Seminars in Arthritis and Rheumatism 65 (2024) 152383

Contents lists available at ScienceDirect

Seminars in Arthritis and Rheumatism

journal homepage: www.elsevier.com/locate/semarthrit

# Hip and pelvis region MRI reference image atlas for scoring inflammation in peripheral joints and entheses according to the OMERACT-MRI WIPE scoring system in patients with spondyloarthritis

Mikkel Østergaard [a,b,*], Robert GW Lambert [c], Anna EF Hadsbjerg [a,b], Iris Eshed [d], Walter P Maksymowych [e,f], Ashish J Mathew [a,g], Lennart Jans [h], Susanne J Pedersen [a], Philippe Carron [i,j], Yasser Emad [k], Gabriele De Marco [l,m], Paul Bird [n], Maria S Stoenoiu [o], Violaine Foltz [p], Joel Paschke [f], Helena Marzo-Ortega [l,m], Signe Møller-Bisgaard [a,q], Philip G Conaghan [l,m], Marie Wetterslev [a]

[a] Copenhagen Center for Arthritis Research (COPECARE), Center for Rheumatology and Spine Diseases, Centre for Head and Orthopaedics, Rigshospitalet, Glostrup, Denmark
[b] Department of Clinical Medicine, University of Copenhagen, Copenhagen, Denmark
[c] Department of Radiology and Diagnostic Imaging, University of Alberta, Edmonton, Alberta, Canada
[d] Department of Diagnostic Imaging, Sheba Medical Center, Affiliated to the School of Medicine, Tel-Aviv University, Israel
[e] Department of Medicine, University of Alberta, Edmonton, Alberta, Canada
[f] CARE Arthritis, Edmonton, Alberta, Canada
[g] Department of Clinical Immunology & Rheumatology, Christian Medical College, Vellore, India
[h] Department of Radiology, Ghent University Hospital, Ghent, Belgium
[i] Department of Rheumatology, Ghent University Hospital, Ghent, Belgium
[j] VIB Inflammation Research Centre, Ghent University, Ghent, Belgium
[k] Department of Rheumatology, Faculty of Medicine, Cairo University, Egypt
[l] Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds, Leeds, UK
[m] NIHR Leeds Biomedical Research Centre, Leeds Teaching Hospitals NHS Trust, Leeds, UK
[n] Division of Medicine, University of New South Wales, Sydney, Australia
[o] Department of Rheumatology, Cliniques Universitaires Saint-Luc, Institut de Recherche Experimentale et Clinique, Université Catholique de Louvain, Bruxelles, Belgium
[p] Department of Rheumatology, Sorbonne University, APHP, Pitié-Salpètrière Hospital, Paris, France
[q] Department of Rheumatology, Slagelse Hospital, Slagelse, Denmark

ARTICLE INFO

*Keywords:*
OMERACT
Spondyloarthritis
Psoriatic arthritis
Whole-body MRI
MRI-WIPE
Enthesitis
Hip
Pelvis

ABSTRACT

*Objective:* To develop a reference image atlas for scoring the hip/pelvis region according to the OMERACT whole-body MRI scoring system for inflammation in peripheral joints and entheses (MRI-WIPE).
*Methods:* We collected image examples of each pathology, location and grade, discussed them at web-based, interactive meetings and, finally, selected reference images by consensus.
*Results:* Reference images for each grade and location of osteitis, synovitis and soft tissue inflammation are provided, as are definitions, reader rules and recommended MRI-sequences.
*Conclusion:* A reference image atlas was created to guide scoring whole-body MRIs for arthritis and enthesitis in the hip/pelvis region in spondyloarthritis/psoriatic arthritis clinical trials and cohorts.

## Introduction

The hip and pelvis region is frequently involved in spondyloarthritis (SpA) including psoriatic arthritis (PsA), often causing considerable pain and reduced function [1,2]. Inflammation in joints and entheses in the region can be captured by magnetic resonance imaging (MRI) [3]. Since

* Corresponding author at: Copenhagen Center for Arthritis Research (COPECARE), Center for Rheumatology and Spine Diseases, Copenhagen University Hospital Rigshospitalet – Glostrup, Valdemar Hansens vej 17, DK-2600 Glostrup, Denmark.
*E-mail address:* mo@dadlnet.dk (M. Østergaard).

