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Development and validation of the OMERACT juvenile idiopathic arthritis MRI- sacroiliac joint score (OMERACT JAMRIS-SIJ): Phase 3

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ABSTRACT

Objective: The OMERACT JAMRIS working group has defined a spectrum of MRI lesions in the sacroiliac joint (SIJ) in pediatric cases with spondyloarthritis (SpA) that match domains for inflammation and structural damage. We aimed to assess longitudinal construct validity using two available instruments, the Spondyloarthritis Research Consortium of Canada (SPARCC) and JAMRIS scores, in two longitudinal cohorts of youth with SpA treated with a tumor necrosis factor inhibitor (TNFi) according to the OFISA framework.

Methods: Two cohorts recruited 60 youth with SpA who had MRI prior to and after TNFi. MRI lesions were assessed blinded to timepoint by 7 readers (5 MSK radiologists, 2 rheumatologists). Analyses compared data from JAMRIS-all slice versus SPARCC selected slices for descriptive variables, reliability, and responsiveness.

Results: Pre- and post-treatment scans (mean (SD) duration between scans 46.6 (47.1) weeks) were available from 60 cases. The major contributor to change in inflammatory lesion scores was bone marrow edema (BME) followed by inflammation in an erosion cavity (IEC), though differences between the two instruments were minimal. For change in structural lesions, minimal differences were evident between SPARCC and JAMRIS-all slice instruments. Reliability for detection of change scores and responsiveness were comparable between SPARCC and JAMRIS-all slice methodologies. Combining scores for inflammatory lesions did not enhance responsiveness compared to BME alone.

Conclusions: BME is the most responsive lesion to treatment with TNFi in axJSpA followed by IEC and then erosion. Validation according to the OFISA framework demonstrates that the JAMRIS-all slice and SPARCC instruments have comparable performance characteristics.

Introduction

The OMERACT Juvenile Idiopathic Arthritis MRI (JAMRIS) Working group has defined a spectrum of MRI lesions in the sacroiliac joint (SIJ) in youth with spondyloarthritis (SpA) that were matched with inflammation and structural target domains for the truth component of the OMERACT Filter Instrument Selection Algorithm (OFISA), and considered for inclusion in a scoring method [1–3]. OMERACT recommendations for the validation of instruments based on imaging also require the identification of sources of variability [4]. Assessment of MRI lesions among JAMRIS readers identified erosion as a frequent lesion in youth with SpA that was not reliably assessed [1]. Calibration of readers using a previously validated real-time iterative calibration module (RETIC) developed by CARE Arthritis [5,6] led to enhanced reliability for detection of erosion, backfill, and inflammation in an erosion cavity [7]. Further validation in the OFISA framework requires

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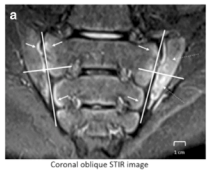
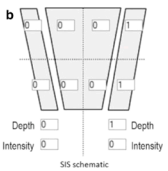
assessment of longitudinal construct validity and feasibility [8].

Systematic literature review focused on quantification of the extent of MRI lesions in the SIJ in youth with SpA revealed limited reports, all describing the application of Spondyloarthritis Research Consortium of Canada (SPARCC) methodology developed for adult axSpA, where assessment of inflammation is limited to bone marrow edema (BME) and where inflammatory and structural lesions (erosion, backfill, sclerosis, fat lesion, ankylosis) are assessed in a limited number of semicoronal slices [9,10]. But only three studies had assessed longitudinal construct validity using the SPARCC method in youth with SpA [6,11,12]. We





