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Updating the OMERACT Filter: Implications for imaging and soluble biomarkers

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Abstract

Objective—The OMERACT Filter provides a framework for the validation of outcome measures for use in rheumatology clinical research. However, imaging and biochemical measures may face additional validation challenges due to their technical nature. The Imaging and Soluble Biomarker Session at OMERACT 11 aimed to provide a guide for the iterative development of an imaging or biochemical measurement instrument so it can be used in therapeutic assessment.

Methods—A hierarchical structure was proposed, reflecting 3 dimensions needed for validating an imaging or biochemical measurement instrument: outcome domain(s), study setting and performance of the instrument. Movement along the axes in any dimension reflects increasing validation. For a given test instrument, the 3-axis structure assesses the extent to which the instrument is a validated measure for the chosen domain, whether it assesses a patient or disease centred-variable, and whether its technical performance is adequate in the context of its application. Some currently used imaging and soluble biomarkers for rheumatoid arthritis, spondyloarthritis and knee osteoarthritis were then evaluated using the original OMERACT filter and the newly proposed structure. Break-out groups critically reviewed the extent to which the candidate biomarkers complied with the proposed step-wise approach, as a way of examining the utility of the proposed 3 dimensional structure.

Results—Although there was a broad acceptance of the value of the proposed structure in general, some areas for improvement were suggested including clarification of criteria for achieving a certain level of validation and how to deal with extension of the structure to areas beyond clinical trials.

Conclusion—General support was obtained for a proposed tri-axis structure to assess validation of imaging and soluble biomarkers; nevertheless, additional work is required to better evaluate its place within the OMERACT Filter 2.0.

Keywords

biomarkers; imaging; OMERACT filter; validation framework

Imaging and biochemical tests are amongst the most rapidly evolving fields within medicine (1-3). In the last 30 years, management of rheumatic diseases has been transformed by the rapid expansion of sophisticated new technologies offering a large range of options for identifying, monitoring and predicting pathological processes. Unfortunately many of these new measurement instruments have been disseminated into daily practice before being rigorously evaluated and have in some cases already been employed as endpoints in randomized clinical trials (RCTs) evaluating therapeutic interventions. The subsequent validation of imaging methods and biochemical tests may be difficult to achieve a priori, due to their already established utilization in clinical settings.

The Outcome Measures in Rheumatology (OMERACT) initiative has worked on validating tools for evaluating the effect of therapeutic interventions in rheumatic diseases since 1992 (4). Its main goal is to achieve consensus over what should be measured and how, especially for developing the most appropriate outcomes for use in RCTs. The process involves choosing a Core Domain Set to measure within a particular condition and in a particular clinical setting, and the application of the OMERACT Filter of truth, discrimination and feasibility to evaluate identified candidate instruments to measure these domains, which result in a validated Core Outcome Set (5). This framework, especially as further developed in preparation for the OMERACT 11 meeting (6) particularly addresses the importance of appropriate identification of the domains, subsequent selection of appropriate instruments, and the correct methodology for developing and validating the instruments for their purpose. However, imaging and biochemical measures may face additional validation challenges due to their technical nature. These challenges might be thought of as equivalent to the technical processes in the development of patient reported outcomes (PRO), as addressed in another session of the meeting (7).

For imaging and soluble biomarkers, there are important questions to address: 1) whether the measure relates to the suspected pathophysiological change (for example, whether erosions on x-rays of the hands identify the same process as lesions on MRI scans or if urinary biochemical measure relates directly to cartilage damage in knee OA); 2) whether the measure has an agreed and consistent procedure (for example, whether x-rays of the knees should always be taken with the patient standing); and 3) to what extent operator expertise is a pre-requisite (for example in the acquisition and interpretation of ultrasound images of synovitis).

At the OMERACT 11 meeting, the Imaging and Biomarker WorkStream presented a draft proposal in which aspects of technical and measurement validity could be expressed and validated as the same time. It was the Group's intention to provide a step-by-step guide for development of an imaging or biochemical measurement instrument such that it could then be used as an outcome in RCTs or as a useful tool for clinical practice (manuscript in preparation). This would serve a similar purpose to the clear statements now available on the technical requirements for developing patient reported outcomes. By considering the currently available evidence for the validity of various imaging and biochemical measures, it should be possible to identify their current level of achievement according to the original OMERACT filter requirements. In a plenary introduction, MA D'Agostino proposed a hierarchical structure, reflecting 3 dimensions needed for validating an imaging or biochemical measurement instrument: (a) outcome domain(s), (b) study setting, and (c) performance of the instrument. By using these three axes of evaluation, it should be clearly defined whether a given instrument is able to measure the domain of interest (for example, whether it is a measure of disease activity, of damage, of both, or of another aspect of the pathological process); whether it assesses a disease or patient centred-variable (for example, if it measures the activity of the disease at joint level or it is an expression of the disease activity at patient level); whether its technical performance is adequate, including its feasibility, and whether the instrument has reached the appropriate validation state relevant to the given purpose (for example whether can be used as a biomarker or as a patient outcome). The global validation level reached by the biological or imaging variable under

evaluation and its usefulness in respect to OMERACT purposes would thus be described by its position relative to all three axes.

During OMERACT 11, the ideas underlying the framework for validating imaging or biochemical instruments as outcome measures in therapeutic trials underwent preliminary consensus-based development. At the same time, some experts in the field of arthritis and imaging and soluble biomarker presented the current state of validation of a number of chosen instruments in a range of rheumatic diseases, in light of the original OMERACT filter and of the newly proposed structure.

Discussion groups

OMERACT 11 attendees were divided into disease-related sub-groups: rheumatoid arthritis (RA); spondyloarthritis (SpA); and knee osteoarthritis (OA). In each sub-group, the domain of measurement (disease activity, irreversible damage or both) and the technical performance and validation state of several currently available imaging or soluble biomarkers were presented by experts in the sub-group field (RA: D. van der Heide, M. Østergaard, and G. Schett; SpA: R. Landewé, W. Maksymowych, and E. Naredo; Knee OA: P. Conaghan, M. Dougados, and A. Iagnocco). The biomarkers varied between sub-groups as shown in Table 1. Following these presentations, each sub-group was divided into smaller discussion groups (about 20 participants each including two patient partners), and were then asked to consider the questions presented in Table 1, and in particular to consider how the biomarkers performed in relation to the emerging description of OMERACT Filter 2.0 (6) and the proposed new hierarchical structure. Each discussion group reported its main points to a plenary session of all participants.

