THERAPEUTIC ADVANCES in
Musculoskeletal Disease

Original Research

Costotransverse joint ankylosis and their association with syndesmophyte progression in patients with radiographic axial spondyloarthritis

Ther Adv Musculoskelet Dis

2024, Vol. 16: 1–11

DOI: 10.1177/1759720X241242852

Hong Ki Min, Se Hee Kim, Sang-Heon Lee, Hae-Rim Kim and Sang-Hoon Lee

Abstract

Background: Abnormal new bone formation can occur not only in the vertebral body but also can occur in facet, costovertebral, and costotransverse joints in radiographic axial spondyloarthritis (r-axSpA) patients. Little is known about the association between syndesmophyte progression and paravertebral joint ankylosis in r-axSpA.

Objectives: Costotransverse joint ankylosis in r-axSpA patients was measured. Furthermore, the association between syndesmophyte progression for 2 years assessed by computed tomography syndesmophyte score (CTSS) and facet, costovertebral, and costotransverse joints ankylosis were evaluated.

Design: Single-center, prospective, cohort study.

Methods: Whole spine CT images taken at baseline and 2-year follow-up were used to calculate the CTSS of the vertebral body. In addition, ankylosis of the facet/costovertebral/costotransverse joints was scored. CTSS (range, 0–552) and facet joint ankylosis (range, 0–46) were assessed at 23 vertebral units. Costovertebral joints at T1–T12 (range, 0–48) and costotransverse joints at T1–T10 (range, 0–20) were also assessed by independent two readers. Intraclass correlation coefficients (ICC) were calculated to determine inter-reader reliability. Odds ratios (OR) were calculated to identify the associations between syndesmophyte progression and the baseline status of facet, costovertebral, and costotransverse joints.

Results: In all, 50 patients with r-axSpA were included. Readers 1 and 2 identified C7–T3 (facet joints), T5–T7 and T12 (costovertebral joints), and T8–T9 (costotransverse joints), as common sites of ankylosis at baseline and at 2-year follow-up. The ICCs for the facet, costovertebral, and costotransverse joints at baseline were 0.876, 0.952, and 0.753, respectively. OR of baseline costovertebral and costotransverse joint ankylosis for predicting syndesmophyte progression of the vertebral body was 4.644 [95% confidence interval (CI), 2.295–9.398] and 1.524 (95% CI, 1.036–2.244), respectively.

Conclusion: Costotransverse joint ankylosis in r-axSpA patients can be measured semi-quantitatively on whole spine CT, and ankylosis of the costotransverse and costovertebral joints predicts the progression of syndesmophytes.

Trial registration: Not applicable.

Keywords: computed tomography, costotransverse joint, radiographic axial spondyloarthritis, syndesmophytes

Received: 4 October 2023; revised manuscript accepted: 13 March 2024.

Correspondence to:
Hong Ki Min
Division of Rheumatology, Department of Internal Medicine, Research Institute of Medical Science, Konkuk University School of Medicine, 120-1 Neungdong-ro (Hwayang-dong), Gwangjin-gu, Seoul 05030, Republic of Korea
alsghdrl1921@naver.com

Sang-Hoon Lee
Division of Rheumatology, Department of Internal Medicine, Kyung Hee University Hospital at Gangdong, College of Medicine, Kyung Hee University, 892 Dongnam-ro, Gangdong-gu, Seoul 05278, Republic of Korea
boltaguni@gmail.com

Se Hee Kim
Division of Rheumatology, Department of Internal Medicine, Kyung Hee University Hospital at Gangdong, College of Medicine, Kyung Hee University, Seoul, Republic of Korea

Sang-Heon Lee
Hae-Rim Kim
Division of Rheumatology, Department of Internal Medicine, Research Institute of Medical Science, Konkuk University School of Medicine, Seoul, Republic of Korea

Introduction

Radiographic axial spondyloarthritis (r-axSpA) is a chronic inflammatory arthritis of the axial joints (spine and sacroiliac joints).[1,2] Inflammation of the axial joints causes inflammatory back pain and morning stiffness, and chronic inflammation in the spine can also lead to ankylosis, which eventually progresses to a 'bamboo spine'.[1,2] Progression of ankylosis is irreversible, and advanced ankylosis reduces spinal motion and quality of life in patients with r-axSpA.[3,4] Therefore, preventing spinal structural progression and evaluating the status of spinal ankylosis are important for appropriate management.

Traditionally, the modified Stoke Ankylosing Spondylitis Spinal Score (mSASSS) has been used to evaluate spinal structural damage in r-axSpA[5]; however, the mSASSS has several limitations.[6] First, it does not measure structural damage in the thoracic (T) spine. Recent research based on computed tomography (CT) of the whole spine revealed that abnormal bone formation (i.e. syndesmophytes) is most common in the T spine. Second, signals generated by adjacent soft tissue and internal organs on simple X-rays can prevent precise evaluation of spinal structures on lateral views of the cervical (C) and lumbar (L) spine, which are used to calculate the mSASSS. Whole spine CT, followed by estimation of a CT syndesmophyte score (CTSS), improves the detection of spinal structural progression in r-axSpA.[7,8] Furthermore, ankylosis of other axial joints such as the facet and costovertebral joints can be evaluated on whole spine CT to measure the degree of ankylosis.[9,10] Facet joint ankylosis on CT predicts syndesmophyte progression.[10] Also, the costovertebral joint abnormality score showed a positive correlation with CTSS.[10] The joint between the costal facet of the spine and the rib is called the costotransverse joint; these joints are present at levels T1–T10. Ligaments hold the costotransverse joints in a relatively fixed position; however, they can glide during inhalation and exhalation. Therefore, ankylosis of the costotransverse joints can limit chest expansion during breathing. One study showed costotransverse joint ankylosis reduced chest expansion capacity in r-axSpA patients.[11] However, none of the previous studies simultaneously evaluated vertebral body syndesmophyte, facet, costovertebral, and costotransverse joint abnormalities in r-axSpA patients.

