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ORIGINAL RESEARCH

Exploring radiographic patterns of the cervical spine, including zygapophyseal joints, in axial spondyloarthritis

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ABSTRACT

Introduction The assessment of the cervical spine (CS) in axial spondyloarthritis (axSpA) and its radiographic characteristics, including the zygapophyseal joints (ZJ), may be helpful for an accurate diagnosis, establishing a prognosis and enhancing treatment decisions.

Objectives To describe the prevalence and characteristics of CS involvement in patients with axSpA and perform a comparison between groups according to cervical radiographic damage.

Methods Patients who fulfilled the Assessment of SpondyloArthritis International Society classification criteria were included from January 2011 to January 2021. Sociodemographic, clinical, radiographic and treatment variables were gathered. Patients were categorised into 'CS group' (Bath Ankylosing Spondylitis Radiology Index ≥2 or De Vlam score ≥3 for ZJ) and 'no CS group' as controls. ZJ fusion and interobserver reliability in ZJ scoring were analysed.

Results A total of 340 patients were included, 244 (71.7%) men, with mean age 57±15 years. CS involvement was observed in 181 (53.2%) patients. Patients in the CS group, as compared with no CS group, were predominantly men, older, had a higher body mass index, higher prevalence of smoking, showed higher disease activity, worse functionality and mobility, as well as more structural damage. Sixty-nine patients with CS involvement had ZJ fusion at some level. These patients showed worse mobility and more radiographic damage. Overall, ZJ involvement was observed in 99 patients (29.1%), 20 of whom did not present with vertebral body involvement.

Conclusion Radiographic evaluation of CS is relevant in patients with axSpA and should be assessed routinely. Evaluation of the ZJ is particularly significant, as it is related to higher disease activity and worse function.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Axial spondyloarthritis (axSpA) involves vertebral spine and sacroiliac joints, and cervical involvement can lead to severe complications and worsened functionality. A significant extent of the radiographic damage observed in the cervical spine is situated within the zygapophyseal joints (ZJ), which are rarely evaluated compared with vertebral bodies.

WHAT THIS STUDY ADDS

⇒ This study reveals that cervical involvement in axSpA is frequent and associated with male gender, age, disease activity and worse mobility. There is a close relationship between vertebral bodies and ZJ involvement in axSpA, and they can occur simultaneously.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The systematic assessment of the cervical spine in patients with axSpA, including the evaluation of ZJ, is essential for detecting radiographic damage. The findings provide insights into factors related to cervical involvement in axSpA and the validity of the De Vlam scoring method for ZJ evaluation.

INTRODUCTION

Axial spondyloarthritis (axSpA) is a chronic inflammatory rheumatic disease characterised by the involvement of the vertebral spine and sacroiliac joints. One of its main features is the development of new bone formation, presenting as syndesmophytes or bony bridges, which are associated with sustained inflammation and can lead to ankylosis. This structural damage, along with other clinical manifestations and comorbidities, is related to worsened functionality and a decreased quality of life in patients.[1 2]

It remains uncertain whether syndesmophyte formation follows a specific direction or distribution. However, it is believed that new bone formation progresses from caudal to cranial, with the cervical spine (CS) being the last to be affected.[3] Despite this widely held belief, some studies suggest that syndesmophyte formation occurs randomly and is more prevalent in the CS compared with the lumbar spine. In contrast, within the lumbar region, the percentage of bony bridges is higher.[4] This could explain why some patients only have cervical involvement. Radiographic damage in the CS has been linked to a more

advanced disease and a worse prognosis, especially when structural changes are present from early stages. Early detection and the evaluation of possible related factors are crucial for appropriate intervention.[5–7]

To quantify structural changes in axSpA, various scoring systems based on lateral views of simple X-rays have been developed, such as the modified Stoke Ankylosing Spondylitis Spinal Score (mSASSS) and the Bath Ankylosing Spondylitis Radiology Index (BASRI), which are the most widely used. Both scoring systems assess only new bone formation in vertebral bodies, overlooking the zygapophyseal joints (ZJ), which are commonly affected in axSpA.[5 8] This typically occurs after vertebral body involvement, but it can also be observed in isolation.[6] Despite the limited research examining the connection between ZJ damage and cervical mobility, it is frequently observed that mobility is substantially reduced.[9] Therefore, there is no doubt that including ZJ in the assessment of cervical radiographic involvement adds value and is relevant in daily clinical practice.[6 10 11] To this end, the validated scoring method proposed by De Vlam,[8 12] which is the most used in studies, allows us to score each ZJ from C2 to C7. This enables us to obtain a better understanding of ZJ radiographic damage.