SPARCC Inflammation Score
Evaluates BME in 6 consecutive slices

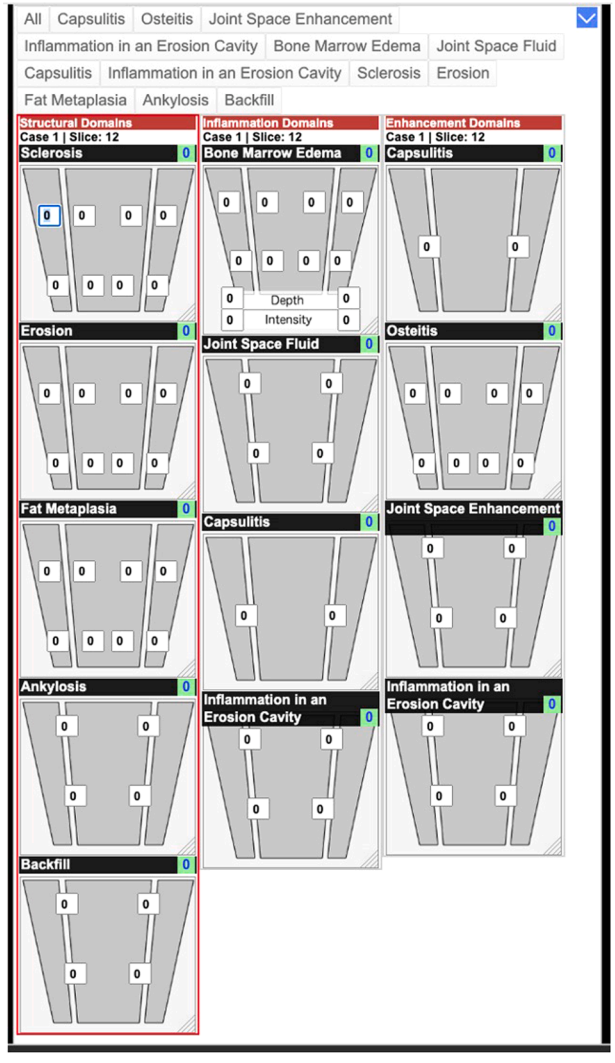
1. Maksymowych et al. Arthritis Rheum 2005;53:703-9
2. Weiss et al. Arthritis Research & Therapy 2018; 20:56

	Score per slice	Number of slices	Scoring range
Fat	0-8	5	0-40
Erosion	0-8	5	0-40
Backfill	0-4	5	0-20
Ankylosis	0-4	5	0-20
Sclerosis	0-8	5	0-40

SPARCC Structural Score
Evaluates structural lesons in 5 consecutive slices starting from the transitional slice

1. Maksymowych et al. J Rheumatol 2015;42:79-86
2. Weiss et al. J Rheumatol 2018;45:1411-7

(a)



(b)

Item	Definition	Segmentation/ slice	Score range/ slice
Bone Marrow Edema (BME)	An ill defined area of high bone marrow signal intensity within the subchondral bone in the ilium or sacrum on fluid sensitive images	4 quadrants/SIJ	0–8
BME Intensity	Presence of hyperintensity of the marrow on fluid sensitive images using the signal of the presacral veins or cerebrospinal fluid (CSF) as reference	1 score /SIJ	0–2
BME Depth	Continuing increased signal on fluid sensitive images of depth ≥ 5mm/ ≥ 1cm from the articular surface	1 score /SIJ	0–2
Osteitis	An ill-defined area of high bone marrow signal intensity within the subchondral bone in the ilium or sacrum on contrast enhanced T1 weighted sequences	4 quadrants/SIJ	0–8
Joint Space Fluid	High signal intensity equivalent to the CSF on fluid sensitive sequences within the joint space of the cartilaginous portion of the SIJ	halves/SIJ	0–4
Joint Space Enhancement	Increased signal intensity on contrast enhanced T1 weighted sequences within the joint space of the cartilaginous portion of the SIJ	halves/SIJ	0–4
Inflammation in erosion cavity	Increased signal intensity on fluid sensitive or contrast enhanced T1 weighted sequences in an erosion cavity of the cartilaginous portion of the SIJ	halves/SIJ	0–4
Enthesitis	Increased signal intensity in bone marrow and/or adjacent soft tissue on fluid sensitive or contrast enhanced T1 weighted sequences at sites where ligaments and tendons attach to a bone excluding retroarticular enthesitis	score per case	0–1
Capsulitis	Increased signal on fluid sensitive or contrast enhanced T1 weighted sequences involving the superior portion of the SIJ capsule	superior halves/ SIJ	0–2

(c)

Item	Definition	Segmentation/ slice	Score range/ slice
Sclerosis	A substantially wider than normal area of very low bone marrow signal intensity within the subchondral bone in the ilium or sacrum on a non-fat suppressed sequence, preferably a non-fat suppressed T1 weighted sequence. This feature must also be present on all other sequences, as available	4 quadrants/SIJ	0-8
Erosions	A focal loss of the low signal of cortical bone at the osteochondral interface and adjacent marrow matrix on T1 weighted images	4 quadrants/SIJ	0-8
Fat lesion (fat metaplasia)	Homogeneous increased signal intensity within the subchondral bone marrow on T1 weighted images	4 quadrants/SIJ	0-8
Backfill	A high signal on non-contrast enhanced T1 weighted sequences in a typical location for an erosion, with signal intensity greater than normal bone marrow, clearly demarcated from adjacent bone marrow by an irregular band of low signal reflecting sclerosis at the border of the original erosion	halves/SIJ	0-4
Ankylosis	Presence of signal equivalent to regional bone marrow continuously bridging a portion of the joint space between the iliac and sacral bones	halves/SIJ	0-4