Here, we measured ankylosis of facet, costovertebral, and costotransverse joints, and CTSS of r-axSpA patients, and evaluated the correlation between costotransverse joint ankylosis score, CTSS, facet joints ankylosis score, and costovertebral joints score. Also, we evaluated whether the degree of facet, costovertebral, and costotransverse joint ankylosis measured at baseline predicts syndesmophyte progression in r-axSpA patients.

Methods

Patients

Patients with r-axSpA who fulfilled the 1984 modified New York criteria,[12] were aged over 18, and had baseline whole spine CT scans taken within 12 months from initial diagnosis of r-axSpA were recruited from a single university-based tertiary hospital (Konkuk University Medical Center).[6] Whole spine CT scans were prospectively collected in these r-axSpA patients to evaluate the progression of spinal structural damage. This study was conducted in accordance with the Declaration of Helsinki (1964, and its later amendments). Written informed consent was obtained from each participant previous to study enrolment. The study was approved by the Institutional Review Board of Konkuk University Medical Center (approval number: KUMC 2021-05-036). The reporting of this study conforms to the Strengthening the Reporting of Observational Studies in Epidemiology statement.[13]

Measurement of CTSS, facet joint ankylosis, costovertebral joint involvement, and costotransverse joint ankylosis on whole spine CT

Whole spine CT scans were performed twice (at baseline and again at the 2-year follow-up). Detailed information about whole spine CT scanning has been provided in a previous article.[6] The CTSS, the degree of facet, costovertebral, and costotransverse joint ankylosis were scored by two independent readers (H.K.M. and S.H.K. – 10, and 4 years of clinical practice as rheumatologist, respectively), and CT images were offered to the readers as Digital Imaging and Communication in Medicine files after patient information and chronological sequence were erased. The CTSS measures the degree of syndesmophyte growth at 23 vertebral units (VU) of vertebral body (from

C2–3 to L5–S1), and the score ranges from 0 to 552 [each VUs score 0–24: four aspects (anterior, posterior, left lateral, and right lateral) × upper/lower aspect of VUs × score 0–3 of each aspect = 24].[7] Facet joint ankylosis at the 23 VU was also evaluated; each VU could be scored 0–2 (right plus left: no ankylosis: 0; ankylosed: 1; total score, 0–46).[9,14] Costovertebral joint abnormalities were evaluated at 12 levels (T1–T12), and the score for each level ranged from 0 to 4 (right plus left; 0: normal, 1: erosion or syndesmophytes; and 2: total ankylosis); the total score ranged from 0 to 48.[10] Costotransverse ankylosis was evaluated at 10 levels (T1–T10) because T11 and T12 do not form a costotransverse joint. The total score ranges from 0 to 20 (each level = 0–2, a dichotomous measurement: ankylosis = 1; no ankylosis = 0). Evaluation of the costotransverse joint was dichotomous because none of the costotransverse joint images included in the present study showed abnormal bone growth, such as syndesmophyte, or erosion.

Statistical analysis and data management

Inter-reader reliability was measured by calculating the intraclass correlation coefficient (ICC). The correlation between the CTSS, the facet joint score, the costovertebral joint score, and the costotransverse joint score was calculated using Pearson's correlation analysis. Pearson's correlation coefficient for the CTSS *versus* the facet joint score was calculated based on the scores for C2–3 to L5–S1; the coefficient for the CTSS *versus* the costovertebral joint score was calculated based on the scores for C7–T1 to T11–T12 score of CTSS and T1 to T12 score of costovertebral joints; and the coefficient for the CTSS *versus* the costotransverse joint score was calculated based on the scores for C7–T1 to T9–T10 score of CTSS and T1 to T10 score of costotransverse joints. CTSS of each VU was the sum of the eight quadrant scores (upper – right lateral, left lateral, anterior, and posterior, lower – right lateral, left lateral, anterior, and posterior quadrants). The CTSS of each VU was matched with correlating levels of facet, costovertebral, and costotransverse joint (e.g. C7–T1 VU CTSS matched with C7–T1 facet joint, T1 costovertebral joint, and T1 costotransverse joint). Syndesmophyte progression per VU was measured by comparing the CTSS per VU at baseline with that at the 2-year follow-up; progression was denoted by a 2-year follow-up CTSS per VU higher than the baseline CTSS per VU with a consensus of two readers. VUs with baseline maximum syndesmophyte scores were excluded. We used multilevel generalized estimating equations models with exchangeable working correlation structures.[15] 'Autoregressive' model was used and imputed baseline bridging syndesmophyte as one of the variables.[15] p Values <0.05 were deemed statistically significant. All analyses were performed using R software (version 3.1.0; R Foundation for Statistical Computing, Vienna, Austria).