Currently, there are no studies that include a large number of patients in whom cervical radiographic damage is quantified by more than two observers and correlated with all clinical, radiographic, treatment-related variables and assessment indices used in clinical practice for all types of axSpA.

Therefore, we conducted this study with the aim of assessing the prevalence of cervical involvement in patients with axSpA, including ZJ involvement, using validated scoring methods, as well as studying potential associated factors.

METHODS

The study included patients with axSpA who met the Assessment of SpondyloArthritis International Society criteria for classification and were treated at the rheumatology department of the Bellvitge University Hospital from January 2011 to January 2021. Patient identification was performed by querying a specific dedicated registry as well as electronic medical records.

Inclusion criteria comprised adult patients (≥18 years old) with axSpA, including radiographic and non-radiographic forms, associated with psoriasis or inflammatory bowel disease. Juvenile-onset forms and patients without a lateral X-ray of the CS were excluded.

The following demographic and clinical variables were collected: gender, age, body mass index (BMI), smoking habit (we classified as non-smokers those individuals who have never smoked), age at symptom onset, age at disease diagnosis, presence of HLA-B27, family history of spondyloarthritis, peripheral and extramusculoskeletal manifestations, type of axSpA, activity and functionality indices (Ankylosing Spondylitis Disease Activity Score (ASDAS-CRP); Bath Ankylosing Spondylitis Disease Activity Index (BASDAI); Bath Ankylosing Spondylitis Functional Index (BASFI)), metrology, radiographic scores and prior biological treatment. Patient age was determined based on the date of the last recorded visit. Clinical and analytical variables were obtained from the nearest visit to the evaluated X-rays.

To evaluate radiographic damage of the CS, BASRI and mSASSS grading systems were applied for vertebral bodies. On the other hand, the method described by De Vlam[8] was used for ZJ scoring. This method allows us to score each ZJ from C2 to C7, based on a scale of 0–3 points for each level (0: normal, 1: decreased joint space, 2: partial obliteration of the space, 3: complete obliteration of the space or ankylosis) obtaining a total score up to 15 points. Figure 1 illustrates examples of this scoring. All radiographic scores were based on simple X-rays, and the evaluators had no access to patients' clinical data.

To assess ZJ involvement, all X-rays were reviewed by two independent observers (LB-A and XJ; 3 and 30 years of experience in rheumatology, respectively). In case of an interobserver difference >2 points, both investigators re-examined the images to reach a consensus. In

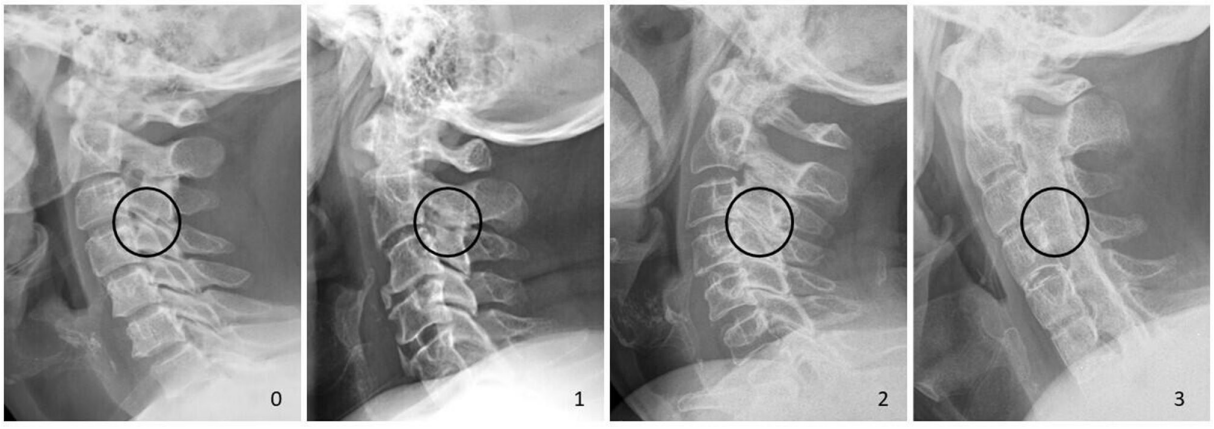

Figure 1 Scoring examples according to De Vlam method. 0: normal; 1: decreased joint space; 2: partial obliteration of the space; 3: complete obliteration of the space or ankylosis.

cases where no agreement was reached, a third investigator (JAN; 20 years of experience in musculoskeletal radiology) reviewed the tests. If there was no discrepancy, >2 points between the first and second investigators, the first investigator's score was chosen; otherwise, the consensus score or, if necessary, the third investigator's score was used.