(d)

Fig. 1. Web-based scoring interfaces and scoring methodologies for the A. SPARCC and B. JAMRIS methods for scoring inflammatory and structural lesions in the SIJ on MRI. JAMRIS is based on the assessment of all slices between the anterior (≥1 cm vertical height of cartilaginous portion) and the most posterior (≥1 cm visible cartilaginous portion) slices and evaluates C. Inflammatory and D. Structural lesions.

aimed to compare the metric properties of the SPARCC with the JAMRIS scores according to the requirements of the OMERACT instrument selection workbook and generate a parsimonious, feasible, scoring instrument for the semi-quantitative evaluation of the degree of inflammation or structural damage on MRI of the SIJ in youth with SpA. Specific aims were: 1. To test the longitudinal construct validity for inflammatory and structural lesions using the SPARCC and JAMRIS scores. 2. To determine whether including additional inflammatory lesions enhanced the longitudinal construct validity of the SPARCC BME score. 3. To determine the most parsimonious scoring method based on a comparison of the all-slice JAMRIS score versus SPARCC-defined 6 and 5 slices for inflammatory and structural lesions, respectively.

Methods

Two longitudinal cohorts recruited youth ≤18 years who had a rheumatologist diagnosis of SpA and had MRI scans of the SIJ performed at the University of Alberta Hospital (Edmonton, Canada) or were enrolled as part of a prospective study which included participants from 4 hospitals (the Children's Hospital of Philadelphia, Nationwide Children's Hospital, Children's of Alabama, and Cincinnati Children's Hospital Medical Center) prior to and after treatment with a tumor necrosis factor inhibitor (TNFi). Participants were aged 8 to 18 years and met the following inclusion criteria: 1) Symptom onset prior to age 16 years, 2) Fulfilled ILAR criteria for enthesitis-related arthritis or psoriatic arthritis or European SpA Study Group criteria. Each cohort provided 30 cases and mean (SD) duration between the scans was 46.6 (47.1) weeks). MR imaging examination contained at a minimum semicoronal T1-weighted (T1W), T2-weighted (T2W) fat-suppressed (FS), or Short Tau Inversion Recovery (STIR) sequences. MRI lesions were assessed on semicoronal slices through the SIJ from the most anterior (≥1 cm vertical height of cartilaginous portion) to the most posterior (≥1 cm visible cartilaginous portion) slice. Structural lesions were assessed first on the T1-weighted scan followed by inflammatory lesions on a fluid-sensitive sequence, as the change in inflammatory lesions may bias the assessment of change in structural lesions. The presence or absence of lesions in each SIJ quadrant (BME or osteitis, erosion, fat metaplasia) or SIJ half (backfill, ankylosis, inflammation in an erosion cavity (IEC), joint fluid) or entire SIJ (capsulitis) was recorded dichotomously by direct online data entry onto a web-based schematic of the SIJ according to JAMRIS and SPARCC methodology [1,9,10] (Fig. 1). The scoring ranges for these lesions using SPARCC are as follows: 0–72 (BME), 0–40 (erosion, fat lesion, sclerosis), 0–20 (ankylosis, backfill). SPARCC BME is assessed on 6 consecutive slices that capture the greatest extent of BME, including lesion depth and intensity, and a different stack of slices may be selected for different time points in a longitudinal study. SPARCC structure assesses lesions in 5 consecutive slices, the first slice being the transitional slice between cartilaginous and ligamentous portion of the SIJ and subsequent slices being anterior to the transitional slice. Assessments were conducted blinded-to timepoint and clinical details by 7 readers (4 pediatric and 1 adult MSK radiologists, 1 adult and 1 pediatric rheumatologist) after standardized calibration using the CARE Arthritis RETIC online modules [5]. MRI lesions were recorded based on standardized lesion definitions derived from the Assessments in Spondyloarthritis international Society (ASAS) and the JAMRIS group in a standardized eCRF (ASAS MRImagine) [1,13,14].

We compared data from assessment of all slices between the anterior and posterior slices using JAMRIS methodology versus data from the 6-slice and 5-slice SPARCC methods for assessment of inflammatory and structural lesions, respectively. Analyses included descriptive statistics, reliability of baseline, follow up and change scores (two-way random effects model, absolute agreement, and single rater intraclass class correlation coefficient (ICC 2.1)), smallest detectable difference (SDD) or change (SDC) [15], and responsiveness (standardized response mean (SRM)). Prespecified targets for acceptable reliability (ICC) have been established by SPARCC developers as follows: BME- ≥0.8 for status, ≥0.7 for change scores, erosion/backfill- ≥0.5 for status and change scores, fat lesion/ankylosis: ≥0.7 for status, ≥0.5 for change scores [16].