Imaging and soluble biomarkers in rheumatoid arthritis

With respect to RA, participants agreed that structural damage depicted by X-rays fulfilled most aspects of former OMERACT filter of truth, discrimination and feasibility, (8,9) and it was recognized that semi-quantitative assessment of erosions and joint space narrowing were currently accepted as structural outcomes for RCTs (10,11). Erosions, bone edema and synovitis depicted by MRI have been shown to cover all aspects of truth (12-17), and the RA MRI score (RAMRIS) for erosions, bone edema and synovitis has also demonstrated responsiveness and discrimination (18-22). Although feasibility issues as accessibility, time, cost and patient compliance may cause limitations in clinical practice, MRI is acceptable for clinical trials. This is further supported by the fact that MRI has been used in an increasing number of RCTs and participants agreed that MRI provides valid outcomes (activity and severity/damage). However it was pointed out that further information is required from a randomized controlled trial setting in order to understand the relationship between MRI outcomes and subsequent radiographic progression. With respect to soluble biomarkers, CRP has been demonstrated to be sensitive to change and to fulfil most of the aspects of truth for therapeutic purposes, but has not been shown to always predict future disease severity (23-27). For the other proposed soluble biomarkers in RA few data are available and will require further validation (28-40).

Imaging and soluble biomarkers in spondyloarthritis

Until recently, imaging and soluble biomarkers have focused on their relationship to radiographic structural change in SpA (41,42). In the breakout groups, there was consensus that there was also an unmet need for validated biomarkers reflecting inflammation in SpA, with the crucial caveat that while validation of a damage biomarker measured by radiography has face validity and feasibility, there is currently still discussion on a feasible imaging or biochemical biomarker measure for the target domain of inflammation. Certain data suggest the utility of MRI for this purpose. MRI of the spine and sacroiliac joints (SIJ) using bone marrow edema (BME) as an inflammatory variable has been assessed using the former OMERACT filter and two instruments prioritized for scoring BME in the spine, the SPARCC and Berlin spinal inflammation scores (43-48) as useful tools for evaluating inflammation. Validation was undertaken principally from the perspective of feasibility and discrimination but not completely for truth. There was agreement in the breakout groups that MRI represented the best currently available imaging measure for the target domain of inflammation, despite limited longitudinal data between inflammation at baseline and changes after institution of TNF blocker therapies (49-52). No soluble biomarker for inflammation in SpA was considered to have met the requirements of the OMERACT filter, and therefore, for being used as an outcome measure (53). Unlike RA, CRP and ESR are increased in only half of patients with active disease (52), and therefore are not broadly applicable measures of inflammatory activity. An increasing number of soluble biomarkers have been analyzed for their potential association with radiographic progression in SpA (MMP3, DKK-1, sclerostin, etc), for example MMP3 is significantly associated with this endpoint and it is now under further evaluation (54-58). Among imaging techniques, ultrasound was considered an interesting candidate for assessing SpA enthesitis as a marker of inflammatory activity both at site specific (entheses) and patient levels (59-63).

Imaging and soluble biomarkers in knee osteoarthritis

As OA may have joint-specific issues, participants agreed that limiting the discussion to knee OA, where there are the most data, was appropriate. In terms of RCTs, joint space narrowing on conventional radiography (JSN) has been demonstrated to fulfil validity requirements, although the relationship between symptoms and structural damage measures is complex (64-66). The ability to identify patients who may subsequently benefit from joint replacement is difficult to determine due to several contributory factors including that the decision to undertake surgery, despite clinical symptoms, is determined by multiple issues such as health care access, individual surgeon and patient factors (including comorbidities). An OMERACT/OARSI working group has proposed criteria for a “virtual” joint replacement outcome given these factors (67-68). Previous OMERACT recommendations have included plain radiographs as outcome measure in a core set for structural modification in OA (69-70). There has been considerable growth in the use of MRI and ultrasound in this field, with much emerging data (71-75). The ability to measure multiple tissue pathologies has highlighted that structure modification studies may focus on only one tissue of interest. MRI cartilage morphometry is the most studied outcome and has demonstrated evidence (summarised in recent reviews) to fulfil the requirements of the OMERACT Filter, although

some feasibility issues remain (73-75). Data are accumulating on measures of other tissue pathologies.

Broader understanding stimulated by the discussions

There was widespread recognition among the groups that many imaging and soluble biomarkers have been widely introduced into clinical practice and used in interventional therapeutic trials without an adequate evaluation of their performance. Although access to healthcare and technology varies considerably, the presentation of the proposed three axes of evaluation provided participants with a structure to think about the place of imaging and other soluble biomarkers in the broader healthcare setting, beyond the OMERACT traditional focus on RCTs. There was strong agreement that a checklist (or standardized framework) would be very helpful for imaging and soluble biomarker development and validation. This standardized approach has already been used in other fields (79). There is also potential for linking imaging and biomarkers with patient reported outcomes (PROs). OMERACT has already started to work towards criteria for validation of soluble biomarkers and surrogates in general (76-78). The new tridimensional structure incorporates previous work and extends the concept of development also to imaging biomarker. This could provide an appropriate reference standard to make measure development issues clearer (fixing an objective and a research agenda), but it may not be feasible for all candidate instruments/biomarkers, as it may be difficult to achieve all levels of validation in particular circumstances. However the early recognition that a specific biomarker would never achieve validation at some critical levels may prevent unnecessary efforts toward further validation. It was also discussed that fulfillment of the OMERACT Filter 2.0 would be a prerequisite for justifiable use of biomarkers in routine clinical interventional trials, but in circumstances where many are already in widespread use, participants favored the explicit development of the requirements as presented but incorporating some modifications and clarifications.

