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The OMERACT whole-body MRI scoring system for inflammation in peripheral joints and entheses (WIPE) in spondyloarthritis - reference image atlas for the knee region

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ABSTRACT

Objective: To develop a reference image atlas for the Outcome Measures in Rheumatology whole-body MRI scoring system for inflammation in peripheral joints and entheses (OMERACT MRI-WIPE) of the knee region.
Methods: Image examples of each pathology, location and grade, were collected and discussed at web-based, interactive meetings within the OMERACT MRI in Arthritis Working Group. Subsequently, reference images were selected by consensus.
Results: Reference images for each grade, pathology and location are depicted, along with definitions, reader rules and recommended MRI-sequences.
Conclusion: The atlas guides scoring whole-body MRIs for inflammation in joints and entheses of the knee region according to MRI-WIPE methodology in clinical trials and cohorts.

Introduction

Peripheral arthritis and enthesitis, i.e. inflammation in peripheral joints and entheses, is common in spondyloarthritis (SpA) including psoriatic arthritis (PsA) [1,2]. Magnetic resonance imaging (MRI) allows detailed assessment of inflammation in both soft tissue and bone related to joints and entheses (osteitis/bone marrow edema), traditionally in a limited anatomical area [3,4]. Whole-body MRI (WB-MRI) allows the

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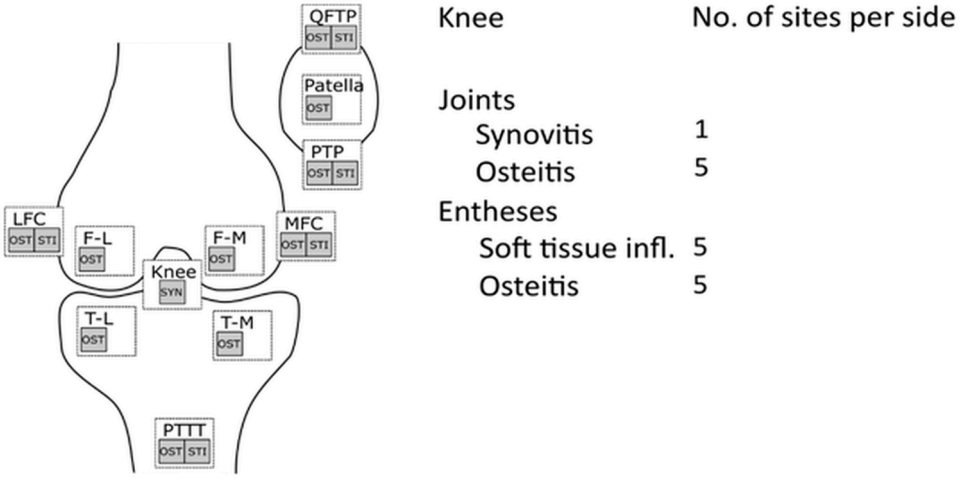

Fig. 1. OMERACT MRI-WIPE schematic and scoring range for the knee region.
Abbreviations: QFTP, quadriceps femoris tendon insertion into patella; PTP, patellar tendon insertion into patella; PTTT, patellar tendon insertion into tibial tuberosity; MFC, medial femoral condyle; LFC, lateral femoral condyle; F-L, femur-lateral; F-M, femur-medial; T-L, tibia-lateral; T-M, tibia-medial.

assessment of the overall inflammatory status in the entire body of arthritis patients, capturing both joints and entheses [5–8], and is therefore an imaging technique that is well suited to evaluate inflammation in patients with active SpA and PsA. Several outcome measurement frameworks such as for rheumatoid arthritis and psoriatic arthritis were previously developed by the Outcome Measures in Rheumatology (OMERACT) group [9–11].

The OMERACT MRI Whole-body score for Inflammation in Peripheral joints and Entheses (OMERACT MRI-WIPE) has been developed and validated for the body as a whole [12,13].

Although knee arthritis is a key cause of functional impairment, no detailed MRI scoring system for knee inflammation in SpA has been published. Therefore, the OMERACT MRI in Arthritis Working Group decided to further develop and validate MRI-WIPE with a modular, i.e. region-based, approach. The reliability for the knee region was then documented [14]. However, the exact area of assessment and the individual grades of MRI-WIPE may be difficult for new readers to conceptualize. Furthermore, the applicability and reproducibility of scoring systems have been shown to improve with accessibility of standard reference images for comparison [15–18]. Therefore, our aim was to develop an MRI reference image atlas for the knee region to use as a guide for scoring inflammation based on the OMERACT MRI-WIPE method.