This phase of the OMERACT validation process did not include patient research partners as we did not analyze construct validity of MRI scores in relation to clinical parameters.

Results

Descriptive data: The mean (SD), median (IQR), range of slices per case for scoring inflammatory and structural lesions using JAMRIS was 8.3 (1.7), 8 (7–9), 6–13. All cases had ≥6 slices for scoring BME using the SPARCC method (range 0–72). BME was the most frequent inflammatory lesion, followed by IEC, and scores for each decreased after TNFi treatment (Fig. 2 and supplementary Tables 1–3). The additional inflammatory lesions were very uncommon and, when present, there was concomitant BME. There was only a single case where the majority of readers agreed there was capsulitis and/or joint fluid and/or inflammation in an erosion cavity in the absence of BME. The mean(SD) change in total JAMRIS inflammation score assessed across all slices was −17.2(22.6) as compared to a score of −13.7(17) for BME alone across all slices and −11.6(13.6) when BME was assessed across only the SPARCC-defined 6 slices (range 0–72) (Fig. 2 and supplementary Table 3). Assessment of the combination of BME and IEC resulted in a greater reduction in inflammation score than BME alone. Assessment of this combination across all slices demonstrated a mean(SD) reduction in inflammation score of −16.3(20.4) versus −14.1(16.6) across the SPARCC-defined 6 slices.

Fifty-eight of 60 (96.7%) cases had ≥5 slices for scoring structural lesions using the SPARCC method (range 0–40 for erosion, fat lesion, sclerosis and range 0–20 for backfill, ankylosis). The most frequent structural lesion was erosion, especially in the ilium, followed by fat lesion and then backfill (Fig. 2 and supplementary Tables 1–3). The mean(SD) change in erosion score assessed across all slices was −2(5.6) as compared to −1.6(4.5) when erosion was assessed across only the SPARCC-defined 5 slices. For fat lesions, the mean(SD) change across all slices versus SPARCC-defined 5 slices was 1.6(5.6) versus 1.2(4.1) and for backfill this was 1.2(3.5) versus 1(2.8).

Reliability: Reliability of baseline scores as assessed by ICC was greater for radiologist than rheumatologist readers and for inflammatory versus structural lesions (supplementary Table 4). But there was little difference when comparing JAMRIS all-slice with SPARCC-defined 6 or 5 slice scores. Similar findings were evident when the reliability of baseline to follow up change scores were analyzed by ICC (Table 1 and supplementary Table 5). SPARCC developer prespecified ICC targets for reliability [16] in change scores were attained for BME, fat lesion, ankylosis, and backfill but not erosion. ICC values for change scores were expected to be lower for structural compared to inflammation scores due to the greater degree of variance between patients in BME change scores. But SDC values, an absolute measure of reliability, were comparable between inflammatory and structural lesion scores regardless of JAMRIS all-slice or SPARCC-defined slice selections. Experience in scoring MRI scans among readers varied considerably, one reader being a pediatric rheumatologist with limited expertise (R6), while two readers were SPARCC score developers (R4, R7), and one pediatric MSK radiologist (R1) had limited experience in the scoring of MRI scans. Pairwise analysis of reliability for baseline and change scores reflects this variation in expertise (Figs. 3 and 4), especially in the evaluation of structural lesions. But reliability was comparable for both inflammatory and structural lesions for JAMRIS all-slice and SPARCC-defined slice scores. This is also evident in cumulative probability plots illustrating baseline and change data on each patient according to individual readers (supplementary figure).

Responsiveness: The most responsive lesion was BME followed by IEC, although combining these two lesions did not enhance responsiveness compared to BME alone (Fig. 5). The most responsive structural lesion was erosion followed by fat lesion and backfill. Responsiveness