Summary and conclusions

While the three disease-related sub-groups each brought to light specific points related to their particular areas of evaluation (Table 1), two common issues related to the proposed axes of evaluation emerged. The first was the need for clarity on the notion of a hierarchical structure to these axes. Would it be possible to satisfy performance criteria on one or more axes without being able to do soon others? The second was whether the use of an outcome measure already applied in clinical practice for diagnosis or prognosis might be justifiable also for therapeutic interventional trials even if that measure has not been shown to meet the OMERACT Filter for use in RCTs and long term observational studies.

The OMERACT 11 meeting examined the proposed Filter 2.0 framework of Core Areas, Core Domains and Contextual Factors, which had already been subject to discussion and development before the meeting. At the same time, the meeting provided a focus for updating each aspect of the Filter (truth, discrimination and feasibility) and the application of the former and the new Filter in terms of imaging and soluble biomarkers in this session. There was broad recognition that many imaging and biomarkers widely performed in clinical practice were used for evaluating therapeutic interventional trials without having

been adequately validated. It would be worth working to more clearly state their use (i.e. whether an imaging or biomarker instrument measures disease activity, irreversible damage or both); whether its technical performance is adequate, and its level of validation including its feasibility. Such a standardised approach will need to be clarified and addressed further within Filter 2.0.

References

1. Thornbury JR, Eugene W. Caldwell Lecture. Clinical efficacy of diagnostic imaging: love it or leave it. *AJR Am J Roentgenol.* 1994; 162(1):1–8. [PubMed: 8273645]
2. Lassere MN. Imaging: the need for standardization. *Best Pract Res Clin Rheumatol.* 2008; 22(6): 1001–18. [PubMed: 19041074]
3. Fineberg HV, Bauman R, Sosman M. Computerized cranial tomography. Effect on diagnostic and therapeutic plans. *JAMA.* 1977; 238(3):224–7. [PubMed: 406427]
4. Boers M, Brooks P, Strand V, Tugwell P. The OMERACT Filter for outcome measures in rheumatology. *J Rheumatol.* 1998; 25:198–9. [PubMed: 9489805]
5. Boers M, Kirwan JR, Wells G, et al. A Framework and Process to Develop Core Outcome Sets: OMERACT Filter 2.0. In preparation.
6. Boers, Maarten; Idzerda, Leanne; Kirwan, John; Beaton, Dorcas; Escorpizo, Reuben; Boonen, Annelies; Magasi, Susan; Sinha, Ian; Stucki, Gerold; Tugwell, Peter. Towards a generalized framework of core measurement areas in clinical trials: A position paper for OMERACT 11. *J Rheumatol.* :XXX.
7. Kirwan, John Richard; Bartlett, Susan J.; Beaton, Dorcas; Boers, Maarten; Bosworth, Ailsa; Brooks, Peter M.; Choy, Ernest; de Wit, Maarten; Guillemin, Francis; Hewlett, Sarah; Kvien, Tore K.; Landewé, Robert BM.; Leong, Amye; Lyddiatt, Anne; March, Lyn; May, James; Montie, Pamela Lesley; Nikai, Enkeleida; Richards, Pam; Voshaar, Marieke MJH.; Smeets, Wilma; Strand, Vibeke; Tugwell, Peter; Gossec, Laure. Updating the OMERACT Filter: Implications for patient reported outcomes. *J Rheumatol.* :XXX.
8. van der Heijde D. Quantification of radiological damage in inflammatory arthritis: rheumatoid arthritis, psoriatic arthritis and ankylosing spondylitis. *Best Pract Res Clin Rheumatol.* 2004; 18(6): 847–860. [PubMed: 15501186]
9. Bruynesteyn K, van der Heijde D, Boers M, van der Linden S, Lassere M, van der Vleuten C. The Sharp/van der Heijde method out-performed the Larsen/Scott method on the individual patient level in assessing radiographs in early rheumatoid arthritis. *J Clin Epidemiol.* 2004; 57(5):502–12. [PubMed: 15196621]
10. Bruynesteyn K, Landewé R, van der Linden S, van der Heijde D. Radiography as primary outcome in rheumatoid arthritis: acceptable sample sizes for trials with 3 months' follow-up. *Ann Rheum Dis.* 2004; 63(11):1413–1418. [PubMed: 15037445]
11. Bruynesteyn K, van der Heijde D, Boers M, Saudan A, Peloso P, Paulus H, Houben H, Griffiths B, Edmonds J, Bresnihan B, Boonen A, van der Linden S. Detecting radiological changes in rheumatoid arthritis that are considered important by clinical experts: Influence of reading with or without known sequence. *J Rheumatol.* 2002; 29(11):2306–12. [PubMed: 12415585]
12. Østergaard M, Peterfy C, Conaghan P, McQueen F, Bird P, Ejbjerg B, et al. OMERACT Rheumatoid Arthritis Magnetic Resonance Imaging Studies. Core set of MRI acquisitions, joint pathology definitions, and the OMERACT RA-MRI scoring system. *J Rheumatol.* 2003; 30(6): 1385–6. [PubMed: 12784422]
13. Haavardsholm EA, Østergaard M, Ejbjerg BJ, Kvan NP, Uhlig TA, Lilleas FG, et al. Reliability and sensitivity to change of the OMERACT rheumatoid arthritis magnetic resonance imaging score in a multireader, longitudinal setting. *Arthritis Rheum.* 2005; 52(12):3860–7. [PubMed: 16320333]
14. Hetland ML, Ejbjerg B, Horslev-Petersen K, Jacobsen S, Vestergaard A, Jurik AG, et al. MRI bone oedema is the strongest predictor of subsequent radiographic progression in early rheumatoid