https://doi.org/10.1016/j.semarthrit.2024.152383

Available online 2 February 2024

SpA and PsA generally involve several anatomical locations, assessing the entheses and joints of the entire body in one examination would be desirable in clinical practice and particularly in clinical trials and cohorts. Whole-body MRI (WBMRI) allows this, and therefore the OMERACT MRI in Arthritis Working Group developed and validated the OMERACT MRI Whole-body scoring system for Inflammation in Peripheral joints and Entheses (OMERACT MRI-WIPE) [4,5]. The reliability for the hip and pelvis region was subsequently documented [6]. However, identifying the exact area to be assessed and ascertaining the differences between the individual grades of the scoring system may be challenging, particularly for new readers. This can be facilitated by the development of effective knowledge transfer tools. The application and reproducibility of scoring systems has been shown to improve by providing standard reference images for comparison [7–10].

Therefore, our aim was to develop a set of standard reference images, a "reference image atlas", for the hip and pelvis region to use as a guide for scoring arthritis and enthesitis in the hip/pelvis region based on the OMERACT MRI-WIPE method.

## Methods

### *Image selection*

Images representing each MRI feature, location and grade, as per MRI-WIPE definitions [5], were collected internationally from working group members and collaborators, and preliminary selections of potential examples of each grade were selected by three group members and 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 each MRI feature were discussed, taking into consideration detailed definitions and reader rules. Subsequently, consensus on the image selection was reached. Images were thereafter cropped and mounted, and subsequently all participating group 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 (Fig. 1).

The osteitis (bone marrow edema) 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 edematous); 2: moderate (34–66 % of bone edematous); 3: severe (67–100 % of bone edematous).

Soft tissue inflammation is assessed inside the ligament/tendon and its immediate surroundings up 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 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.

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 it as 0 (none). 2) Lesion judged borderline between two scores: If the lesion is judged borderline grades 1 vs. 2 or 2 vs. 3, the signal intensity (brightness) of the lesion may be considered. For instance, if a lesion is borderline between grades 1 (mild) and 2 (moderate), it may be scored 1 (mild) if not judged intense. Similarly, for instance, if a lesion is borderline between grades 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 to be 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.

## Results

A graphical display of locations of the individual MRI features in the hip and pelvis region that should be scored in WIPE is provided in Fig. 1, together with the scoring ranges for the region. The areas assessed for