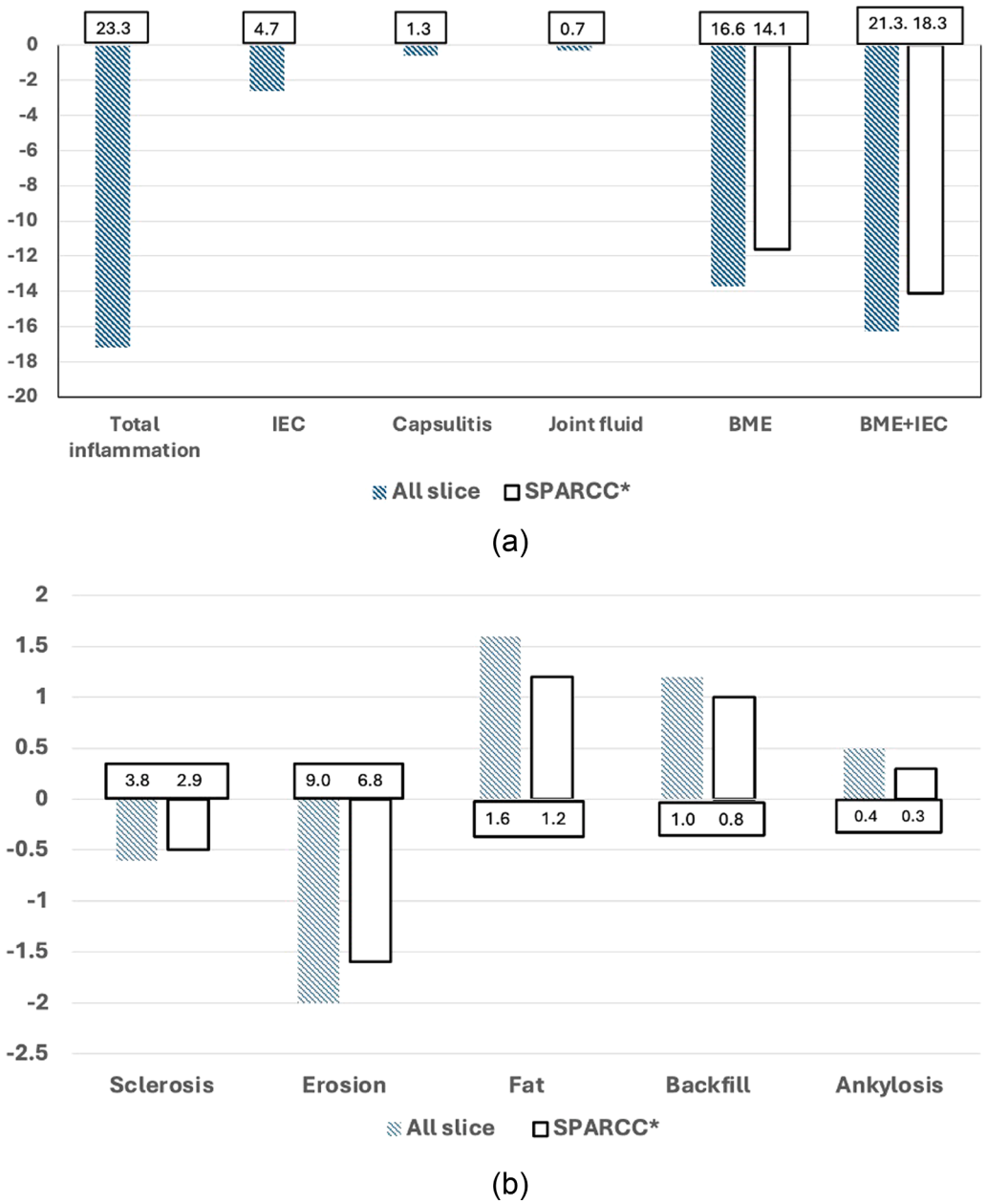


Fig. 2. Change scores from baseline in MRI lesions in the SIJ in 60 youth with SpA treated with TNFi. Baseline values are provided in the boxes. A. Inflammatory lesions (IEC-inflammation in an erosion cavity). SPARCC scores are based on the assessment of BME in 6 consecutive semicoronal slices. JAMRIS is based on the assessment of all slices. B. Structural lesions. SPARCC scores are based on the assessment of structural lesions in 5 consecutive semicoronal slices. JAMRIS is based on the assessment of all slices.

was comparable between JAMRIS all-slice and SPARCC-defined slice scores.

Discussion

This study describes the first comparative validation of two scoring methodologies for evaluating MRI lesions in the SIJ of youth with SpA according to the requirements of the OFISA framework. Assessment of all inflammatory and structural lesions in the SIJ using the comprehensive JAMRI method, which quantifies lesions across all slices, had similar reliability and longitudinal construct validity to the SPARCC method, which limits assessment to 6 slices for BME and 5 slices for structural lesions. Moreover, combining inflammatory lesions did not enhance responsiveness when compared to BME alone. Consequently, the parsimonious SPARCC method would be expected to enhance feasibility, especially the time required to assess the scan, without compromising performance.