Results

Distribution of costotransverse, costovertebral, and facet joint ankylosis at baseline and 2-year follow-up

In all, 50 patients with r-axSpA were included in the analysis. The median age was 33.5 years, and 38 patients (76%) were male. The median disease duration between the initial diagnosis of r-axSpA to the time of the first whole spine CT scan was 2 months. The detailed characteristics of the enrolled r-axSpA patients are described in Supplemental Table 1.[6] Representative abnormal findings at the costotransverse, costovertebral, and facet joints are presented in Figure 1. The T3–4 to T10–11 levels were the most common sites of syndesmophytes at baseline.[6] The distribution of syndesmophyte progression is shown in Supplemental Figure 1. Reader 1 reported that facet joint ankylosis was most common at T2–T3 at baseline, whereas reader 2 reported that it was most common at C7–T1/T1–T2 [Figure 2(a)]. With respect to costovertebral joint ankylosis, readers 1 and 2 reported that T12 was the most common site at baseline [Figure 2(b)]. Both readers reported that costotransverse joint ankylosis at baseline was the most common at T8 and T9 (reader 1: T8, 17%; T9, 23%; reader 2: T8, 40%; T9, 40%) [Figure 2(c)]. A heatmap showing the distribution of ankylosed facet, costovertebral, and costotransverse joints is presented in Figure 2.

Inter-reader reliability of the CTSS, facet, costovertebral, and costotransverse joint scores at baseline and the 2-year follow-up

The mean with SD of CTSS, facet joint, costovertebral, and costotransverse joint scores were summarized in Table 1. The ICC was calculated to evaluate the inter-reader reliability. The ICC for the total facet joint score was 0.876 [95% confidence interval (CI), 0.782–0.930] and 0.939

Table 1. Summary of CTSS, facet joint, costovertebral, and costotransverse joint scores of readers 1 and 2.

Scores	Reader 1	Reader 2	ICC (95% CI)
CTSS (baseline, 0–552)	25.7 ± 43.2	23.0 ± 34.1	0.975 (0.955–0.986)
CTSS (2 years f/u, 0–552)	32.9 ± 46.0	35.0 ± 47.7	0.991 (0.984–0.995)
Change in CTSS during 2 years f/u	7.2 ± 12.0	12.0 ± 16.5	0.626 (0.340–0.788)
Facet joint score (baseline, 0–46)	3.9 ± 3.9	3.3 ± 3.7	0.876 (0.782–0.930)
Facet joint score (2 years f/u, 0–46)	5.3 ± 4.7	5.0 ± 4.5	0.939 (0.893–0.965)
Change in facet joint score during 2 years f/u	1.3 ± 2.7	1.7 ± 2.6	0.838 (0.714–0.908)
Costovertebral joint score (baseline, 0–48)	3.4 ± 6.4	3.7 ± 6.7	0.952 (0.915–0.973)
Costovertebral joint score (2 years f/u, 0–48)	3.9 ± 7.2	4.5 ± 7.4	0.962 (0.933–0.978)
Change in costovertebral joint score during 2 years f/u	0.5 ± 2.3	0.8 ± 1.9	0.591 (0.279–0.768)
Costotransverse joint score (baseline, 0–20)	1.3 ± 1.9	3.3 ± 3.3	0.753 (0.564–0.860)
Costotransverse joint score (2 years f/u, 0–20)	2.0 ± 2.3	4.1 ± 3.1	0.877 (0.784–0.930)
Change in costotransverse joint score during 2 years f/u	0.7 ± 1.4	0.8 ± 1.9	0.221 (−0.373 to 0.558)

CI, confidence interval; CTSS, computed tomography syndesmophyte score; ICC, intraclass correlation coefficients.

(95% CI 0.893–0.965) at baseline and 2-year follow-up, respectively. The baseline ICC for the total costovertebral joint score was 0.952 (95% CI, 0.915–0.973) and the 2-year follow-up ICC was 0.962 (95% CI, 0.933–0.978). The ICC for the total costotransverse joint score was 0.753 (95% CI, 0.564–0.860) at baseline and 0.877 (95% CI, 0.784–0.930) at 2-year follow-up (Table 1). The cumulative probability plots of progression for facet, costovertebral, and costotransverse joint scores are presented in Figure 3.

Correlation between the CTSS, facet joint score, costovertebral joint score, and costotransverse joint score at baseline and the 2-year follow-up. The scores of CTSS, facet joint ankylosis, costovertebral joint involvement, and costotransverse joint ankylosis at each level were used to calculate Pearson's correlation coefficient. The score at C2–3 to L5–S1 VU was used to measure the correlation between CTSS and facet joint score. The CTSS for C7–T1 to T11–12 and the costovertebral joint score at T1–12 were used to measure the correlation between CTSS and the costovertebral joint score. The CTSS for C7–T1 and T9–10 and the costotransverse joint score at T1–10 were used to measure the correlation between CTSS and the costotransverse joint score. Similarly, the correlation between the facet joint and the costovertebral joint scores (C7–T1 to T11–T12 for facet joints; T1–12 for costovertebral joints), the correlation between the facet joint and costotransverse joint scores (C7–T1 to T9–10 for facet joints; T1–10 for costotransverse joints), and the correlation between the costovertebral joint and costotransverse joint scores (T1–10 for both the costovertebral and costotransverse joints) were calculated. For reader 1, the calculated correlation coefficient between the CTSS and the facet joint score was 0.18 ($p < 0.001$), between the CTSS and the costovertebral joint score was 0.47 ($p < 0.001$), and between the CTSS and the costotransverse joint score was 0.29 ($p < 0.001$) at baseline. For reader 2, the correlation coefficients were 0.14 ($p = 0.002$), 0.51 ($p < 0.001$), and 0.26 ($p < 0.001$) for CTSS *versus* facet joint score, CTSS *versus* costovertebral joint score, and CTSS *versus* costotransverse score at baseline, respectively. The correlation coefficients at the 2-year follow-up were similar to those at baseline for both readers 1 and 2. However, the changes (2-year follow-up score minus the baseline score) in the CTSS, facet joint score, costovertebral joint score, and the costotransverse joint score did not