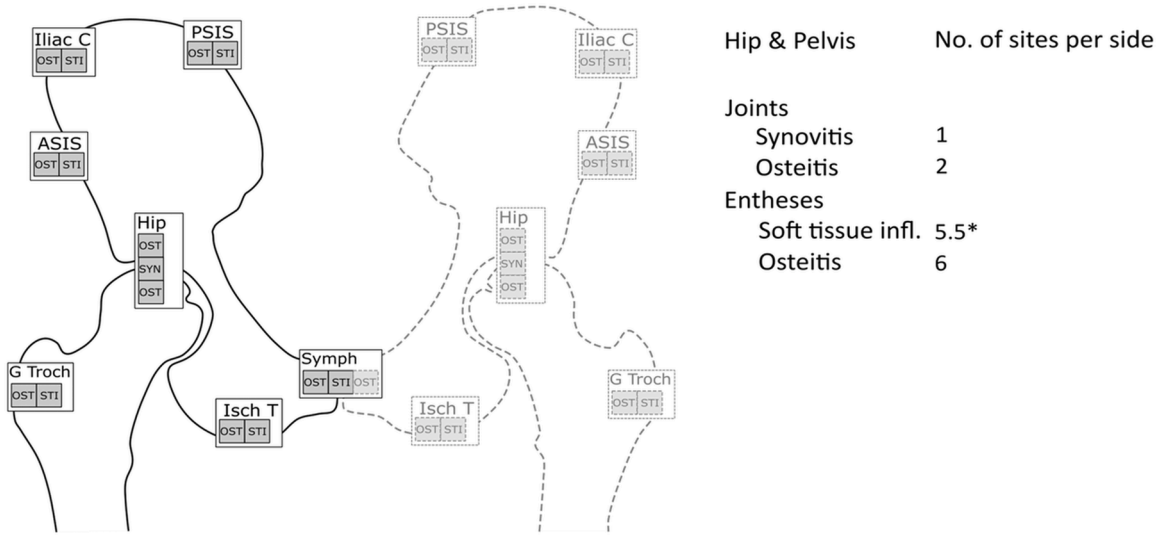


**Fig. 1.** OMERACT MRI-WIPE schematic and scoring range for the hip and pelvis region. Abbreviations: SYN, synovitis; STI, Soft tissue inflammation, OST, Osteitis (bone marrow edema); ASIS: anterior superior iliac spine; G Troch, greater trochanter; Hip, hip joint; Iliac C, iliac crest; Isch T, ischial tuberosity; PSIS, posterior superior iliac spine, Symph, Pubic symphysis. *STI at pubic symphysis is only scored once per pelvis; thus it only counts as a ½ on each side. In the entire pelvis, joint synovitis is scored at 2 sites, joint osteitis at 4 sites, entheseal soft tissue inflammation at 11 sites and entheseal osteitis at 12 sites; all sites are scored are scored 0–3 per site, giving a max total score of 87 (joints: 18; entheses 69).

each hip joint are 2 locations of subchondral bone marrow edema/osteitis (acetabulum and femoral head), as well as hip joint synovitis. Furthermore, osteitis and soft tissue inflammation are assessed separately at the symphysis (osteitis separately in left and right pubic bone + soft tissue inflammation), as well as at 5 different entheses per side, 10 in total (greater trochanter, ischial tuberosity, anterior superior iliac spine, iliac crest, posterior superior iliac spine). In total, synovitis and osteitis are scored at 2 and 4 joint locations, respectively, while soft tissue inflammation and osteitis are scored at 11 respectively 12 entheseal locations, respectively, i.e. in total 29 individual scores are assigned.

Representative examples of the 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. Images of some grades of pathologies at certain locations were not available.

## Discussion

In this MRI reference image atlas, we have depicted different grades of each MRI pathology in the hip and pelvis region to be scored using the OMERACT whole-body MRI scoring system for inflammation in peripheral joints and entheses in patients with SpA or PsA in clinical trials and cohorts.

OMERACT is a global, volunteer-driven, not-for-profit organisation committed to improving outcomes for patients with autoimmune and musculoskeletal diseases by advancing the design and quality of clinical studies. It has developed outcome measurement instruments, including imaging tools, for use in clinical trials [11–13]. An OMERACT whole-body MRI scoring system was published in 2019 [5]. Other WBMRI assessment systems have been reported, differing from the MRI-WIPE in being less validated and by focusing on the lower