In the baseline descriptive study, categorical variables were presented as the number and percentage of subjects in each category. Continuous variables were described as mean and SD or median and IQR, depending on the distribution.

Patients were categorised into two distinct groups based on the presence or absence of cervical involvement, specifically defined by BASRI ≥2 and/or ZJ ≥3. These groups were referred to as 'CS group' (comprising patients with cervical involvement) and 'no CS group' (including those without cervical involvement, with the latter serving as the control group in our study). Lumbar spine involvement was considered in patients with lumbar BASRI ≥2.

Group differences were analysed using the X^2 test or Fisher's test for categorical variables. Normality of quantitative variables was verified using the Kolmogorov-Smirnov test. For quantitative variables meeting normality criteria, the Student's t-test was used, while non-parametric tests (Mann-Whitney U) were applied for variables that did not meet normality criteria.

Within the group of patients with cervical involvement, the frequency of individuals with ZJ fusion at any level was examined, as well as the differential characteristics between subgroups (no fusion group and fusion group), using the X^2 test or Fisher's test for categorical variables. The normality of quantitative variables was verified using the Kolmogorov-Smirnov test. For quantitative variables meeting normality criteria, Student's t-test was employed, and non-parametric tests (Mann-Whitney U) were used for those that did not meet normality criteria.

Furthermore, a descriptive analysis was conducted for the subgroup of patients presenting the following characteristics: exclusive vertebral body involvement, concomitant involvement of both ZJ and vertebral bodies, exclusive ZJ involvement, cervical damage without lumbar involvement, and cervical and lumbar involvement without sacroiliitis (spondylitis without sacroiliitis).

Interobserver variability in the scoring of ZJ was analysed using the De Vlam method between the two independent investigators (LB-A and XJ). Interobserver agreement was calculated using Cohen's kappa coefficient. A value of $p<0.05$ was considered statistically significant. The z-value calculation was employed to determine the statistical significance of the kappa coefficient.

Missing data were handled following standard statistical methods, including interpolation or extrapolation when necessary. All analyses were conducted using R (V.4.2.2), and the significance level was set at $p<0.05$.

RESULTS

A total of 340 patients were included, of whom 244 (71.7%) were males, with a BMI of 26.4±4.3, and 140 (42.8%) were non-smokers. The mean age was 57.4±14.9 years, and the ages at symptom onset and diagnosis were 26.9±9.2 and 33.1±11.2 years, respectively.

A total of 181 patients (53.2%) presented with CS involvement. Table 1 presents the general characteristics of the population and a comparison between patients without CS damage and those with radiographic CS involvement.

In the CS group, the proportion of males was higher (n=151; 83.4% vs n=93; 58.4%), patients were older (63.8±13 vs 50±13.5 years) and had a higher BMI (27.6±4.4 vs 25.1±3.8). In the no CS group, a higher proportion of non-smokers was registered (37.7% vs 48.6%).

In the CS group, the predominant type of axSpA was ankylosing spondylitis (AS) (n=165; 91.1%), and higher disease activity was observed with higher scores of both BASDAI and ASDAS-CRP (BASDAI: 3.7±2.1 vs 3.2±2.7; ASDAS-CRP: 2.4±0.9 vs 2.1±0.9). Patients with radiographic cervical involvement also had worse functionality, with a higher BASFI (4.5±2.7 vs 2.7±2.3), worse cervical mobility (cervical rotations: 53.9°±24.6° vs 80.9°±11°; Fleche: 6.7±6.8 cm vs 0.6±2 cm) and lumbar mobility (Schober: 2.6±1.6 cm vs 4.2±1.1 cm). Additionally, CS group patients obtained higher scores in radiographic indices, both in sacroiliac joints (BASRI: 3.4±0.8 vs 2.4±1) and lumbar spine (BASRI: 2.4±1.5 vs 0.7±1.1).