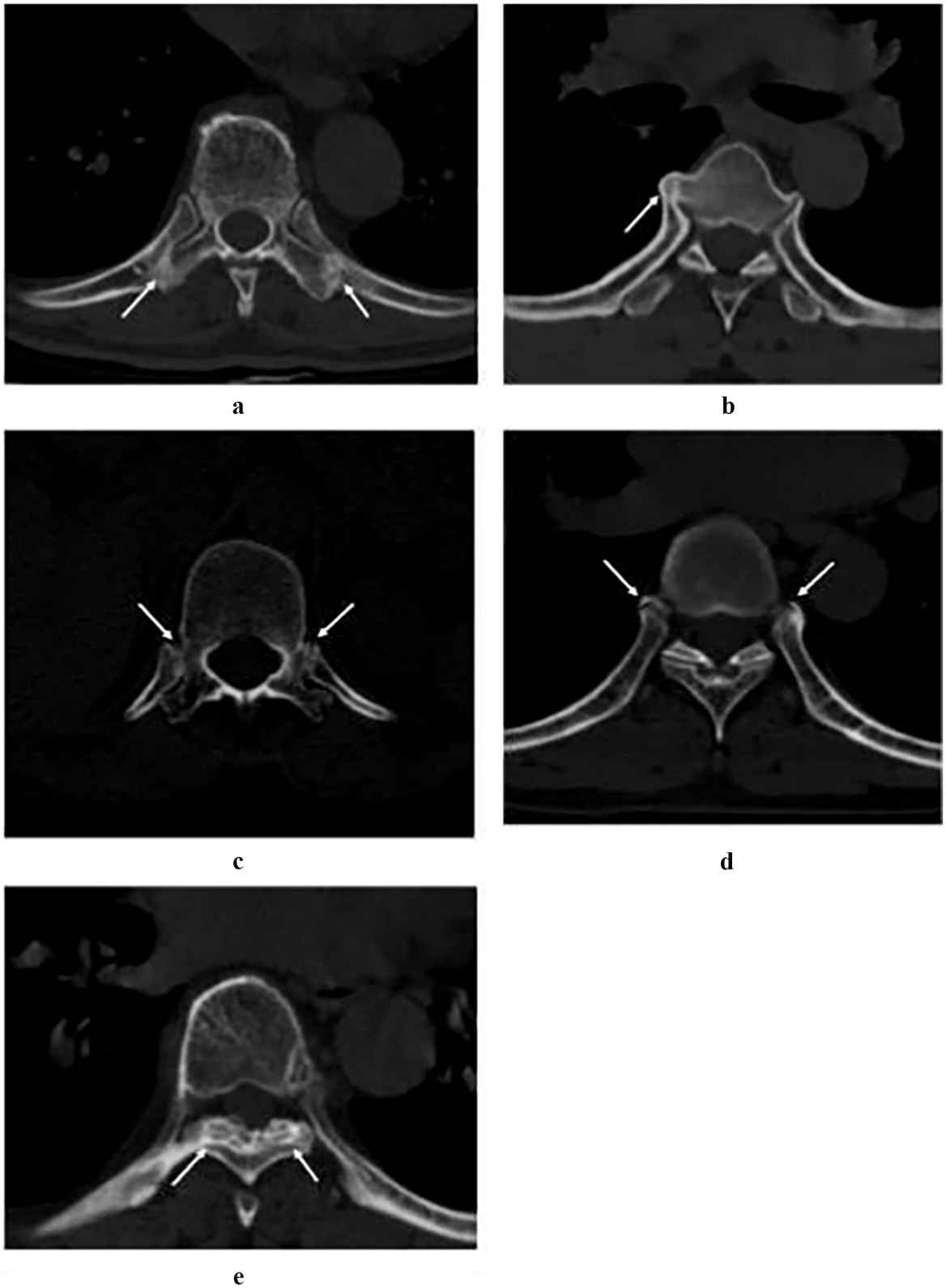

Figure 1. Representative CT images showing costotransverse, costovertebral, and facet joint abnormalities. (a) Bilateral ankylosis of costotransverse joints (white arrow), (b) ankylosis of costovertebral joints on the right side (white arrow), (c) erosion of the bilateral costovertebral joints (white arrow), (d) syndesmophytes on the bilateral costovertebral joints (white arrow), and (e) bilateral facet joint ankylosis.
CT, computed tomography.