Methods

Image selection

Images representing each MRI feature, location and grade, as per the MRI-WIPE definitions, were collected from working group members and collaborators in centres in Copenhagen, Edmonton, Tel Aviv, Ghent, Cairo and Leeds, and preliminary selections of potential examples of each grade were selected for each area of interest by three group members. Sagittal T2-weighted fat-saturated (T2-FS) and short tau inversion recovery (STIR) images were preferred, except for lateral/medial femoral condyle entheses, where coronal images were preferred. The images were presented for general discussion at web-based, interactive meetings between the members (rheumatologists and radiologists) of the OMERACT MRI in Arthritis Working Group. At these web-based meetings example images of each grade of MRI features were discussed, also considering detailed definitions and reader rules. Subsequently, consensus on the image selection was reached. Images were cropped and mounted, and subsequently all participating members approved the final set of reference images.

MRI-WIPE scoring methodology

Using OMERACT MRI-WIPE, osteitis is assessed in the bone from the articular surface/entheseal insertion to a depth of 1 cm on all available images.

The osteitis (bone marrow edema, BME) grading scale is 0–3 based on the proportion of bone with oedema, compared to the "assessed bone volume", judged on all available images: 0: normal; 1: mild (1–33 % of bone oedematous); 2: moderate (34–66 % of bone oedematous); 3: severe (67–100 % of bone oedematous).

Soft tissue inflammation (STI) is assessed inside the ligament/tendon and its immediate surroundings to 1 cm from the entheseal insertion (grades 0–3): 0: normal; 1: mild; 2: moderate; 3: severe – by thirds of the maximum potential volume of inflammatory tissue.

Synovitis (SYN) is assessed in the entire synovial compartment on all available images (grades 0–3): 0: normal; 1: mild; 2: moderate; 3: severe – by thirds of the maximum potential volume of enhancing tissue in the synovial compartment [7].

When both knees are examined, joint synovitis is scored at 2 sites, joint osteitis at 10 sites, entheseal soft tissue inflammation at 10 sites and entheseal osteitis at 10 sites; all sites are scored 0–3 per site, giving a max total score of 96 (joints: 36; entheses 60).

Additional reader rules are as follows: (1) Positive vs. negative score: A positive score of 1 should only be made when the reader is confident that there is an abnormality. All synovial joints contain normal joint fluid; this should not be scored. The scoring system aims at scoring inflammation. If the reader is hesitating whether to score a possible lesion 1 (mild) or 0 (none), the recommendation is to score as 0 (none). (2) Lesion judged borderline between two scores: If the lesion is judged borderline 1 vs. 2 or 2 vs. 3, the signal intensity (brightness) of the lesion may be taken into account. For instance, if a lesion is borderline between 1 (mild) and 2 (moderate), it may be scored 1 (mild) if not judged intense. Similarly, if a lesion is borderline between 2 (moderate) and 3 (severe), it may be scored 3 (severe) if judged intense. When there is an increased amount of synovial tissue, not just effusion, and the lesion is judged borderline between two scores, the higher score may be assigned.

Preferentially, synovitis and soft tissue inflammation are assessed on T1-post-Gd images and osteitis on Short Tau Inversion Recovery (STIR)/T2-Weighted Fat Saturated (T2FS) images, but if only STIR/T2FS is available, synovitis and soft tissue inflammation can be assessed based on this. The current atlas focuses on STIR/T2FS images.