- arthritis. Results from a 2-year randomised controlled trial (CIMESTRA). *Ann Rheum Dis.* 2009; 68(3):384–90. [PubMed: 18388160]
15. Jimenez-Boj E, Nobauer-Huhmann I, Hanslik-Schnabel B, Dorotka R, Wanivenhaus AH, Kainberger F, et al. Bone erosions and bone marrow edema as defined by magnetic resonance imaging reflect true bone marrow inflammation in rheumatoid arthritis. *Arthritis Rheum.* 2007; 56(4):1118–24. [PubMed: 17393390]
 16. McQueen FM, Gao A, Østergaard M, King A, Shalley G, Robinson E, et al. High-grade MRI bone oedema is common within the surgical field in rheumatoid arthritis patients undergoing joint replacement and is associated with osteitis in subchondral bone. *Ann Rheum Dis.* 2007; 66(12): 1581–7. [PubMed: 17491098]
 17. Døhn UM, Ejbjerg BJ, Court-Payen, Hasselquist M, Narvestad E, Szkudlarek M, et al. Are bone erosions detected by magnetic resonance imaging and ultrasonography true erosions? A comparison with computed tomography in rheumatoid arthritis metacarpophalangeal joints. *Arthritis Res Ther.* 2006; 8(4):R110. [PubMed: 16848914]
 18. Haavardsholm EA, Østergaard M, Hammer HB, Boyesen P, Boonen A, van der Heijde D, et al. Monitoring anti-TNFalpha treatment in rheumatoid arthritis: responsiveness of magnetic resonance imaging and ultrasonography of the dominant wrist joint compared with conventional measures of disease activity and structural damage. *Ann Rheum Dis.* 2009; 68(10):1572–9. [PubMed: 19019893]
 19. Conaghan PG, Emery P, Østergaard M, Keystone EC, Genovese MC, Hsia EC, et al. Assessment by MRI of inflammation and damage in rheumatoid arthritis patients with methotrexate inadequate response receiving golimumab: results of the GO-FORWARD trial. *Ann Rheum Dis.* 2011; 70(11):1968–74. [PubMed: 21784729]
 20. Østergaard M, Emery P, Conaghan PG, Fleischmann R, Hsia EC, Xu W, et al. Significant improvement in synovitis, osteitis, and bone erosion following golimumab and methotrexate combination therapy as compared with methotrexate alone: A magnetic resonance imaging study of 318 methotrexate-naive rheumatoid arthritis patients. *Arthritis Rheum.* 2011; 63(12):3712–22. [PubMed: 22127693]
 21. Conaghan PG, Durez P, Alten RE, Burmester GR, Tak PP, Klareskog L, et al. Impact of intravenous abatacept on synovitis, osteitis and structural damage in patients with rheumatoid arthritis and an inadequate response to methotrexate: the ASSET randomised controlled trial. *Ann Rheum Dis.* 2013; 72:1287–94. [PubMed: 22915624]
 22. Peterfy C, Emery P, Tak PP, Østergaard M, DiCarlo J, Otsa K, et al. Rituximab (RTX) plus methotrexate (MTX) prevents bone erosion and joint-space narrowing (JSN) and reduces synovitis, osteitis as shown on MRI: results from a randomized placebo controlled trial in patients with rheumatoid arthritis (RA-SCORE). *Ann Rheum Dis.* 2011; 70(Suppl 3):152.
 23. Kaptoge S, Di Angelantonio E, Lowe G, Pepys MB, Thompson SG, Collins R, Danesh J. Emerging Risk Factors Collaboration. C-reactive protein concentration and risk of coronary heart disease, stroke, and mortality: an individual participant meta-analysis. *Lancet.* 2010 Jan.375:132–40. [PubMed: 20031199]
 24. Möttönen T, Paimela L, Leirisalo-Repo M, Kautiainen H, Ilonen J, Hannonen P. Only high disease activity and positive rheumatoid factor indicate poor prognosis in patients with early rheumatoid arthritis treated with “sawtooth” strategy. *Ann Rheum Dis.* 1998; 57:533–9. [PubMed: 9849312]
 25. Plant MJ, Williams AL, O'Sullivan MM, Lewis PA, Coles EC, Jessop JD. Relationship between time-integrated C-reactive protein levels and radiologic progression in patients with rheumatoid arthritis. *Arthritis Rheum.* 2000; 43:1473–7. [PubMed: 10902748]
 26. van Leeuwen MA, van Rijswijk MH, van der Heijde DM, Te Meerman GJ, van Riel PL, Houtman PM, van De Putte LB, Limburg PC. The acute-phase response in relation to radiographic progression in early rheumatoid arthritis: a prospective study during the first three years of the disease. *Br J Rheumatol.* 1993; 32(Suppl 3):9–13. [PubMed: 8508266]
 27. van Leeuwen MA, van Rijswijk MH, Sluiter WJ, van Riel PL, Kuper IH, van de Putte LB, Pepys MB, Limburg PC. Individual relationship between progression of radiological damage and the acute phase response in early rheumatoid arthritis. Towards development of a decision support system. *J Rheumatol.* 1997; 24:20–7. [PubMed: 9002006]