No differences were found between groups in terms of HLA-B27 positivity, age at diagnosis, family history of axSpA, the prevalence of extramusculoskeletal manifestations, peripheral involvement, nor the percentage of patients receiving biological treatment.

Sixty-nine of the patients with CS involvement (69 of 181; 38.1%) had ZJ fusion at some level. Differences between groups based on the presence of posterior fusion are described in table 2. Worse cervical mobility was observed (cervical rotations: 39.14°±25.14° vs 62.88°±19.64°; Fleche: 10.50±7.46 cm vs 4.50±5.27 cm) among patients with ZJ fusion, as well as reduced lumbar mobility (Schober: 1.89±1.36 cm vs 3.18±1.66 cm; modified Schober: 3.04±1.86 cm vs 4.85±2.26 cm). These patients also had higher scores in radiographic indices (BASRI CS: 3.23±1.21 vs 2.24±0.99; mSASSS CS: 21.32±13.52 vs 6.48±6.63; BASRI sacroiliac joints: 3.72±0.82 vs 3.29±0.84; BASRI lumbar spine: 2.90±1.38 vs 2.18±1.51; mSASSS lumbar spine 19.77±14.67 vs 10.70±12.10). No differences were observed in the rest of the variables between groups.

In the global cohort, ZJ involvement was observed in 99 patients (29.1%), 20 of whom did not present with concomitant vertebral body involvement. A total of 90 patients (26.5%) had only vertebral body involvement, and 40 (11.8%) had cervical spine involvement without radiographic changes in the lumbar spine. Only two patients (0.6%) had cervical and lumbar involvement

Table 1 Patients' characteristics and differences between groups regarding cervical involvement

		Total (n=340)	CS group (n=181)	No CS group (n=159)	P value
Male sex		244 (71.76)	151 (83.43)	93 (58.49)	<0.001
Age		57.40±14.93	63.88±13.02	50.02±13.50	<0.001
BMI		26.47±4.33	27.64±4.42	25.10±3.80	<0.001
Non-smokers		140 (42.81)	66 (37.71)	74 (48.68)	0.001
Age at symptom onset		26.97±9.20	26.34±9.07	27.67±9.33	0.186
Age at diagnosis		33.11±11.2	33.5±11.9	32.7±10.4	0.527
HLA-B27 (+)		278 (81.36)	152 (83.98)	123 (78.34)	0.235
Family history of SpA		79 (23.24)	37 (20.44)	42 (26.4)	0.241
Uveitis		79 (23.24)	39 (21.55)	40 (25.16)	0.511
Psoriasis		24 (7.06)	10 (5.52)	14 (8.81)	0.334
IBD		31 (9.12)	14 (7.73)	17 (10.69)	0.449
Peripheral arthritis		101 (29.71)	59 (32.60)	42 (26.41)	0.260
Enthesitis		68 (20)	41 (22.65)	27 (16.98)	0.246
Dactylitis		8 (2.35)	3 (1.66)	5 (3.14)	0.586
axSpA type	AS	280 (82.35)	165 (91.16)	115 (72.33)	<0.001
	EnA	23 (6.76)	9 (4.98)	14 (8.81)	
	Ps SpA	11 (3.24)	4 (2.21)	7 (4.40)	
	nr-axSpA	26 (7.65)	3 (1.66)	23 (14.47)	
BASDAI		3.55±2.11	3.78±2.14	3.29±2.72	0.036
BASFI		3.70±2.70	4.55±2.72	2.72±2.31	<0.001
ASDAS-CRP		2.27±0.99	2.42±0.96	2.11±0.99	0.005
CS mobility (grades)		66.53°±23.74°	53.94°±24.66°	80.98°±11.08°	<0.001
Fleche (cm)		3.90±6.03	6.79±6.83	0.60±2.03	<0.001
Schober (cm)		3.43±1.66	2.69±1.67	4.28±1.18	<0.001
Modified Schober (cm)		5.19±2.30	4.16±2.29	6.36±1.68	<0.001
CS mSASSS		6.55±10.71	12.14±12.18	0.19±0.83	<0.001
Sacroiliac BASRI		2.99±1.07	3.45±0.86	2.46±1.04	<0.001
Lumbar BASRI		1.64±1.59	2.46±1.50	0.72±1.13	<0.001
Lumbar mSASSS		8.42±12.12	14.17±13.82	1.91±4.12	<0.001
bDMARD		127 (37.35)	75 (41.44)	52 (32.70)	0.122