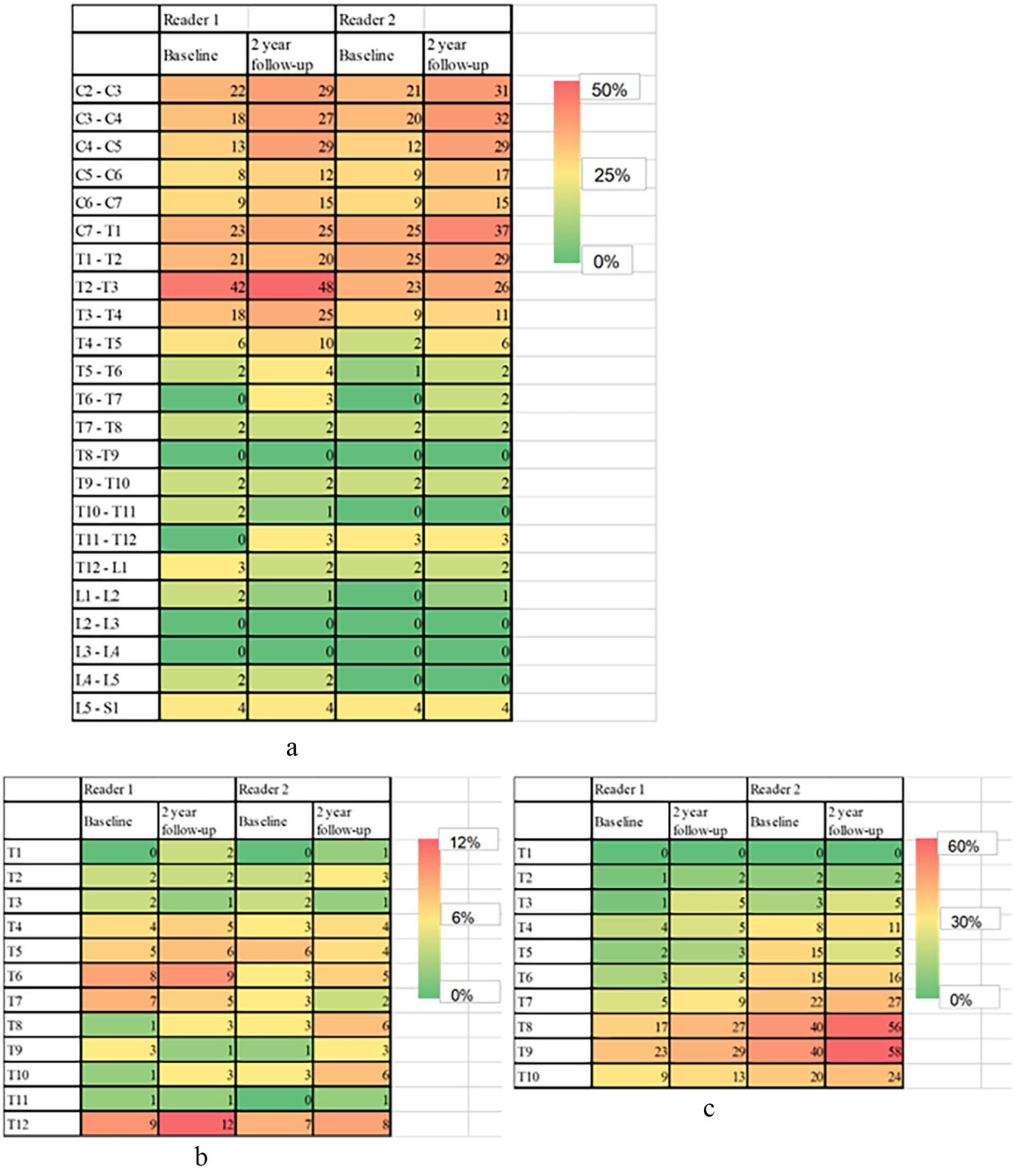

Figure 2. Distribution of ankylosed facet joints (a), costovertebral joints (b), and costotransverse joints (c) at baseline and at the 2-year follow-up (the number inside each cell is a percentage).

correlate significantly, except a correlation between the change in the facet score *versus* the costovertebral score and the costovertebral *versus* the costotransverse score (reader 1). The detailed correlation coefficients are presented in Table 2.

Association between facet, costovertebral, costotransverse joint score, and syndesmophyte progression. Odds ratios (ORs) of baseline bridging syndesmophyte, facet joint ankylosis, costovertebral joint ankylosis, and costotransverse joint ankylosis on predicting the progression of the

syndesmophyte at the VU level were calculated. The CTSS and facet joint scores at C7–T1 to T9–10 and the costovertebral and costotransverse joint scores at T1–10 were used for the analysis. Two VUs among 500 VUs (10 levels [C7–T1 to T9–10] × 50 patients) were excluded from the analysis because they showed total ankylosis (maximum CTSS) at baseline, indicating that syndesmophyte progression was impossible. Therefore, a total of 498 levels were used. Univariable analysis revealed that the OR for baseline bridging as a predictor of syndesmophyte progression was 1.33 (95% CI, 0.715–2.486), facet joint ankylosis at baseline was 1.427 (95% CI, 0.948–2.147), costovertebral joint ankylosis at baseline was 5.143 (95% CI, 2.655–9.960), and costotransverse joint ankylosis at baseline was 1.715 (95% CI, 1.194–2.465). Multivariable regression analysis revealed that only baseline costovertebral joint ankylosis (OR = 4.644; 95% CI, 2.295–9.398) and baseline costotransverse joint ankylosis (OR = 1.524; 95% CI, 1.036–2.244) were significant predictors of syndesmophyte progression (Table 3).

Discussion

Here, we present a novel semi-quantitative scoring method for costotransverse joint ankylosis in r-axSpA patients. The total score for costotransverse joint ankylosis correlated significantly with the CTSS and costovertebral joint score (Table 2), but progression of costotransverse joint ankylosis did not correlate with change of the CTSS, facet the joint score, or the costovertebral joint score; this implies that progression of structural damage at the costotransverse joints may happen independently of progression at other adjacent joints in the spine (e.g. vertebral bodies, facet joints, costovertebral joints). However, baseline ankylosis of the costovertebral and costotransverse joints was positively associated with the progression of syndesmophyte, which suggests that more severe structural damage between the vertebral body and rib may predict future syndesmophyte progression in patients with r-axSpA.