28. Visser K, Goekoop-Ruiterman YP, de Vries-Bouwstra JK, Roday HK, Seys PE, Kerstens PJ, Huizinga TW, Dijkmans BA, Allaart CF. A matrix risk model for the prediction of rapid radiographic progression in patients with rheumatoid arthritis receiving different dynamic treatment strategies: post hoc analyses from the BeSt study. *Ann Rheum Dis.* 2010; 69:1333–7. [PubMed: 20498212]
29. Machold KP, Stamm TA, Nell VP, Pflugbeil S, Aletaha D, Steiner G, Uffmann M, Smolen JS. Very recent onset rheumatoid arthritis: clinical and serological patient characteristics associated with radiographic progression over the first years of disease. *Rheumatology (Oxford).* 2007; 46:342–9. [PubMed: 16899498]
30. Buyse M, Sargent DJ, Grothey A, Matheson A, de Gramont A. Biomarkers and surrogate end points--the challenge of statistical validation. *Nat Rev Clin Oncol.* 2010; 7:309–17. [PubMed: 20368727]
31. Rönnelid J, Wick MC, Lampa J, Lindblad S, Nordmark B, Klareskog L, van Vollenhoven RF. Longitudinal analysis of citrullinated protein/peptide antibodies (anti-CP) during 5 year follow up in early rheumatoid arthritis: anti-CP status predicts worse disease activity and greater radiological progression. *Ann Rheum Dis.* 2005; 64:1744–9. [PubMed: 15843452]
32. Kastbom A, Strandberg G, Lindroos A, Skogh T. Anti-CCP antibody test predicts the disease course during 3 years in early rheumatoid arthritis (the Swedish TIRA project). *Ann Rheum Dis.* 2004; 63:1085–9. [PubMed: 15308517]
33. Forslind K, Ahlmén M, Eberhardt K, Hafström I, Svensson B. BARFOT Study Group. Prediction of radiological outcome in early rheumatoid arthritis in clinical practice: role of antibodies to citrullinated peptides (anti-CCP). *Ann Rheum Dis.* 2004; 63:1090–5. [PubMed: 15308518]
34. Hammer HB, Ødegård S, Syversen SW, Landewé R, van der Heijde D, Uhlig T, Mowinckel P, Kvien TK. Calprotectin (a major S100 leucocyte protein) predicts 10-year radiographic progression in patients with rheumatoid arthritis. *Ann Rheum Dis.* 2010; 69:150–4. [PubMed: 19095696]
35. Posthumus MD, Limburg PC, Westra J, van Leeuwen MA, van Rijswijk MH. Serum matrix metalloproteinase 3 in early rheumatoid arthritis is correlated with disease activity and radiological progression. *J Rheumatol.* 2000; 27:2761–8. [PubMed: 11128661]
36. Garnero P, Landewé R, Boers M, Verhoeven A, Van Der Linden S, Christgau, Van Der Heijde D, Boonen A, Geusens P. Association of baseline levels of markers of bone and cartilage degradation with long-term progression of joint damage in patients with early rheumatoid arthritis: the COBRA study. *Arthritis Rheum.* 2002; 46:2847–56. [PubMed: 12428224]
37. Landewé R, Geusens P, Boers M, van der Heijde D, Lems W, teKoppele J, van der Linden S, Garnero P. Markers for type II collagen breakdown predict the effect of disease-modifying treatment on long-term radiographic progression in patients with rheumatoid arthritis. *Arthritis Rheum.* 2004; 50:1390–9. [PubMed: 15146408]
38. Geusens PP, Landewé RB, Garnero P, Chen D, Dunstan CR, Lems WF, Stinissen P, van der Heijde DM, van der Linden S, Boers M. The ratio of circulating osteoprotegerin to RANKL in early rheumatoid arthritis predicts later joint destruction. *Arthritis Rheum.* 2006; 54:1772–7. [PubMed: 16736519]
39. Charni N, Juillet F, Garnero P. Urinary type II collagen helical peptide (HELIX-II) as a new biochemical marker of cartilage degradation in patients with osteoarthritis and rheumatoid arthritis. *Arthritis Rheum.* 2005; 52:1081–90. [PubMed: 15818703]
40. Sharif M, Salisbury C, Taylor D, Kirwan JR. Changes in biochemical markers of joint tissue metabolism in a randomised controlled trial of glucocorticoids in early rheumatoid arthritis. *Arthritis and Rheumatism.* 1998; 41:1203–9. [PubMed: 9663476]
41. Maksymowych WP. MRI and X-ray in axial spondyloarthritis: the relationship between inflammatory and structural changes. *Arthritis Res Ther.* 2012; 14:207. [PubMed: 22524305]
42. Wanders AJ, Landewe RB, Spoorenberg A, et al. What is the most appropriate radiologic scoring method for ankylosing spondylitis? A comparison of the available methods based on the Outcome Measures in Rheumatology Clinical Trials filter. *Arthritis Rheum.* 2004; 50:2622–32. [PubMed: 15334477]

43. Gong Y, Zheng N, Chen SB, Xiao ZY, Wu MY, Liu Y, Zeng QY. Ten Years Experience on Needle Biopsy in the Early Diagnosis of Sacroiliitis. *Arthritis Rheum.* 2012; 64:1399–1406. [PubMed: 22076932]
44. Maksymowych WP, Inman RD, Salonen D, et al. Spondyloarthritis Research Consortium of Canada magnetic resonance imaging index for assessment of sacroiliac joint inflammation in ankylosing spondylitis. *Arthritis Rheum.* 2005; 53:703–709. [PubMed: 16208659]
45. Landewe RB, Hermann KG, van der Heijde DM, et al. Scoring sacroiliac joints by magnetic resonance imaging: a multiple-reader reliability experiment. *J Rheumatol.* 2005; 32:2050–2055. [PubMed: 16206369]
46. Maksymowych WP, Dhillon SS, Park R, et al. Validation of the Spondyloarthritis Research Consortium of Canada (SPARCC) MRI spinal inflammation index: is it necessary to score the entire spine? *Arthritis Rheum.* 2007; 57:501–507. [PubMed: 17394179]
47. Lukas C, Braun J, van der Heijde D, et al. ASAS/OMERACT MRI in AS Working Group. Scoring inflammatory activity of the spine by magnetic resonance imaging in ankylosing spondylitis: a multireader experiment. *J Rheumatol.* 2007; 34:862–870. [PubMed: 17407241]
48. van der Heijde D, Landewe R, Hermann KG, et al. ASAS/OMERACT MRI in AS Working Group. Is there a preferred method for scoring activity of the spine by magnetic resonance imaging in ankylosing spondylitis? *J Rheumatol.* 2007; 34:871–873. [PubMed: 17407242]
49. Braun J, Baraliakos X, Golder W, et al. Magnetic resonance imaging examinations of the spine in patients with ankylosing spondylitis, before and after successful therapy with infliximab: evaluation of a new scoring system. *Arthritis Rheum.* 2003; 48:1126–1136. [PubMed: 12687557]
50. Lambert RGW, Salonen D, Rahman P, Inman RD, Wong RL, Einstein SG, Thomson GTD, Beaulieu A, Choquette D, Maksymowych WP. Adalimumab significantly reduces both spinal and sacroiliac joint inflammation in patients with ankylosing spondylitis. *Arthritis Rheum.* 2007; 56:4005–14. [PubMed: 18050198]
51. Braun J, Baraliakos X, Hermann KG, van der Heijde D, Inman RD, Deodhar AA, Baratelle A, Xu S, Xu W, Hsu B. Golimumab reduces spinal inflammation in ankylosing spondylitis: MRI results of the randomised, placebo- controlled GO-RAISE study. *Ann Rheum Dis.* 2012; 71:878–84. [PubMed: 22128083]
52. Visvanathan S, Wagner C, Marini JC, et al. Inflammatory biomarkers, disease activity and spinal disease measures in patients with ankylosing spondylitis after treatment with infliximab. *Ann Rheum Dis.* 2008; 67:511–7. [PubMed: 17644552]
53. Maksymowych WP. Biomarkers in spondyloarthritis: From pathophysiology to disease assessment. *Joint Bone Spine.* 2012; 79:4–6. [PubMed: 22119346]
54. Maksymowych WP, Landewé R, Conner-Spady B, et al. Serum matrix metalloproteinase 3 is an independent predictor of structural damage progression in patients with ankylosing spondylitis. *Arthritis Rheum.* 2007; 56:1846–53. [PubMed: 17530713]
55. Appel H, Ruiz-Heiland G, Listing J, et al. Altered skeletal expression of sclerostin and its link to radiographic progression in ankylosing spondylitis. *Arthritis Rheum.* 2009; 60:3257–3262. [PubMed: 19877044]
56. Heiland GR, Appel H, Poddubnyy D, Zwerina J, Hueber A, Haibel H, Baraliakos X, Listing J, Rudwaleit M, Schett G, Sieper J. High level of functional dickkopf-1, predicts protection from syndesmophyte formation in patients with ankylosing spondylitis. *Ann Rheum Dis.* 2012; 71:572–4. Epub 2011 Dec 20. [PubMed: 22186710]
57. Park MC, Park YB, Lee SK. Relationship of bone morphogenetic proteins to disease activity and radiographic damage in patients with ankylosing spondylitis. *Scand J Rheumatol.* 2008; 37:200–204. [PubMed: 18465455]
58. Sieper J, Appel H, Rudwaleit M, et al. Inverse correlation between serum levels of dickkopf 1 (DKK1) and new bone formation in ankylosing spondylitis patients. *Ann Rheum Dis.* 2010; 69(Suppl 3):442. abstract.
59. Gandjbakhch F, Terslev L, Joshua F, Wakefield RJ, Naredo E, D'Agostino MA. OMERACT Ultrasound Task Force. Ultrasound in the evaluation of enthesitis: status and perspectives. *Arthritis Res Ther.* 2011; 13:R188. Epub 2011 Nov 17. [PubMed: 22093457]