Our data indicates that assessment of erosion was the most challenging aspect of scoring lesions in the SIJ, especially in the sacrum, and this was evident despite readers conducting calibration reads prior to scoring. This is not surprising and likely reflects the lack of a distinct cortical margin at the sacrum due to incomplete ossification together with the presence of red marrow in the sacrum, which accounts for the diminished T1W fat signal relative to adult marrow which contains more fat [17]. A standardized consensus-based diagnostic acquisition protocol for evaluation of sacroiliitis in adults has been adopted by the ASAS and the Spondyloarthritis Research and Treatment Network (SPARTAN) professional societies that includes a high-resolution 3D acquisition erosion-sensitive sequence to enhance visualization between subchondral bone and the overlying cartilage/joint space [18]. Several

Table 1
Reliability of change from baseline scores in MRI lesions in the SIJ in 60 youth with SpA treated with TNFi. A. Inflammatory lesions (IEC-inflammation in an erosion cavity). JAMRIS is based on the assessment of all slices between the anterior and posterior slices. SPARCC scores are based on the assessment of BME in 6 consecutive semicoronal slices. B. Structural lesions. JAMRIS is based on the assessment of all slices between the anterior and posterior slices. SPARCC scores are based on the assessment of structural lesions in 5 consecutive semicoronal slices.

A.

MRI Inflammatory lesion	Overall ICC	MSK Radiologist Overall ICC	Rheumatologist Overall ICC	Overall SDC (% of scoring range)	MSK Radiologist SDC (% of scoring range)	Rheumatologist SDC (% of scoring range)
JAMRIS Total inflammation-change	0.80	0.84	0.71	7.18 (4.3%)	8.10 (4.9%)	12.84 (13.5%)
JAMRIS BME (all slice)	0.85	0.89	0.70	4.70 (4.2%)	4.90 (4.4%)	11.06 (12.1%)
BME (SPARCC-6 slice)	0.82	0.87	0.67	4.10 (4.5%)	4.37 (5.2%)	9.43 (12.1%)
JAMRIS Inflammation in erosion cavity (IEC)	0.50	0.61	0.10	2.63 (6.7%)	3.16 (8.1%)	3.49 (20.5%)
JAMRIS BME + IEC (all slice)	0.83	0.87	0.71	8.74 (6.2%)	9.53 (6.8%)	17.19 (17.5%)
BME + IEC (SPARCC-6 slice)	0.80	0.84	0.69	7.65 (7.4%)	8.55 (8.2%)	14.76 (17.2%)
JAMRIS Capsulitis	0.62	0.69	0.44	1.08 (4.3%)	1.28 (5.1%)	1.59 (11.3%)
JAMRIS Joint space fluid	0.17	0.23	0.07	2.21 (6.1%)	2.75 (7.6%)	3.11 (13.5%)

B.

MRI structural Lesion	Overall ICC	MSK Radiologist Overall ICC	Rheumatologist Overall ICC	Overall SDC (% of scoring range)	MSK Radiologist SDC (% of scoring range)	Rheumatologist SDC (% of scoring range)
JAMRIS Sclerosis (all slice)	0.29	0.32	0.11	1.97 (6.8%)	2.50 (8.6%)	3.05 (16.1%)
Sclerosis (SPARCC-5 slice)	0.30	0.33	0.13	1.59 (6.4%)	2.02 (8.1%)	2.24 (18.7%)
JAMRIS Erosion (all slice)	0.35	0.44	−0.10	3.30 (6.6%)	3.74 (8.1%)	7.44 (24.8%)
Erosion (SPARCC-5 slice)	0.33	0.39	−0.07	2.65 (7.4%)	3.10 (9.7%)	5.88 (23.5%)
JAMRIS Fat (all slice)	0.53	0.54	0.61	2.77 (3.9%)	3.64 (5.1%)	2.66 (9.5%)
Fat (SPARCC-5 slice)	0.59	0.58	0.71	1.89 (4.3%)	2.50 (5.7%)	1.93 (7.7%)
JAMRIS Ankylosis (all slice)	0.89	0.96	0.87	0.97 (2.1%)	0.81 (1.7%)	1.27 (5.1%)
Ankylosis (SPARCC-5 slice)	0.86	0.92	0.72	0.66 (2.5%)	0.63 (2.4%)	1.26 (7%)
JAMRIS Backfill (all slice)	0.510	0.50	0.60	1.82 (5.2%)	2.33 (6.6%)	2.21 (13%)
Backfill (SPARCC-5 slice)	0.50	0.47	0.63	1.50 (6.2%)	1.95 (8.1%)	1.93 (12.8%)

reports have described superior performance of these sequences to conventional T1W scans in the detection of erosion when compared to CT as gold standard [19–21]. In addition, there have been reports in adults and children describing a CT-equivalent MRI method of erosion detection in the SIJ without using ionizing radiation such as Zero echo time (ZTE) MRI or MRI-based synthetic CT (sCT) [22–25]. A JAMRIS working group is currently drafting a standardized and consensus-based image acquisition protocol for the evaluation of the SIJ in children.