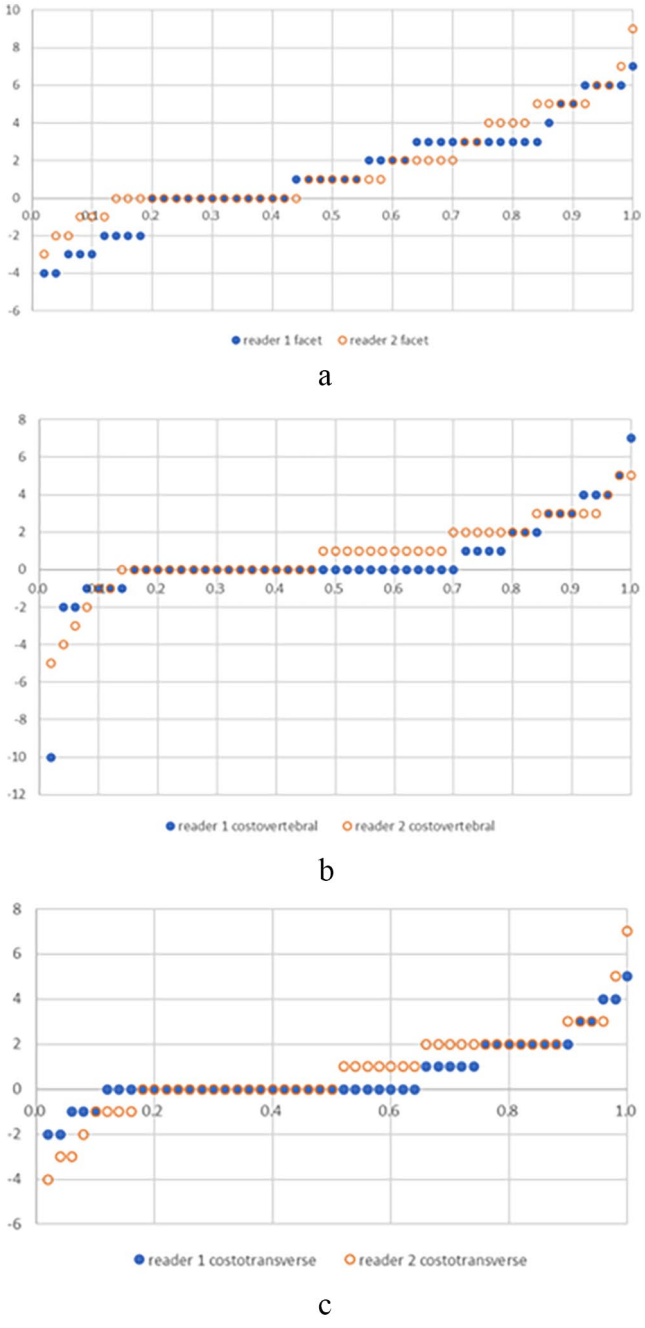

Figure 3. Cumulative probability plot of 2-year progression of (a) facet joint score, (b) costovertebral joint score, and (c) costotransverse joint score by readers 1 and 2.

With respect to the distribution of facet joint ankylosis, there are some differences between the data presented in the present study and those presented in previous studies. A previous study of sensitive imaging of ankylosing spondylitis (SIAS) and Incheon Saint Mary's Axial SPondyloArthritis study (ISAXSPA) cohorts revealed that the percentage of ankylosed facet joints was highest in the T spine, with a lower percentage in the C spine.[9,14] However, we found the highest percentage of ankylosed facet joints at T2–3 (reader 1), and at C7–T1 and T1–2 (reader 2) [Figure 2(a)], which represent the lower C/upper T levels. Furthermore, we found a higher percentage of facet joint ankylosis at C2–3 and C3–4, and a much lower percentage at T4–5 and T11–12

Table 2. Correlation between the CTSS, the facet joint score, the costovertebral joint score, and the costotransverse joint score at baseline and 2-year follow-up scores, changes in the scores for readers 1 and 2.

Reader 1 (baseline)	**CTSS**	**Facet joint score**	**Costovertebral joint score**	**Costotransverse joint score**
CTSS	1			
Facet joint score	0.18 ($p < 0.001$)	1		
Costovertebral joint score	0.47 ($p < 0.001$)	0.11 ($p = 0.013$)	1	
Costotransverse joint score	0.29 ($p < 0.001$)	−0.05 ($p = 0.232$)	0.27 ($p < 0.001$)	1
Reader 1 (2-year follow-up)	**CTSS**	**Facet joint score**	**Costovertebral joint score**	**Costotransverse joint score**
CTSS	1			
Facet joint score	0.24 ($p < 0.001$)	1		
Costovertebral joint score	0.60 ($p < 0.001$)	0.16 ($p < 0.001$)	1	
Costotransverse joint score	0.28 ($p < 0.001$)	−0.01 ($p = 0.880$)	0.33 ($p < 0.001$)	1
Reader 1 (score change)	**CTSS**	**Facet joint score**	**Costovertebral joint score**	**Costotransverse joint score**
CTSS	1			
Facet joint score	0.01 ($p = 0.740$)	1		
Costovertebral joint score	0.08 ($p = 0.092$)	0.12 ($p = 0.008$)	1	
Costotransverse joint score	−0.02 ($p = 0.611$)	−0.03 ($p = 0.540$)	0.22 ($p < 0.001$)	1
Reader 2 (baseline)	**CTSS**	**Facet joint score**	**Costovertebral joint score**	**Costotransverse joint score**
CTSS	1			
Facet joint score	0.14 ($p = 0.002$)	1		
Costovertebral joint score	0.51 ($p < 0.001$)	0.06 ($p = 0.169$)	1	
Costotransverse joint score	0.26 ($p < 0.001$)	−0.10 ($p = 0.026$)	0.29 ($p < 0.001$)	1
Reader 2 (2-year follow-up)	**CTSS**	**Facet joint score**	**Costovertebral joint score**	**Costotransverse joint score**
CTSS	1			
Facet joint score	0.11 ($p = 0.015$)	1		
Costovertebral joint score	0.56 ($p < 0.001$)	0.04 ($p = 0.38$)	1	
Costotransverse joint score	0.25 ($p < 0.001$)	−0.12 ($p = 0.006$)	0.28 ($p < 0.001$)	1
Reader 2 (score change)	**CTSS**	**Facet joint score**	**Costovertebral joint score**	**Costotransverse joint score**
CTSS	1			
Facet joint score	0.01 ($p = 0.899$)	1		
Costovertebral joint score	0.06 ($p = 0.215$)	0.01 ($p = 0.979$)	1	
Costotransverse joint score	0.08 ($p = 0.088$)	−0.09 ($p = 0.051$)	0.07 ($p = 0.110$)	1