60. Naredo E, Wakefield RJ, Iagnocco A, Terslev L, Filippucci E, Gandjbakhch F, Aegerter P, Aydin S, Backhaus M, Balint PV, Bruyn GA, Collado P, Finzel S, Freeston JE, Gutierrez M, Joshua F, Jousse-Joulin S, Kane D, Keen HI, Moller I, Mandl P, Ohrndorf S, Pineda C, Schmidt WA, Szkudlarek M, Conaghan PG, D'Agostino MA. The OMERACT ultrasound task force--status and perspectives. *J Rheumatol.* 2011; 38:2063–7. [PubMed: 21885518]
61. Naredo E, Batlle-Gualda E, García-Vivar ML, García-Aparicio AM, Fernández-Sueiro JL, Fernández-Prada M, Giner E, Rodriguez-Gomez M, Pina MF, Medina-Luezas JA, Toyos FJ, Campos C, Gutiérrez-Polo R, Ferrer MA, Martínez O, Díaz-Torne C, Gonzalez T, Campos S, Queiro R, Castaño-Sánchez M, Aznar JJ, Bustabad S, Paez-Camino M, Tuneu R, Ruiz T, Mateo L, Pujol M, Ponce A, Ros I, Gallegos A, Moreno J, Gumbau D, Sianes M, Poveda-Elices MJ, Romero-Gómez M, Raya E. Ultrasound Group of the Spanish Society of Rheumatology. Power Doppler ultrasonography assessment of entheses in spondyloarthropathies: response to therapy of enthesal abnormalities. *J Rheumatol.* 2010; 37:2110–7. Epub 2010 Sep 1. [PubMed: 20810495]
62. D'Agostino, MA.; Conaghan, PG.; Naredo, E.; Aegerter, P.; Iagnocco, A.; Freeston, JE.; Filippucci, E.; Moller, I.; Pineda, C.; Joshua, F.; Backhaus, M.; Keen, HI.; Kaeley, G.; Ziswiler, HR.; Schmidt, WA.; Balint, PV.; Bruyn, GA.; Jousse-Joulin, S.; Kane, D.; Moller, I.; Szkudlarek, M.; Terslev, L.; Wakefield, RJ. *J Rheumatol.* Vol. 36. Zisweiler, Hans-Rudolf; 2009. The OMERACT ultrasound task force -Advances and priorities; p. 1829-32. Erratum in: *J Rheumatol.* 2009 Nov;36(11):2625. [corrected to Ziswiler, Hans-Rudolf]
63. D'Agostino MA, Aegerter P, Jousse-Joulin S, Chary-Valckenaere I, Lecoq B, Gaudin P, Brault I, Schmitz J, Dehaut FX, Le Parc JM, Breban M, Landais P. How to evaluate and improve the reliability of power Doppler ultrasonography for assessing enthesitis in spondylarthritis. *Arthritis Rheum.* 2009; 61:61–9. [PubMed: 19116967]
64. Reichmann WM, Maillefert JF, Hunter DJ, et al. Responsiveness to change and reliability of measurement of radiographic joint space width in osteoarthritis of the knee: A systematic review. *Osteoarthritis Cartilage.* 2011; 19:550–6. [PubMed: 21396469]
65. Conaghan PG, Hunter DJ, Maillefert JF, et al. Summary and Recommendations of the OARSI FDA Osteoarthritis Assessment of Structural Change Working Group. *Osteoarthritis Cartilage.* 2011; 19:606–10. [PubMed: 21396466]
66. Bellamy N, Kirwan J, Boers M, et al. Recommendations for a core set of outcome measures for future phase III clinical trials in knee, hip, and hand osteoarthritis. Consensus development at OMERACT III. *J Rheumatol.* 1997; 24:799–802. [PubMed: 9101522]
67. Manno RL, Bingham CO 3rd, Paternotte S, Gossec L, Halhol H, Giacobelli G, Rovati L, Mazzuca SA, Clegg DO, Shi H, Tajana Messi E, Lanzarotti A, Dougados M. OARSI-OMERACT initiative: defining thresholds for symptomatic severity and structural changes in disease modifying osteoarthritis drug (DMOAD) clinical trials. *Osteoarthritis Cartilage.* 2012; 20:93–101. Epub 2011 Nov 28. 10.1016/j.joca.2011.11.013 [PubMed: 22178465]
68. Gossec L, Paternotte S, Bingham CO 3rd, Clegg DO, Coste P, Conaghan PG, Davis AM, Giacobelli G, Gunther KP, Hawker G, Hochberg MC, Jordan JM, Katz JN, Kloppenburg M, Lanzarotti A, Lim K, Lohmander LS, Mahomed NN, Maillefert JF, Manno RL, March LM, Mazzuca SA, Pavelka K, Punzi L, Roos EM, Rovati LC, Shi H, Singh JA, Suarez-Almazor ME, Tajana-Messi E, Dougados M. OARSI-OMERACT Task Force Total Articular Replacement as Outcome Measure in OA. OARSI/OMERACT initiative to define states of severity and indication for joint replacement in hip and knee osteoarthritis. An OMERACT 10 Special Interest Group. *J Rheumatol.* 2011; 38:1765–9. 10.3899/jrheum.110403 [PubMed: 21807799]
69. Iagnocco A, Perricone C, Scirocco C, Ceccarelli F, Modesti M, Gattamelata A, Vavala C, Rutigliano IM, Musetescu A, Valesini G. The interobserver reliability of ultrasound in knee osteoarthritis. *Rheumatology (Oxford).* 2012; 51:2013–9. Epub 2012 Jul 27. 10.1093/rheumatology/kes161 [PubMed: 22843774]
70. Keen HI, Mease PJ, Bingham CO 3rd, Giles JT, Kaeley G, Conaghan PG. Systematic review of MRI, ultrasound, and scintigraphy as outcome measures for structural pathology in interventional therapeutic studies of knee arthritis: focus on responsiveness. *J Rheumatol.* 2011; 38:142–54. Epub 2010 Oct 1. [PubMed: 20889598]
71. Conaghan PG, D'Agostino MA, Le Bars M, Baron G, Schmidely N, Wakefield R, Ravaud P, Grassi W, Martin-Mola E, So A, Backhaus M, Malaise M, Emery P, Dougados M. Clinical and