There has been very limited assessment of longitudinal construct validity, a key metric for assessment of discrimination under the OFISA framework, of MRI scoring instruments in youth with SpA. Our data demonstrates that more is not necessarily better when adding additional inflammatory lesions, such as IEC, to BME to enhance responsiveness. This may reflect the greater variability in detection of IEC relative to the increase in effect size. Three reports have evaluated only the SPARCC method. The first included 30 cases, 26 of whom received TNFi therapy, with a median time between scans depicting inflammation being 27.3 months and scans depicting structural lesions being 36.4 months [6]. Responsiveness and reliability were comparable to that noted in our study with the exception that these measures were greater for erosion and sclerosis. This could reflect the much longer duration between scans compared to our study (47 weeks) allowing for greater progression of structural lesions, which could explain the greater reliability of change scores together with greater responsiveness. A second report assessed SPARCC BME in 45 cases and SPARCC structural lesions in 18 cases [11]. Time between imaging studies was 14.5 months for assessment of inflammation and 46.1 months for structural lesions. Mean reduction in SPARCC inflammation score in those exposed to TNFi was −20, but responsiveness data according to the SRM was not provided. Eleven (85%) TNFi exposed and 8 (89%) unexposed subjects with a baseline SPARCC inflammation score ≥0 met the minimal important change (MIC; ≥2.5). There was very little change in SPARCC erosion score. Reliability for detection of erosion was better, but worse for backfill and sclerosis, compared to our study. There was a relatively low prevalence of structural lesions among these patients underscoring the impact of differences in baseline disease characteristics on performance metrics and the importance of conducting comparative validation of scoring methods in the same disease population. In a third study, SPARCC inflammation and structural lesion scores were assessed in 57 patients receiving TNFi who had baseline and 12-week follow up scans [12].

Total Inflammation baseline scores, JAMRIS all slice ICC

	R2	R3	R4	R5	R6	R7
R1	0.915	0.703	0.745	0.769	0.679	0.586
R2		0.815	0.798	0.839	0.751	0.665
R3			0.918	0.885	0.694	0.853
R4				0.877	0.701	0.916
R5					0.705	0.759
R6						0.617
Median	0.759					

BME baseline scores, SPARCC 6-slice

	R2	R3	R4	R5	R6	R7
R1	0.927	0.831	0.923	0.835	0.788	0.796
R2		0.812	0.879	0.833	0.812	0.734
R3			0.915	0.876	0.677	0.908
R4				0.891	0.722	0.883
R5					0.652	0.806
R6						0.601
Median	0.831					

Erosion baseline scores, JAMRIS all slice

	R2	R3	R4	R5	R6	R7
R1	0.448	0.681	0.581	0.669	0.373	0.375
R2		0.564	0.641	0.706	0.359	0.602
R3			0.767	0.64	0.425	0.663
R4				0.777	0.392	0.808
R5					0.466	0.559
R6						0.276
Median	0.581					

Erosion baseline scores, SPARCC 5-slice

	R2	R3	R4	R5	R6	R7
R1	0.541	0.639	0.622	0.755	0.461	0.437
R2		0.567	0.673	0.741	0.463	0.609
R3			0.775	0.651	0.382	0.708
R4				0.804	0.499	0.806
R5					0.57	0.594
R6						0.342
Median	0.609					

Fig. 3. Pairwise ICC values for MRI SIJ inflammation and structural lesion JAMRIS and SPARCC scores at baseline in 60 youth with SpA.