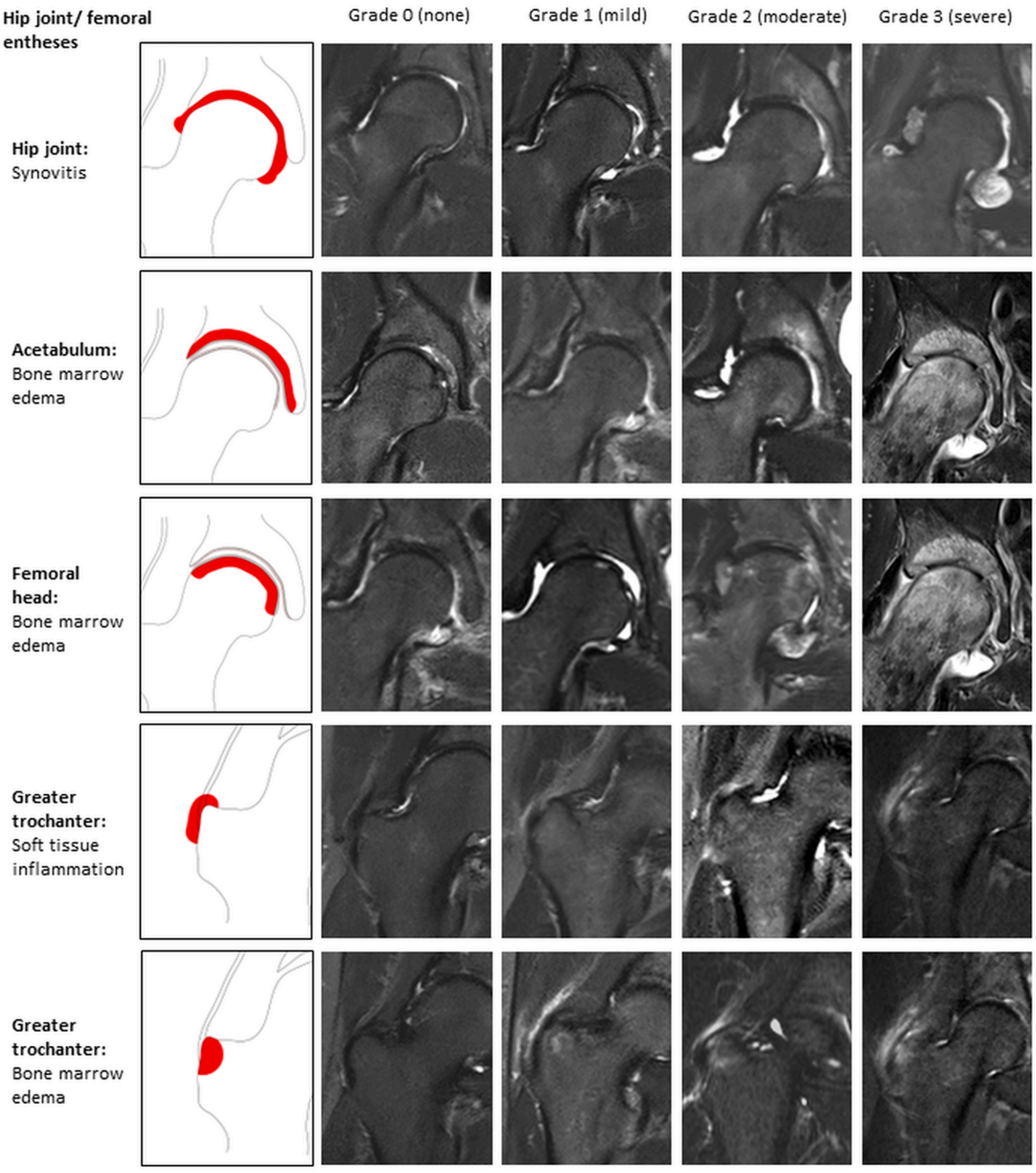


**Fig. 2.** MRI-WIPE scoring system grades for inflammatory pathologies at hip joint and femoral entheses. A line drawing (left) depicts the area to assess. Images are coronal short tau inversion recovery or T2-weghted fat saturated MR images.