CTSS, computed tomography syndesmophyte score.

compared to previous studies.[9,14] Also, baseline facet joint ankylosis in the SIAS cohort showed a significant positive association with syndesmophyte progression,[15] whereas we found only a

Table 3. Univariable and multivariable regression analyses of factors predicting progression of the syndesmophyte score.

Variables	Univariate		Multivariate	
	OR	95% CI	OR	95% CI
Baseline bridging of vertebral bodies (CTSS)	1.33	0.72–2.49	0.73	0.36–1.50
Baseline facet joint ankylosis	1.43	0.95–2.15	1.42	0.92–2.17
Baseline costovertebral joint ankylosis	5.14	2.66–9.96	4.64	2.30–9.40
Baseline costotransverse joint ankylosis	1.72	1.19–2.47	1.52	1.04–2.24

CI, confidence interval; CTSS, computed tomography syndesmophyte score; OR, odds ratio.

tendency toward an increase in the likelihood of CTSS progression (i.e. OR = 1.415; 95% CI, 0.924–2.166 in multivariable regression analysis; Table 3). These differences may be due to the relatively small sample size in the present study. Another reason could be that we only included r-axSpA patients, whereas the ISAXSPA cohort also included non-radiographic axSpA patients.[14] In addition, we only included r-axSpA patients with less than 12 months of disease duration, whereas the previous two cohorts (SIAS and ISAXSPA) had a wider range of disease durations before enrolment.[7,14] Finally, we used a conventional dose of radiation for whole spine CT, whereas the previous studies used low-dose CT, resulting in lower-quality images compared with those in the present study.[16] These differences in radiation dose (conventional dose *versus* low dose) may affect the quality of the CT images and thus the ability to score accurately/consistently[16]; for example, we may have been able to score facet joints at C5–6 to T1–2, which may not have been assessable in the SIAS cohort.[9] However, the conventional dose CT which was used in the present study also has limitations on clinical applicability due to higher radiation dose.

The preexisting syndesmophyte or bridging on the vertebra body is a well-known predictor for syndesmophyte progression in r-axSpA.[17–19] Also, a higher mSASSS score at baseline was associated with a significantly higher risk for further progression of mSASSS.[20] However, some studies have shown that baseline mSASSS or preexisting syndesmophytes are not associated with further spinal structure progression in r-axSpA.[21,22] Previous studies used C-/L-spine X-ray to evaluate baseline spinal structural damage (mSASSS) or syndesmophyte,[17–22] and the X-ray-based approach has several limitations as previously mentioned in the 'Introduction' section. CTSS was developed in the SIAS cohort and showed a better detection rate for syndesmophyte progression than the mSASSS.[7,8] Recent studies that used whole spine CT did not reveal an association between preexisting syndesmophyte or bridging of vertebra body were predictors for syndesmophyte progression,[6,8,15] and the preexisting bridging of vertebra body only showed a tendency to increase the risk of syndesmophyte progression in the present study. Therefore, further studies with larger sample sizes and longer follow-up durations should be conducted to clarify this issue.

The joints between the vertebra and ribs comprise the costovertebral and costotransverse joints. Unlike the elbow, knee, or shoulder, these are not fully mobile. However, gliding over each other facilitates inspiration and expiration. The limitation of chest expansion is one of the classification criteria in the modified New York criteria.[12] This means that limited chest expansion is an important clinical manifestation of r-axSpA, and so evaluating ankylosis of the costovertebral and costotransverse joints is important.[11] Here, we found that baseline ankylosis of the costovertebral and costotransverse joints is positively associated with future syndesmophyte progression. Also, a previous study of the ISAXSPA cohort revealed that the total score for the costovertebral joints was associated significantly with the CTSS.[10] Therefore, proper measurement of ankylosis of the costovertebral and costotransverse joints is important for predicting the chest expansion ability and future syndesmophyte progression in patients with r-axSpA.

The present study has several limitations, the most important of which is the small sample size. Second, the CT used in the present study used a

conventional dose of radiation, meaning that follow-up CT was limited to avoid adverse events. However, whole spine CT was undertaken to evaluate the progression of structural damage for medical needs. Third, we did not include C-/L-spine lateral view X-rays or magnetic resonance images of the spine. Therefore, we could not compare the ability of these methods to detect syndesmophytes, facet joint ankylosis, costovertebral joint involvement, or costotransverse joint ankylosis.

Conclusion

In conclusion, ankylosis of the costotransverse joints occurs in r-axSpA patients. In addition, the degree of baseline costotransverse joint ankylosis may predict the progression of syndesmophytes.

Declarations

Ethics approval and consent to participate

Written informed consent was obtained from each participant previous to study enrolment. The study was approved by the Institutional Review Board of Konkuk University Medical Center (approval number: KUMC 2021-05-036).

Consent for publication

Not applicable.

Author contributions

Hong Ki Min: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing – original draft; Writing – review & editing.

Se Hee Kim: Data curation.

Sang-Heon Lee: Data curation.

Hae-Rim Kim: Data curation.