Total Inflammation change, JAMRIS all slice

	R2	R3	R4	R5	R6	R7
R1	0.893	0.813	0.826	0.778	0.683	0.683
R2		0.89	0.862	0.829	0.813	0.76
R3			0.93	0.845	0.771	0.877
R4				0.807	0.756	0.912
R5					0.708	0.732
R6						0.707
Median	0.813					

BME change, SPARCC 6-slice

	R2	R3	R4	R5	R6	R7
R1	0.901	0.837	0.93	0.796	0.763	0.789
R2		0.865	0.91	0.822	0.849	0.781
R3			0.92	0.831	0.751	0.928
R4				0.832	0.77	0.891
R5					0.675	0.771
R6						0.671
Median	0.831					

Erosion change, JAMRIS all slice

	R2	R3	R4	R5	R6	R7
R1	0.341	0.605	0.634	0.719	0.357	0.244
R2		0.394	0.178	0.169	0.199	0.322
R3			0.539	0.336	0.157	0.423
R4				0.628	0.316	0.352
R5					0.565	0.033
R6						-0.096
Median	0.341					

Erosion change, SPARCC 5-slice

	R2	R3	R4	R5	R6	R7
R1	0.327	0.552	0.518	0.717	0.464	0.203
R2		0.314	0.133	0.152	0.293	0.32
R3			0.478	0.261	0.117	0.422
R4				0.548	0.272	0.309
R5					0.575	0.003
R6						-0.072
Median	0.314					

Fig. 4. Pairwise ICC values for baseline to follow up change in MRI inflammation and structural lesion scores in 60 youth with SpA after treatment with TNFi therapy.

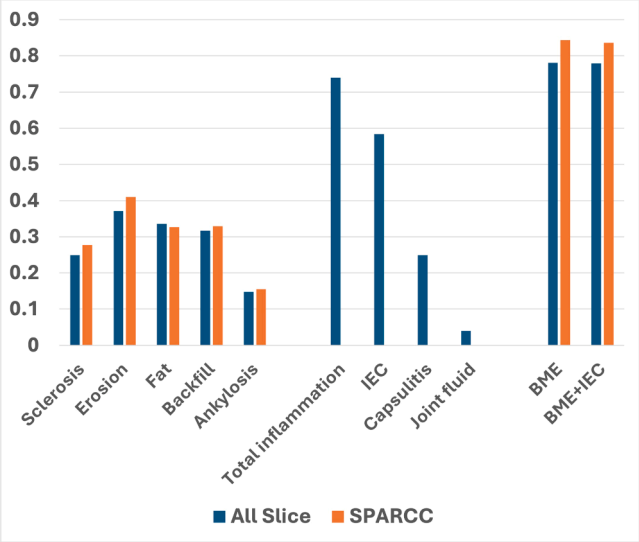


Fig. 5. Responsiveness of JAMRIS and SPARCC methods for scoring inflammatory and structural lesions on MRI of the SIJ in 60 youth with SpA after treatment with TNFi therapy.

Median change for SPARCC inflammation score was −8, 63% achieved resolution of inflammation (SPARCC <2), and median change for SPARCC erosion was −3, but reliability and responsiveness data was not provided.

There are several study limitations, the principal one being the lack of a placebo control group to assess discrimination and the potential impact of background therapy, such as non-steroidal anti-inflammatory drugs (NSAIDs), or disease course on the evolution of lesions over time. Moreover, the time frame between pre- and post-treatment MRI scans was much longer than the placebo-controlled phase of trials conducted in adults with axSpA, which have typically been 12–16 weeks. Nevertheless, SPARCC BME and structural scores have proven to be sufficiently discriminatory in adult axSpA trials to demonstrate significant differences between therapies with different mechanisms of action versus placebo [26–29]. Our sample size was limited and was a convenience sample rather than a sample of cases that would be typical of cases recruited to a clinical trial. Nevertheless, the accrued experience in both adults and youth with SpA indicates that future trials should incorporate MRI as an exploratory endpoint, especially since there is little correlation with clinical measures of disease activity. SPARCC BME has now been included in a core set of measures developed for youth with axial SpA [30].

In conclusion, comparative validation of the JAMRIS-all slice and SPARCC-designated 6-slice and 5-slice methods for scoring inflammatory and structural lesions on MRI of the SIJ in youth with SpA demonstrated comparable longitudinal construct validity and reliability for change scores. Reliability and responsiveness for scoring inflammatory lesions was comparably high using both methods. It is unlikely that increasing the number of inflammatory types of lesions assessed will enhance the responsiveness of scoring BME alone. Reliable assessment of erosion on T1W scans requires further evaluation with sequences providing greater resolution and delineation of cortical bone. This methodology should now undergo further assessment in the setting of a randomized placebo-controlled trial in youth with SpA.

Author contributions

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be published. All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Ethics in publishing

The use of the anonymized MRI scans for research and consent for publication was approved by the respective IRBs (University of Alberta Health Research Ethics Board; Children's Hospital of Philadelphia's Committee for the Protection of Human Subjects (IRB 19-016713).) Written informed consent was obtained from all study participants to use the data for future research.

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Declaration of competing interest

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Supplementary materials

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