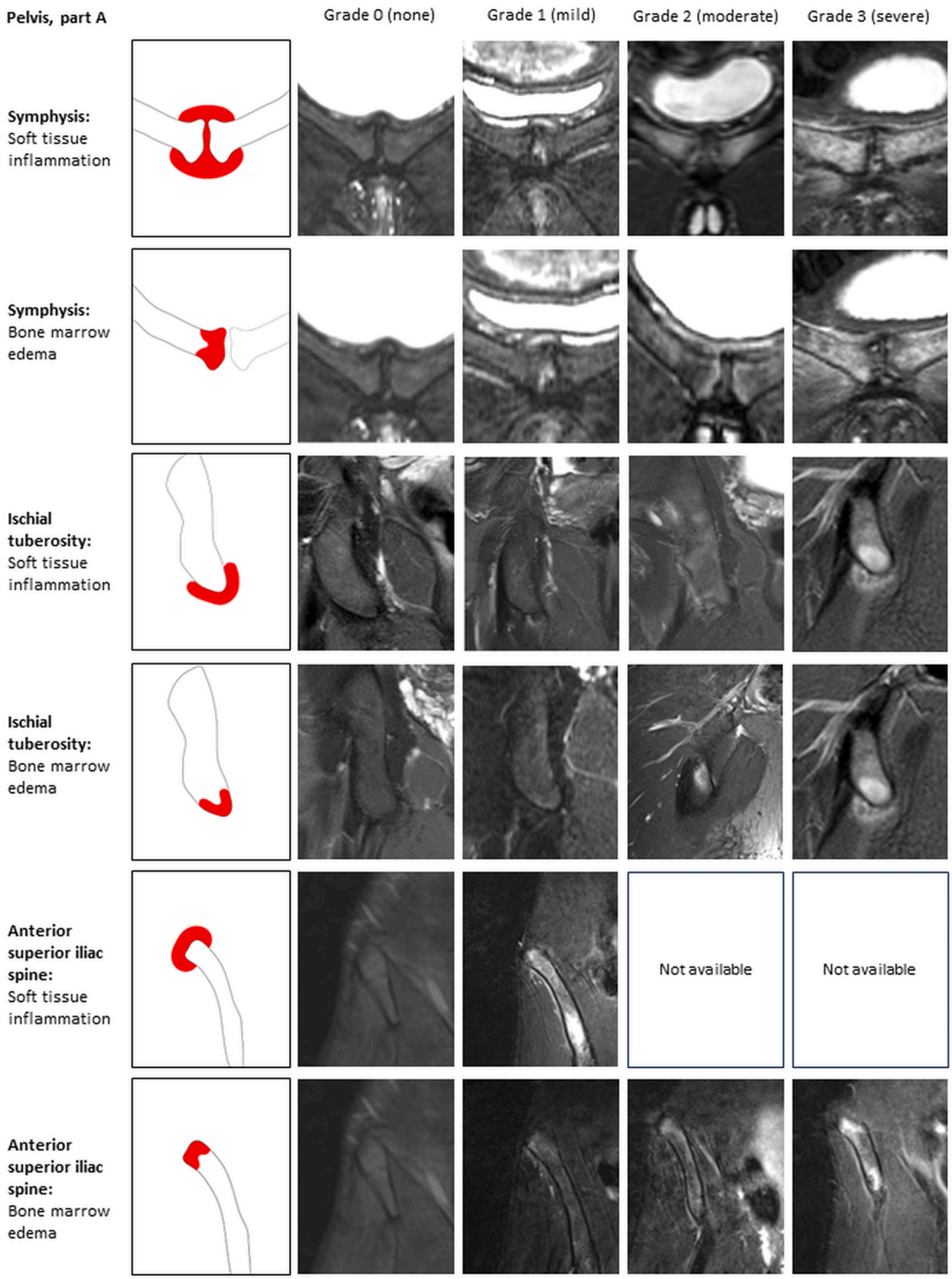


**Fig. 3.** MRI-WIPE scoring system grades for enthesitis in the pelvis region (Part A). A line drawing (left) depicts the area to assess. Images are coronal short tau inversion recovery or T2-weighted fat saturated MR images.

extremities [3,14], adding or deleting a few enthesitis locations compared to MRI-WIPE and/or using binary or 0–2 scoring systems [2, 14-17]. These studies consistently provide evidence in support of the sensitivity of WBMRI in detecting and detecting change in inflammation in joints and entheses. The current atlas will complement existing MRI-WIPE publications by easing conceptualization of relevant inflammatory pathologies and their individual grades. It is important that readers are sufficiently aware of the relevant anatomy, the MRI appearance of the region, pathologies of interest in SpA, and common pitfalls in their assessment. It is highly recommended that a reader trains and calibrates with a trained WIPE reader, since training and calibration are known to increase reproducibility [7,9,10]. For evaluation we