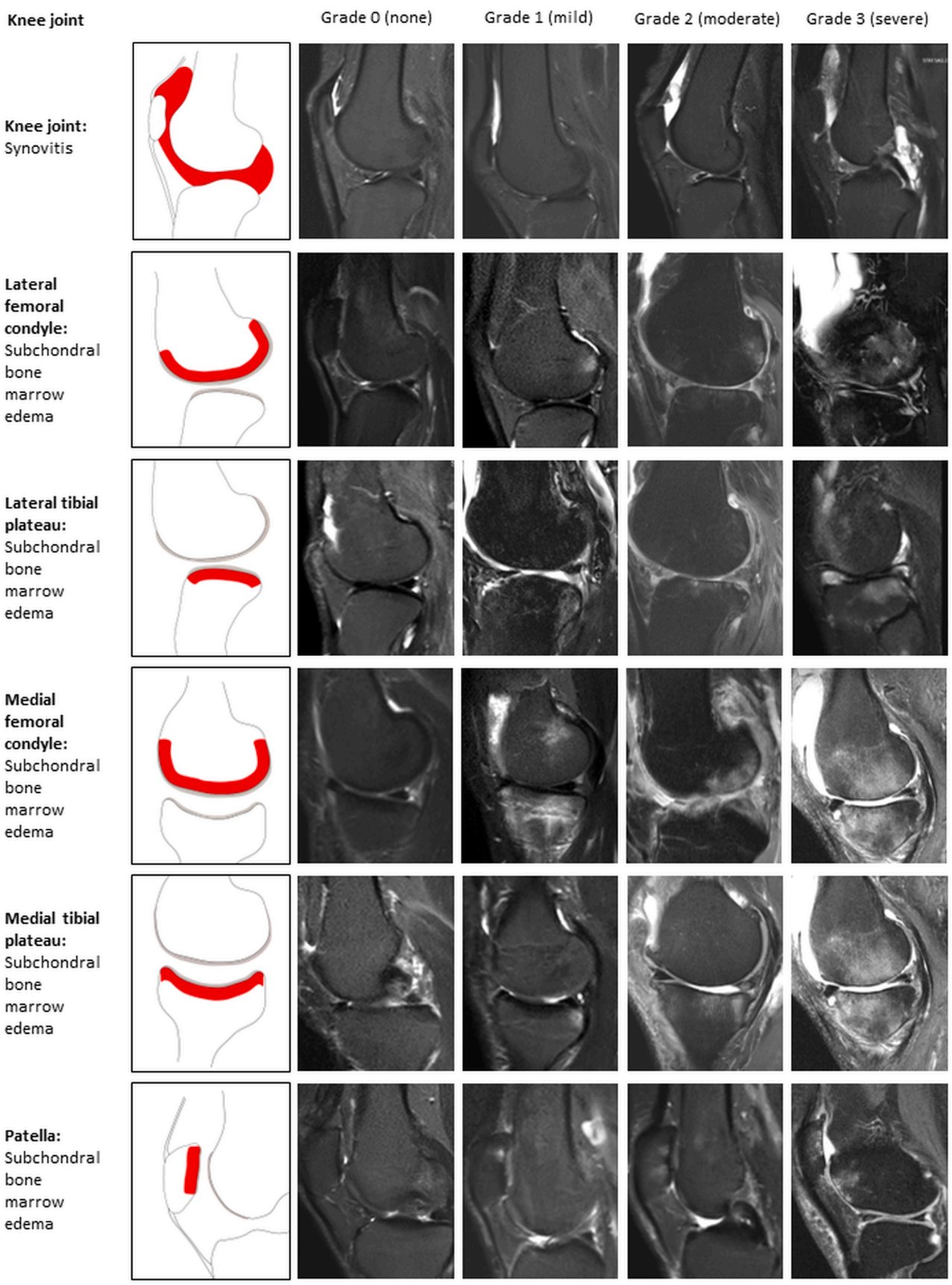

Fig. 2. MRI-WIPE scoring system grades for knee joint inflammatory pathologies.
A line drawing (left) depicts the area to assess. Images are sagittal short tau inversion recovery or T2-weghted fat saturated MR images, if not otherwise indicated.