Sang-Hoon Lee: Conceptualization; Supervision; Writing – review & editing.

Acknowledgements

None.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Competing interests

The authors declare that there is no conflict of interest.

Availability of data and materials

Data are available upon reasonable request. The data underlying this article will be shared on reasonable request to the corresponding author.

ORCID iD

Hong Ki Min https://orcid.org/0000-0003-1147-1046

Supplemental material

Supplemental material for this article is available online.

References

1. Robinson PC, van der Linden S, Khan MA, *et al*. Axial spondyloarthritis: Concept, construct, classification and implications for therapy. *Nat Rev Rheumatol* 2021; 17: 109–118.
2. Inman RD. Axial spondyloarthritis: Current advances, future challenges. *J Rheum Dis* 2021; 28: 55–59.
3. Min HK, Lee J, Ju JH, *et al*. Predictors of Assessment of Spondyloarthritis International Society (ASAS) health index in axial spondyloarthritis and comparison of ASAS health index between ankylosing spondylitis and nonradiographic axial spondyloarthritis: Data from the Catholic Axial Spondyloarthritis COhort (CASCO). *J Clin Med* 2019; 8: 467.
4. Poddubnyy D, Listing J, Haibel H, *et al*. Functional relevance of radiographic spinal progression in axial spondyloarthritis: Results from the GErman SPondyloarthritis Inception Cohort. *Rheumatology* (*Oxford*) 2018; 57: 703–711.
5. Creemers MC, Franssen MJ, van't Hof MA, *et al*. Assessment of outcome in ankylosing spondylitis: An extended radiographic scoring system. *Ann Rheum Dis* 2005; 64: 127–129.
6. Min HK, Kim SH, Lee SH, *et al*. Proposal of simplified CT syndesmophyte score (sCTSS) and comparison with CTSS in patients with ankylosing spondylitis. *Sci Rep* 2023; 13: 1283.
7. de Bruin F, de Koning A, van den Berg R, *et al*. Development of the CT Syndesmophyte Score (CTSS) in patients with ankylosing spondylitis:

Data from the SIAS cohort. *Ann Rheum Dis* 2018; 77: 371–377.

8. de Koning A, de Bruin F, van den Berg R, *et al*. Low-dose CT detects more progression of bone formation in comparison to conventional radiography in patients with ankylosing spondylitis: Results from the SIAS cohort. *Ann Rheum Dis* 2018; 77: 293–299.
9. Stal R, van Gaalen F, Sepriano A, *et al*. Facet joint ankylosis in r-axSpA: Detection and 2-year progression on whole spine low-dose CT and comparison with syndesmophyte progression. *Rheumatology* (*Oxford*) 2020; 59: 3776–3783.
10. Jung SM, Kim MY, Hong YS, *et al*. Costovertebral joint involvement in patients with axial spondyloarthritis. *Joint Bone Spine* 2023; 90: 105546.
11. Ata EB, Durhan G, Bilgin E, *et al*. Costovertebral and costotransverse joint involvement in spondyloarthritis. *Int J Rheum Dis* 2023; 26: 2141–2150.
12. van der Linden S, Valkenburg HA and Cats A. Evaluation of diagnostic criteria for ankylosing spondylitis. A proposal for modification of the New York criteria. *Arthritis Rheum* 1984; 27: 361–368.
13. von Elm E, Altman DG, Egger M, *et al*. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. *J Clin Epidemiol* 2008; 61: 344–349.
14. Jung JY, Kim MY, Hong YS, *et al*. Association between facet joint ankylosis and functional impairment in patients with radiographic axial spondyloarthritis. *Semin Arthritis Rheum* 2021; 51: 1005–1010.
15. Stal R, Sepriano A, van Gaalen FA, *et al*. Associations between syndesmophytes and facet joint ankylosis in radiographic axial spondyloarthritis patients on low-dose CT over 2 years. *Rheumatology* (*Oxford*) 2022; 61: 4722–4730.
16. Lambert RGW, Hermann KGA and Diekhoff T. Low-dose computed tomography for axial spondyloarthritis: Update on use and limitations. *Curr Opin Rheumatol* 2021; 33: 326–332.
17. van Tubergen A, Ramiro S, van der Heijde D, *et al*. Development of new syndesmophytes and bridges in ankylosing spondylitis and their predictors: A longitudinal study. *Ann Rheum Dis* 2012; 71: 518–523.
18. Braun J, Baraliakos X, Hermann KG, *et al*. The effect of two golimumab doses on radiographic progression in ankylosing spondylitis: Results through 4 years of the GO-RAISE trial. *Ann Rheum Dis* 2014; 73: 1107–1113.
19. Kang KY, Kwok SK, Ju JH, *et al*. The predictors of development of new syndesmophytes in female patients with ankylosing spondylitis. *Scand J Rheumatol* 2015; 44: 125–128.
20. Molnar C, Scherer A, Baraliakos X, *et al*. TNF blockers inhibit spinal radiographic progression in ankylosing spondylitis by reducing disease activity: Results from the Swiss Clinical Quality Management cohort. *Ann Rheum Dis* 2018; 77: 63–69.
21. Min HK, Lee J, Ju JH, *et al*. Alcohol consumption as a predictor of the progression of spinal structural damage in axial spondyloarthritis: Data from the Catholic Axial Spondyloarthritis COhort (CASCO). *Arthritis Res Ther* 2019; 21: 187.
22. Koo BS, Oh JS, Park SY, *et al*. Tumour necrosis factor inhibitors slow radiographic progression in patients with ankylosing spondylitis: 18-year real-world evidence. *Ann Rheum Dis* 2020; 79: 1327–1332.