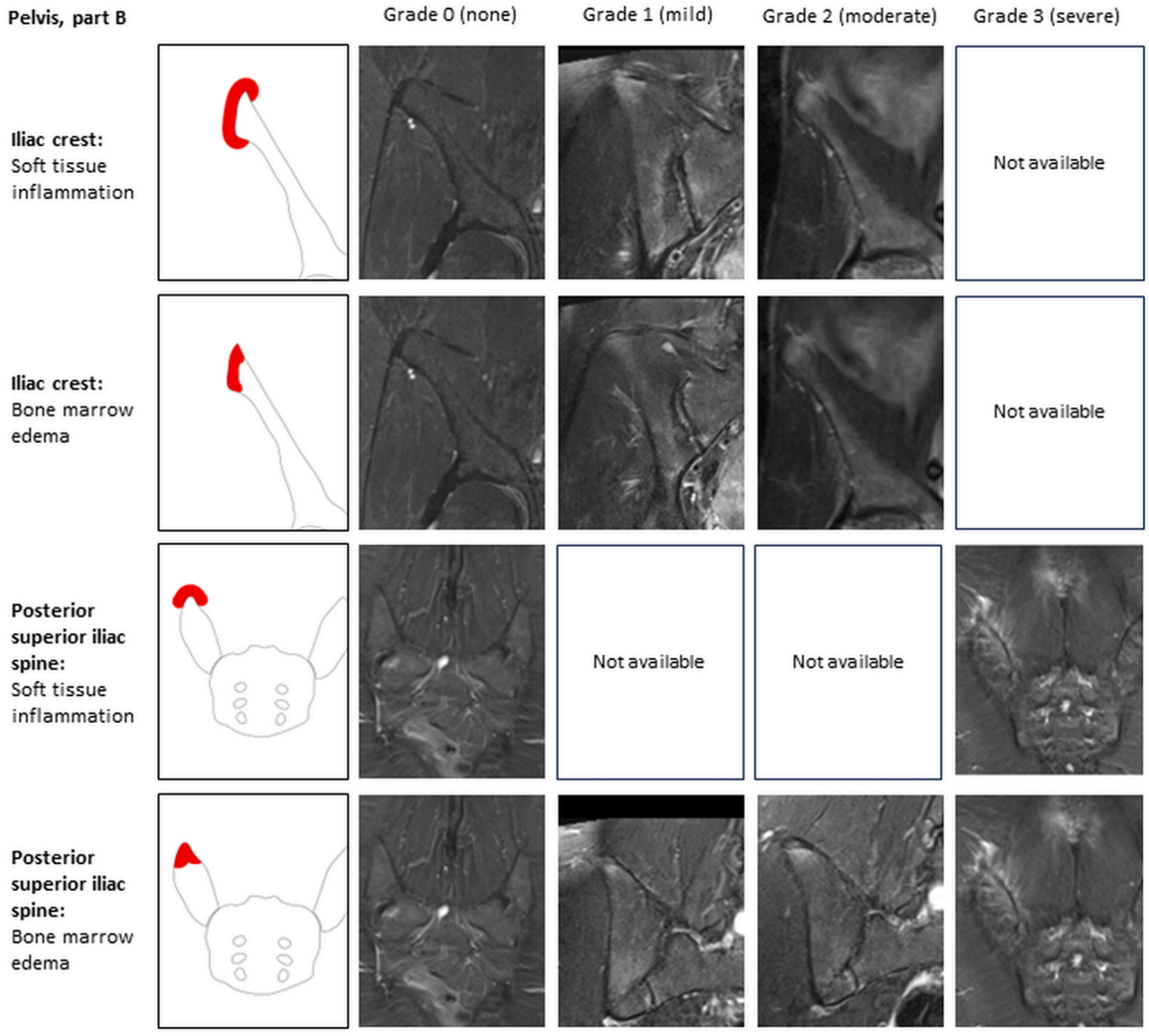


**Fig. 4.** MRI-WIPE scoring system grades for enthesitis in the pelvis region (Part B). A line drawing (left) depicts the area to assess. Images are coronal short tau inversion recovery or T2-weighted fat saturated MR images.

recommend a monitor size of at least 24 inches with a resolution of at least 2 megapixels.

The current atlas presents short-tau inversion recovery (STIR) and T2-weighted fat saturated MR images, which are well-suited for assessing inflammation without the use of intravenous contrast [18]. The MRI-WIPE definitions of the grades of the individual pathologies should always be kept in mind, but the atlas is considered the best reference to keep scoring consistent between readers. MRI-WIPE scores can be entered in dedicated online modules located at https://samri3.zitelab.eu and https://www.carearthritis.com. It would have been optimal to display the entire volume of the entheses and not only a selected slice. However, this was not technically feasible. The above-mentioned images do not allow proper assessment of structural changes, but for the purpose of scoring disease activity in a clinical trial this is not essential. For use in clinical practice, the goal of the MRI examination may be different, e.g., diagnosis, requiring additional MRI sequences, e.g., T1-weighted images. Optimal assessment of synovitis requires T1-weighted images before and after administration of gadolinium contrast [19,20], which can depict the inflamed synovium distinct from joint fluid. To save time and to allow the entire body to be scanned, such sequences are often omitted in WBMRI as is imaging in more than only one plane per individual region. Assessment of structural changes, such as bone erosions, would also require other sequences than STIR/T2FS images, e.g. T1-weighted images. Furthermore, higher image resolution would be needed, particularly in the smaller joints. This would increase acquisition time, which is already long. Assessment of bone erosion in smaller joints is, therefore, not currently feasible in WBMRI protocols, but may soon be, due to rapid technical developments.

As the most important locations of inflammatory pathologies in the hip and pelvis region (such as hip joint, greater trochanter, and the pubic symphysis) are well depicted in coronal images, this plane is recommended if time only allows one imaging plane. Consequently, the reference images in the current atlas are in the coronal plane (Figs. 2-4). Using only this plane hinders evaluation of certain parts of the entheseal attachments on the ilium and sacrum. In clinical practice, other planes may therefore be added.