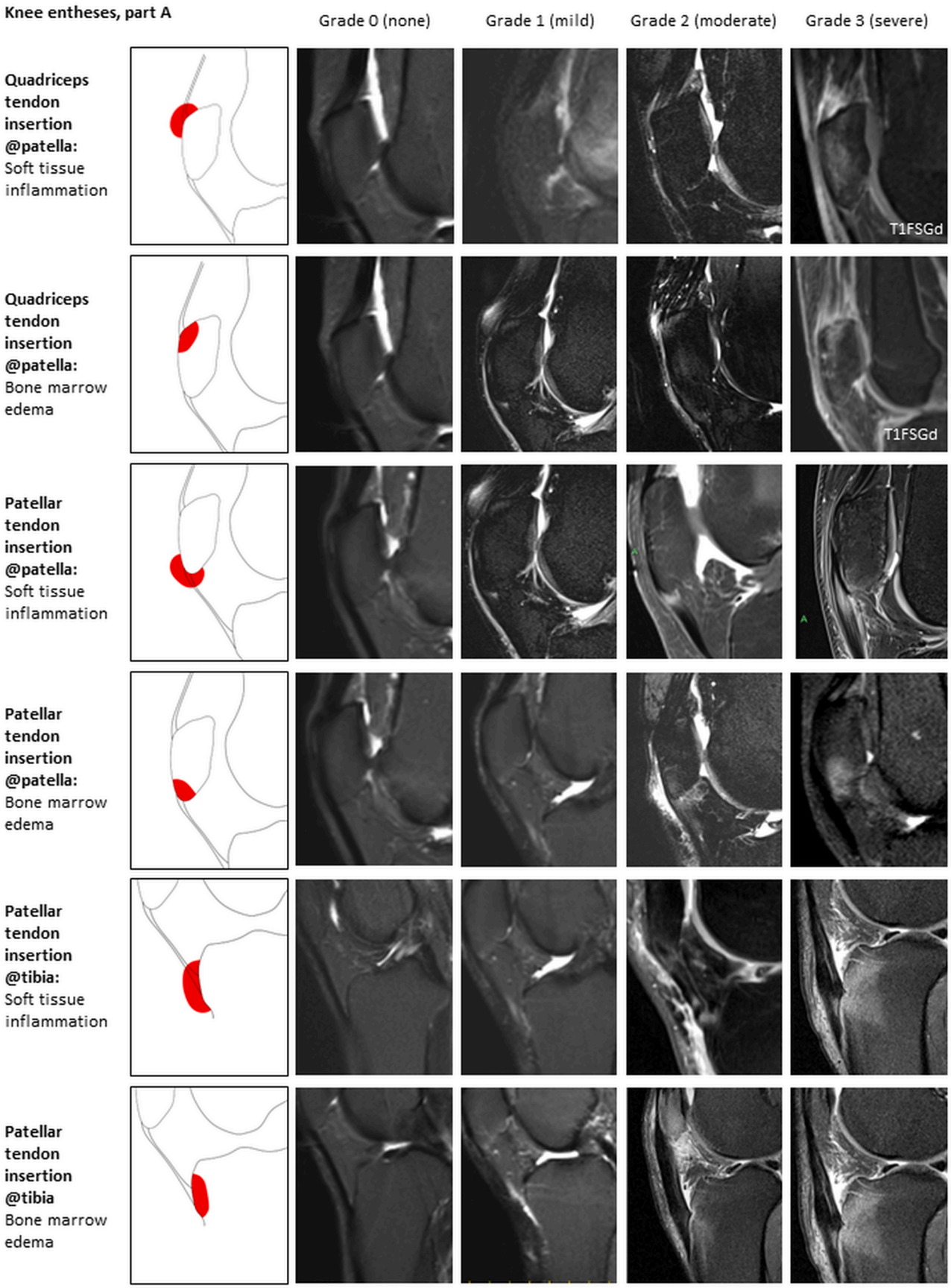

Fig. 3. MRI-WIPE scoring system grades for enthesitis in the knee region (Part A).
A line drawing (left) depicts the area to assess. Images are sagittal short tau inversion recovery or T2-weighted fat saturated MR images, if not otherwise indicated. T1FSGd: T1-weighted fat saturated image after intravenous gadolinium contrast injection.