- ultrasonographic predictors of joint replacement for knee osteoarthritis: results from a large, 3-year, prospective EULAR study. *Ann Rheum Dis.* 2010; 69:644–7. Epub 2009 May 10. [PubMed: 19433410]
72. D'Agostino MA, Conaghan P, Le Bars M, Baron G, Grassi W, Martin-Mola E, Wakefield R, Brasseur JL, So A, Backhaus M, Malaise M, Burmester G, Schmidely N, Ravaud P, Dougados M, Emery P. EULAR report on the use of ultrasonography in painful knee osteoarthritis. Part 1: prevalence of inflammation in osteoarthritis. *Ann Rheum Dis.* 2005; 64:1703–9. Epub 2005 May 5. [PubMed: 15878903]
73. Conaghan P, D'Agostino MA, Ravaud P, Baron G, Le Bars M, Grassi W, Martin-Mola E, Wakefield R, Brasseur JL, So A, Backhaus M, Malaise M, Burmester G, Schmidely N, Emery P, Dougados M. EULAR report on the use of ultrasonography in painful knee osteoarthritis. Part 2: exploring decision rules for clinical utility. *Ann Rheum Dis.* 2005; 64:1710–4. Epub 2005 May 5. [PubMed: 15878902]
74. Hunter DJ, Zhang W, Conaghan PG, et al. Systematic review of the concurrent and predictive validity of MRI biomarkers in OA. *Osteoarthritis Cartilage.* 2011; 19:557–88. [PubMed: 21396463]
75. Hunter DJ, Zhang W, Conaghan PG, et al. Responsiveness and reliability of MRI in knee osteoarthritis: a meta-analysis of published evidence. *Osteoarthritis Cartilage.* 2011; 19:589–605. [PubMed: 21396465]
76. Lassere MN, Johnson KR, Boers M, Tugwell P, Brooks P, Simon L, Strand V, Conaghan P, Østergaard M, Maksymowych WP, Landewé R, Bresnihan B, Tak PP, Wakefield R, Grassi W, Mease P, Bingham CO III, Hughes M, Altman D, Buyse M, Galbraith S, Wells G. Definitions and validation criteria for biomarkers and surrogate endpoints: development and testing of a quantitative hierarchical levels of evidence schema. *J Rheumatol.* 2007; 34:670–15.
77. Maksymowych WP, Landewe R, Tak PP, Ritchlin CJ, Ostergaard M, Mease PJ, Gabalawy HE, Garnero P, Gladman DD, Fitzgerald O, Aletaha D, Bykerk VP, Bathon JM, Syversen SW, Boers M, Geusens P, Inman RD, Kraus VB, Kvien TK, Taylor WJ, Wells GA, van der Heijde D. Reappraisal of OMERACT 8 draft validation criteria for a soluble biomarker reflecting structural damage endpoints in rheumatoid arthritis, psoriatic arthritis, and spondyloarthritis: The OMERACT 9 v2 criteria. *J Rheumatol.* 2009; 36:1785–91. [PubMed: 19671813]
78. Maksymowych WP, Fitzgerald O, Wells GA, Gladman DD, Landewe R, Ostergaard M, Taylor WJ, Christensen R, Tak PP, Boers M, Wyversen SW, Bathon JM, Ritchlin CJ, Mease PJ, Bykerk VP, Garnero P, Geusens P, Gabalawy HE, Aletaha D, Inman RD, Kraus VB, Kvien TK, van der Heijde D. Proposal for levels of evidence schema for validation of a soluble biomarker reflecting damage endpoints in rheumatoid arthritis, psoriatic arthritis, and ankylosing spondylitis, and recommendations for study design. *J Rheumatol.* 2009; 36:1792–9. [PubMed: 19671814]
79. Mokkink LB, Terwee CB, Patrick DL, Alonso J, Stratford PW, Knol DL, Bouter LM, de Vet HC. The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: an international Delphi study. *Qual Life Res.* 2010 May; 19(4):539–49. [PubMed: 20169472]

