with muscle being one of the tissues of increasing interest.

Other modalities than MRI have been less explored. To date most imaging research is still performed on the knee joint although there has been a continued interest in spine, hip and hand OA since the last OARSI meeting.

Authors contributions

(1) All authors were involved in the conception and design of the study, or acquisition of data, or analysis and interpretation of data.
(2) All authors contributed to drafting the article or revising it critically for important intellectual content.
(3) All authors gave their final approval of the manuscript to be submitted.

Additional contributions

- Analysis and interpretation of the data: FWR, AG
- Drafting of the article: FWR, AG
- Provision of study materials or patients: FWR, AG
- Statistical expertise: N/A
- Obtaining of funding: N/A
- Collection and assembly of data: FWR, AG

Responsibility for the integrity of the work as a whole, from inception to finished article, is taken by F. Roemer, MD (first author; froemer@bu.edu).

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Competing interests

Dr Guermazi has received consulting fees, speaking fees, and/or honoraria from Sanofi-Aventis, Merck Serono, and TissuGene and is President and shareholder of Boston Imaging Core Lab (BICL), LLC a company providing image assessment services. Dr. Roemer is Chief Medical Officer and shareholder of BICL, LLC.

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