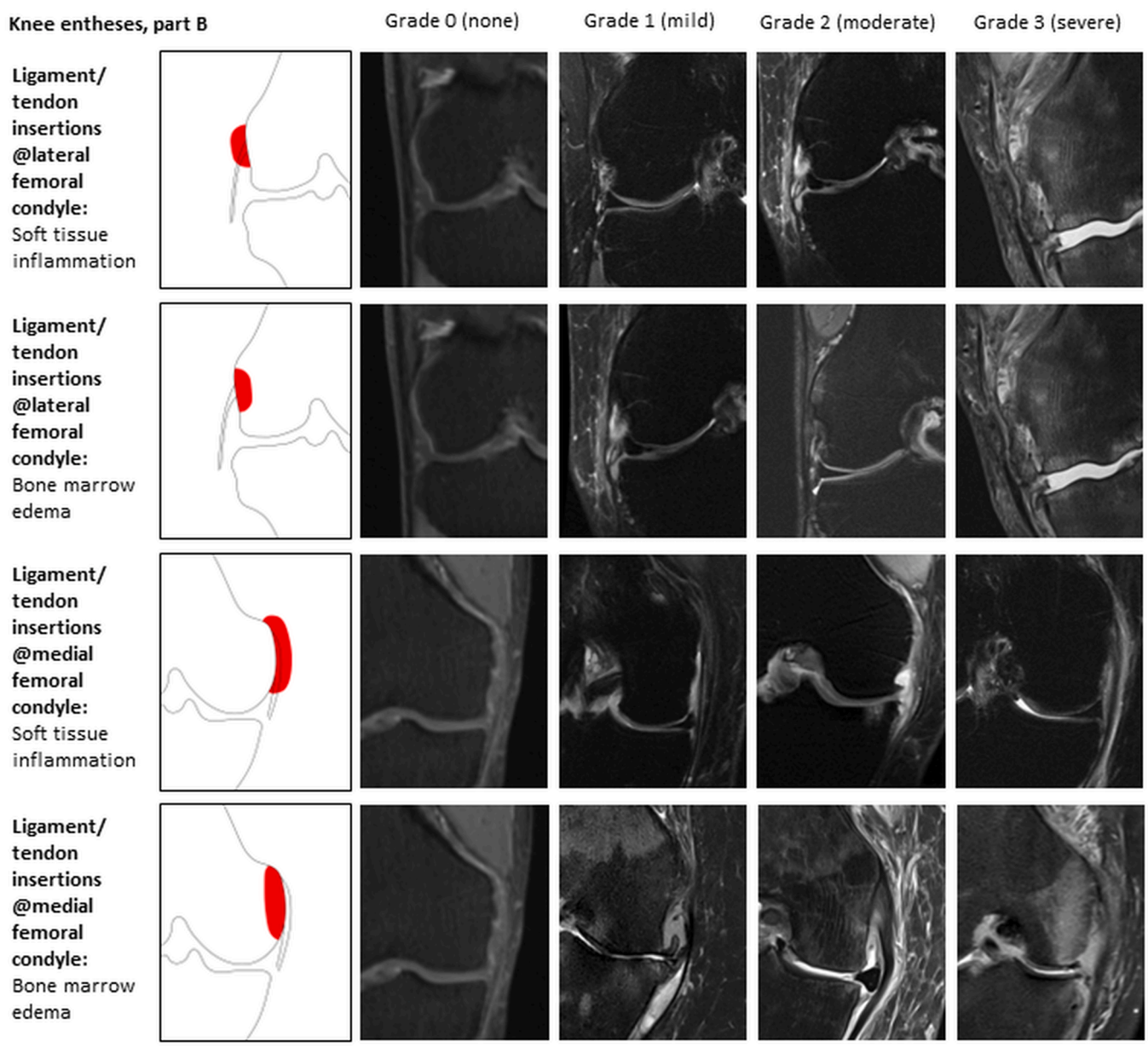

Fig. 4. MRI-WIPE scoring system grades for enthesitis in the knee region (Part B).
A line drawing (left) depicts the area to assess. Images are coronal short tau inversion recovery or T2-weighted fat saturated MR images.

Results

The areas assessed for each knee joint include 5 different locations (lateral femoral condyle, lateral tibial plateau, medial femoral condyle, medial tibial plateau and patella) of subchondral bone marrow edema (osteitis), as well as knee joint synovitis. Furthermore, osteitis and soft tissue inflammation are assessed separately at 5 different entheses (quadriceps femoris tendon insertion into patella, patellar tendon insertion into patella, patellar tendon insertion into tibia, tendon/ligament insertions into the medial and lateral femoral condyles). A graphical display of locations of the individual MRI features in the knee region that should be scored in WIPE is provided in Fig. 1 along with their definitions. Representative examples of different grades for each of the MRI features to be assessed are presented in Figs. 2–4. Line drawings, depicting the area of focus while scoring each MRI feature according to WIPE, are included.

Discussion

The OMERACT MRI-WIPE is the first international consensus-based and validated, comprehensive whole-body MRI scoring system for inflammation in peripheral joints and entheses in patients with SpA, including PsA. In this atlas, we have depicted different grades of each MRI pathology to be scored in the knee region in patients with SpA/PsA in clinical trials or cohorts.

For efficient use of this atlas, the reader should be familiar with the relevant anatomy of the region, the MRI appearance of the knee joint, and common pitfalls in assessment.

Before assigning a score, the reader is recommended to window each image appropriately in order to prevent overappreciation or underappreciation of inflammation, and to scroll through all the available images, comparing them with the reference images and grade definitions in this atlas. Calibration with a trained WIPE reader is highly recommended to provide reliable assessments and enhance the overall outcome, since calibration is known to increase reproducibility [15,17,

18]. For evaluation we recommend a monitor size of at least 24 inches with a resolution of at least 2 megapixels.