In conclusion, we have provided a set of standard reference images depicting inflammation of joints and entheses in the hip and pelvis region to enhance calibration between readers in clinical trials and cohorts. The reference image set may also be useful for new readers interested in MRI assessment of the hip/pelvis region 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. **Robert GW Lambert:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing. **Anna EF Hadsbjerg:** Methodology, Software, Validation, Writing – review & editing, Visualization. **Iris Eshed:** Validation, Resources, Writing – review & editing. **Walter P Maksymowych:** Conceptualization, Validation, Writing – review & editing. **Ashish J Mathew:** Validation, Writing – review & editing. **Lennart Jans:** Validation, Resources, Writing – review & editing. **Susanne J Pedersen:** Validation, Writing – review & editing. **Philippe Carron:** Resources, Writing – review & editing. **Yasser Emad:** Validation, Resources, Writing – review & editing. **Gabriele De Marco:** Resources, Writing – review & editing. **Paul Bird:** Validation, Writing – review & editing. **Maria S Stoenoiu:** Validation, Writing – review & editing. **Violaine Foltz:** Validation, Writing – review & editing. **Joel Paschke:** Validation, 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. **Marie Wetterslev:** Conceptualization, Methodology, Validation, Investigation, Data curation, Writing – review & editing, Visualization, Supervision, Project administration.

## 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. Robert GW Lambert has received research grants from Calyx and Care Arthritis, and consultancy fees from Image Analysis Group, Calyx and Care Arthritis. 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. The remaining authors declare no financial interests/personal relationships.

## Acknowledgements

We acknowledge the contribution of SIG (Special Interest Group) participants at the OMERACT Conference on May 3, 2023. GDM, HM-O and PGC are supported by the National Institute for Health Research (NIHR) Leeds Biomedical Research Centre (LBRC). The views expressed are those of the authors and not necessarily those of the (UK) National Health Service (NHS), the NIHR, or the (UK) Department of Health.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.semarthrit.2024.152383.

## References

[1] de Vlam K, Steinfeld S, Toukap AN, et al. The burden of psoriatic arthritis in the biologics era: data from the Belgian Epidemiological Psoriatic Arthritis Study. Rheumatology (Oxford) 2021;60(12):5677–85. https://doi.org/10.1093/rheumatology/keab233.

[2] Poggenborg RP, Eshed I, Østergaard M, et al. Enthesitis in patients with psoriatic arthritis, axial spondyloarthritis and healthy subjects assessed by 'head-to-toe' whole-body MRI and clinical examination. Ann Rheum Dis 2015;74(5):823–9. https://doi.org/10.1136/annrheumdis-2013-204239. annrheumdis-2013-204239 [pii][doi].

[3] Renson T, Carron P, De Craemer AS, et al. The value of magnetic resonance imaging for assessing disease extent and prediction of relapse in early peripheral spondyloarthritis. Arthritis Rheumatol 2021;73(11):2044–51. https://doi.org/10.1002/art.41783.

[4] Østergaard M, Eshed I, Althoff CE, et al. Whole-body magnetic resonance imaging in inflammatory arthritis: systematic literature review and first steps toward standardization and an OMERACT scoring system. J. Rheumatol 2017;44(11):1699–705. https://doi.org/10.3899/jrheum.161114. jrheum.161114 [pii][doi].

[5] Krabbe S, Eshed I, Gandjbakhch F, et al. Development and validation of an OMERACT MRI whole-body score for inflammation in peripheral joints and entheses in inflammatory arthritis (MRI-WIPE). J Rheumatol 2019;46(9):1215–21. https://doi.org/10.3899/jrheum.181084. jrheum.181084 [pii][doi].

[6] Wetterslev M, Lambert RG, Maksymowych WP, et al. Arthritis and enthesitis in the hip and pelvis region in spondyloarthritis - OMERACT validation of two whole-body MRI methods. Semin Arthritis Rheum 2021;51(4):940–5. https://doi.org/10.1016/j.semarthrit.2021.05.006.

[7] Maksymowych WP, Chiowchanwisawakit P, Pedersen SJ, et al. Development and validation of web-based training modules for the systematic evaluation of active inflammatory lesions in the spine and sacroiliac joints in spondyloarthritis. J Rheumatol 2009;36(84):48–57. Suppl.