Table 1
Summary of three disease-groups presentation: Rheumatoid Arthritis, Spondylarthritis and Knee Osteoarthritis

Disease-group	Measurement instrument	Unit of measurement	What are the outcome domains currently covered by the instrument?	Validation reached	Is the chosen instrument/measure validated enough for being considered in a core set of outcomes?
RA	X rays	Joint (hands and feet)	Structural damage (erosion, joint space narrowing)	Most of the scoring methods of erosions and joint space narrowing have been demonstrated to fulfill all aspects of validity. Can be considered as patient outcome in randomized controlled trials (RCTs), observational studies and in clinical care.	Erosion/JSN as combined scoring system has been measured in many RCTs and has been considered critical for both evaluating efficacy and guiding evaluation and treatment. It has been demonstrated to be a good prognostic outcome of severity and mortality as well as it has been used as surrogate for patient outcome in observational studies. Therefore it is used also in the context of patient outcome in usual clinical care.
MRI		Joint (hand)	Disease activity (synovitis, osteitis)	The RAMRIS scoring method for synovitis/osteitis has been demonstrated to fulfill face, construct and some aspects of discrimination validity, and also to be predictive of future radiographic damage. Feasibility was suggested by its use in multiple large RCTs.	Synovitis/osteitis good candidate outcome measures: prognostication+++ sensitivity to change+++
			Structural damage (erosion, joint space narrowing (JSN)).	The RAMRIS scoring method for erosions has been demonstrated to fulfill face, construct and some aspects of discrimination validity. These data support further evaluation of erosion as candidate outcome measure (surrogate of X rays structural damage) for future trials The RAMRIS scoring method for JSN has been demonstrated to fulfill face and construct validity. These data support further evaluation of JSN as candidate outcome measure for future trials	Erosion: Good Possible candidate for severity and damage JSN: Possible candidate for severity and damage
Soluble biomarkers		Patient (blood)	Disease activity Damage/severity (ACPA, collagen I and II cleavage products, matrix metalloproteinase 3, calprotectin and receptor agonist of nuclear factor B ligand)	CRP has been demonstrated to fulfill all aspects of validity but some aspects of discrimination remain a problem. It is also considered a good indicator for future severity and mortality. Some biomarkers are clearly related to structural radiographic progression and severity (e.g.: ACPA, MMP3) and some of them have demonstrated change in accordance with x-ray progression (MMP3). However further validation is needed before using them as candidates outcome measures for future interventional trial.	This measure has been used in many trials and has been considered critical for both evaluating efficacy and severity. Only prediction of future radiographic damage was demonstrated Further validation is needed

Disease-group	Measurement instrument	Unit of measurement	What are the outcome domains currently covered by the instrument?	Validation reached	Is the chosen instrument/measure considered an outcome measure and included in a core set of outcomes?
SpA	MRI	Joint (axial-SIJ, spine)	Disease activity (bone marrow edema)	Several Scoring methods at SIJ and spine levels have been demonstrated to fulfill face validity and discrimination). Feasibility not widely examined. Noted that MRI is considered to be quite good for diagnostic purposes (i.e. presence of sacro-iliitis)	Bone marrow edema as quantified by SPARCC spine and SIJ and Berlin spine MRI scores are excellent candidate outcome measures for disease activity. Not validated for structural damage.
			Structural damage (bone marrow edema, erosions, fat lesions).	Preliminary data for bone marrow edema and fat lesions.	Further data needed from longitudinal and interventional studies
	Ultrasound	Joint (peripheral entheses)	Disease activity (synovitis, enthesitis)	Detection of synovitis has been demonstrated to be valid but yet sensitive to change in RCTs. Detection of enthesitis has been demonstrated to fulfill some aspects of truth and discrimination (including sensitivity to change) but no in RCTs. Feasibility remains a problem.	Possible good candidate, but no data available.
			Structural damage (erosions, enthesophytes, calcifications).	Truth aspect demonstrated for erosions and enthesophytes. Sensitivity to change/responsiveness not yet demonstrated. No data available in RCTs	No data available.
Knee OA	X-rays	Patient (blood)	Disease activity Systemic inflammation (CRP, IL6)	CRP has been demonstrated to fulfill face validity, some aspect of construct and discrimination validity, and also to be weakly predictive of future radiographic damage.	CRP usually used in RCTs, but lack of representation in all patients with active disease
			Damage/severity (matrix metalloproteinase 3)	Not enough data available for suggesting extensive use or being tested in clinical trials	Only prediction of future radiographic damage was demonstrated
			Structural damage (joint space narrowing, osteophytes)	JSN fulfills all aspects of validity, reliability related to acquisition technique. Noted that JSN is used in clinical decision making.	JSN already accepted in core set of OA trials from previous OMERACT recommendations
			Disease activity (synovitis, effusion)	Synovitis, effusion have criterion, reliability and responsiveness data, as well as predictive validity for severe progression (knee replacement).	Recommendations from OARSI suggest cartilage measures should be included as a primary outcome measure in structure modification trials. More RCT data required. More data from RCT required on other biomarkers such as bone measures.
	MRI	Joint	Structural damage (cartilage, bone, menisci, ligaments)	Cartilage morphology is the most studied feature and is valid. Bone marrow lesions have criterion and discrimination (reliability and some data on responsiveness) validity and also to be predictive of future structural damage.	
	Ultrasound	Joint	Disease activity (synovitis, effusion)	Detection of synovitis and effusion has demonstrated validity but not in RCTs. Both	Possible good candidate, but not data available.

Disease-group	Measurement instrument	Unit of measurement	What are the outcome domains currently covered by the instrument?	Validation reached	Is the chosen instrument/measure validated enough for being considered an outcome measure and included in a core set of outcomes?
			Structural damage (cartilage loss, osteophytes)	<p>detection of synovitis and effusion have been demonstrated for severe progression (knee replacement)</p> <p>detection of synovitis and effusion have been demonstrated for severe progression (knee replacement)</p> <p>Validity demonstrated for both cartilage loss (limited anatomical view acknowledged) and osteophytes. No data available as outcomes candidates in RCTs</p>	<p>Possible good candidates, but not data available.</p>