Optimal assessment of synovitis requires obtaining T1-weighted images before and after administration of gadolinium contrast [19, 20], allowing clearer differentiation of the inflamed synovium from the joint fluid. However, WBMRI requires imaging of many regions (generally six separate acquisitions/stations, and more if the sacroiliac joints and spine also need to be assessed), reducing the amount of sequences that can be obtained. Therefore, the current atlas focuses on short-tau inversion recovery (STIR) and T2-weighted fat saturated sequences, which are well-suited for assessing inflammation without the use of intravenous contrast [2].

Also to save image acquisition time, MR images obtained as part of a whole-body MRI examination are most often only obtained in one plane per region. As most relevant inflammatory pathologies in the knee region are best depicted in sagittal images, this plane is recommended if time only allows imaging in a single plane. Therefore, the vast majority of reference images in the current atlas are in the sagittal plane (Figs. 2 and 3). Adding another plane, coronal or axial, will provide additional information, particularly for the entheses at the medial and lateral femoral condyles. Consequently, displayed reference images for these locations are in the coronal plane (Fig. 4).

In conclusion, we have provided a set of knee region standard reference images for inflammation of joints and entheses to allow improved calibration between readers in clinical trials and cohorts. The reference image set may also be used as a handy teaching tool for new readers interested in MRI assessment of knees in patients with SpA and PsA.

CRediT authorship contribution statement

Mikkel Østergaard: Conceptualization, Methodology, Software, Validation, Investigation, Data curation, Writing – original draft, Visualization, Supervision, Project administration. **Marie Wetterslev:** Conceptualization, Methodology, Validation, Investigation, Data curation, Writing – review & editing, Visualization, Supervision, Project administration. **Anna EF Hadsbjerg:** Methodology, Software, Validation, Writing – review & editing, Visualization. **Walter P Maksymowych:** Conceptualization, Validation, Writing – review & editing. **Iris Eshed:** Validation, Resources, Writing – review & editing. **Lennart Jans:** Validation, Resources, Writing – review & editing. **Yasser Emad:** Validation, Resources, Writing – review & editing. **Susanne J Pedersen:** Validation, Writing – review & editing. **Maria S Stoenoiu:** Validation, Writing – review & editing. **Paul Bird:** Validation, Writing – review & editing. **Violaine Foltz:** Validation, Writing – review & editing. **Ashish J Mathew:** Validation, Writing – review & editing. **Joel Paschke:** Validation, Writing – review & editing. **Philippe Carron:** Resources, Writing – review & editing. **Gabriele De Marco:** Resources, Writing – review & editing. **Helena Marzo-Ortega:** Resources, Writing – review & editing. **Signe Møller-Bisgaard:** Validation, Writing – review & editing. **Philip G Conaghan:** Conceptualization, Validation, Writing – review & editing. **Robert GW Lambert:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Mikkel Østergaard has received research grants from Abbvie, BMS, Merck, Novartis and UCB, consultancy fees from Abbvie, BMS, Celgene, Eli-Lilly, Galapagos, Gilead, Janssen, MEDAC, Merck, Novartis, Pfizer, Sandoz, and UCB Abbvie, BMS, Celgene, Eli-Lilly, Galapagos, Gilead, Janssen, MEDAC, Merck, Novartis, Pfizer, Sandoz, and UCB and speaker fees from Abbvie, BMS, Celgene, Eli-Lilly, Galapagos, Gilead, Janssen, MEDAC, Merck, Novartis, Pfizer, Sandoz, and UCB. Walter P Maksymowych is Chief Medical Officer at CARE Arthritis Limited. Helena Marzo-Ortega has received research grants from Janssen, Novartis, Pfizer and UCB, and speaker fees from AbbVie, Amgen, Biogen, Eli Lilly, Janssen, Novartis, Pfizer, Takeda, UCB. Philip G Conaghan has received consultancy fees from AbbVie, BMS, Eli Lilly, Galapagos, GSK, Janssen, Novartis and Takeda and speaker fees from AbbVie, Eli Lilly and Novartis. Robert GW Lambert has received research grants from Calyx and Care Arthritis, and consultancy fees from Image Analysis Group, Calyx and Care Arthritis. The remaining authors declare no financial interests/personal relationships.

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