[8] Conaghan P, Bird P, Ejbjerg B, et al. The EULAR-OMERACT rheumatoid arthritis MRI reference image atlas: the metacarpophalangeal joints. Ann Rheum Dis 2005;64(1):i11–21. Suppl.

[9] Hadsbjerg A, Østergaard M, Paschke J, et al. Increasing the proficiency for scoring sacroiliac joint radiographs according to the modified New York criteria for ankylosing spondylitis by using an online real-time iterative calibration (RETIC) module (abstract). Arthritis Rheumatol 2022;74(S9):1986–8.

[10] Maksymowych WP, Hadsbjerg A, Østergaard M, et al. Validation of the SPARCC-RETIC E-tool for ensuring scoring proficiency of MRI lesions in axial spondyloarthritis (Abstract). Arthritis Rheumatol 2022;74(S9):2026–9.

[11] Maxwell LJ, Beaton DE, Boers M, et al. The evolution of instrument selection for inclusion in core outcome sets at OMERACT: filter 2.2. Semin Arthritis Rheum 2021;51(6):1320–30. https://doi.org/10.1016/j.semarthrit.2021.08.011.

[12] Boers M, Beaton DE, Shea BJ, et al. OMERACT filter 2.1: elaboration of the conceptual framework for outcome measurement in health intervention studies. J Rheumatol 2019;46(8):1021–7. https://doi.org/10.3899/jrheum.181096.

[13] D'Agostino MA, Beaton DE, Maxwell LJ, et al. Improving domain definition and outcome instrument selection: lessons learned for OMERACT from imaging. Semin Arthritis Rheum 2021;51(5):1125–33. https://doi.org/10.1016/j.semarthrit.2021.08.004.

[14] Krabbe S, Renson T, Jans L, et al. Performance of an MRI scoring system for inflammation of joints and entheses in peripheral SpA: post-hoc analysis of the CRESPA trial. Rheumatology (Oxford) 2023;62(6):2130–8. https://doi.org/10.1093/rheumatology/keac567.

[15] Weckbach S, Schewe S, Michaely HJ, Steffinger D, Reiser MF, Glaser C. Whole-body MR imaging in psoriatic arthritis: additional value for therapeutic decision making. Eur. J Radiol 2011;77(1):149–55. https://doi.org/10.1016/j.ejrad.2009.06.020. S0720-048X(09)00394-5 [pii][doi].

[16] Poggenborg RP, Pedersen SJ, Eshed I, et al. Head-to-toe whole-body MRI in psoriatic arthritis, axial spondyloarthritis and healthy subjects: first steps towards global inflammation and damage scores of peripheral and axial joints. Rheumatology (Oxford) 2015;54(6):1039–49. https://doi.org/10.1093/rheumatology/keu439. keu439 [pii][doi].

[17] Krabbe S, Eshed I, Sørensen IJ, et al. Whole-body magnetic resonance imaging inflammation in peripheral joints and entheses in axial spondyloarthritis: distribution and changes during adalimumab treatment. J Rheumatol 2020;47:50–9. https://doi.org/10.3899/jrheum.181159. jrheum.181159 [pii][doi].

[18] Østergaard M, Jen H, Jaremko JL, Lambert RGW. Imaging in Rheumatic Diseases. In: Firestein G, Budd RC, Gabriel SE, McInnes IB, O'Dell JR, editors. Kelley and Firestein's textbook of rheumatology. Philadelphia: Elsevier; 2020. p. 851–907.

[19] Sudol-Szopinska I, Jurik AG, Eshed I, et al. Recommendations of the ESSR Arthritis Subcommittee for the Use of Magnetic Resonance Imaging in Musculoskeletal Rheumatic Diseases. Semin Musculoskelet Radiol 2015;19(4):396–411. https://doi.org/10.1055/s-0035-1564696 [doi].

[20] Østergaard M, Conaghan PG, O'Connor P, et al. Reducing invasiveness, duration, and cost of magnetic resonance imaging in rheumatoid arthritis by omitting intravenous contrast injection – does it change the assessment of inflammatory and destructive joint changes by the OMERACT RAMRIS? J. Rheumatol 2009;36(8):1806–10. https://doi.org/10.3899/jrheum.090350. 36/8/1806 [pii][doi].