Results are expressed as n (%) or mean±SD. Ages are expressed in years.
AS, ankylosing spondylitis; ASDAS-CRP, Ankylosing Spondylitis Disease Activity Score; axSpA, axial spondyloarthritis; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; BASFI, Bath Ankylosing Spondylitis Functional Index; BASRI, Bath Ankylosing Spondylitis Radiology Index; bDMARD, biological disease-modifying antirheumatic drug; BMI, body mass index; CS, cervical spine; EnA, entheropathic arthritis (IBD-associated spondyloarthritis); IBD, inflammatory bowel disease; mSASSS, modified Stoke Ankylosing Spondylitis Spinal Score; nr-axSpA, non-radiographic axial spondyloarthritis; Ps SpA, psoriatic spondyloarthritis; SpA, spondyloarthritis.

without sacroiliiitis (spondylitis without sacroiliiitis), both of them with psoriasis.

The interobserver agreement in the scoring of ZJ using De Vlam's method yielded a kappa value of 0.536 ($p<0.001$, $z=21.1$), indicating a moderate level of agreement among observers.

DISCUSSION

In our cohort of patients with axSpA, CS involvement was frequent and associated with male gender, higher age and BMI, smoking habit and higher disease activity. Additionally, it was more common in AS than in other types of axSpA, and clearly associated with worse mobility, functionality and greater radiographic damage. Interobserver agreement in scoring the ZJ using the De Vlam method indicated a moderate level of agreement among observers, reaffirming the validity of this method. Identifying possible factors related to cervical involvement in axSpA and recognising the validity of the De Vlam scoring method for ZJ are relevant for diagnosis and treatment of radiographic damage to prevent or slow its progression, which leads to patient disability and decreased quality of life.

Radiographic cervical damage can be observed independently of lumbar involvement in patients with axSpA. In a study by van Tubergen *et al*,[4] which evaluated clinical and radiological data from 132 patients over 4 years of follow-up, they found new bone formation at all levels, suggesting that it may not follow a specific direction and can occur arbitrarily at any level. In our study, approximately 12% of patients had CS involvement without radiographic changes in the lumbar spine. While this percentage may appear modest, it underscores the

Table 2 Differences between groups regarding zygapophyseal fusion

		Fusion group (n=69)	No fusion group (n=112)	P value
Male sex		62 (89.86)	89 (79.46)	0.105
Age		65.65±12.69	62.79±13.15	0.149
BMI		27.03±4.49	27.99±4.36	0.174
Non-smokers		26 (38.80)	40 (37.04)	0.809
Age at symptom onset		24.97±9.04	27.19±9.02	0.113
Age at diagnosis		31.56±11.78	34.63±11.93	0.094
HLA-B27 (+)		58 (84.06)	94 (83.93)	1
Family history of SpA		17 (24.64)	20 (17.86)	0.363
Uveitis		18 (26.09)	21 (18.75)	0.327
Psoriasis		6 (8.70)	4 (3.57)	0.258
IBD		8 (11.59)	6 (5.36)	0.215
Peripheral arthritis		30 (43.48)	29 (25.89)	0.022
Enthesitis		15 (21.74)	26 (23.21)	0.96
Dactylitis		1 (1.45)	2 (1.79)	1
axSpA type	AS	62 (89.86)	103 (91.96)	0.931
	EnA	4 (5.80)	5 (4.46)	
	Ps SpA	2 (2.90)	2 (1.79)	
	nr-axSpA	1 (1.45)	2 (1.79)	
BASDAI		3.65±2.02	3.85±2.22	0.539
BASFI		5.12±2.80	4.19±2.63	0.032
ASDAS-CRP		2.47±0.96	2.39±0.96	0.615
CS mobility (grades)		39.14°±25.14°	62.88°±19.64°	<0.001
Fleche (cm)		10.50±7.46	4.50±5.27	<0.001
Schober (cm)		1.89±1.36	3.18±1.66	<0.001
Modified Schober (cm)		3.04±1.86	4.85±2.26	<0.001
CS BASRI		3.23±1.21	2.24±0.99	<0.001
CS mSASSS		21.32±13.52	6.48±6.63	<0.001
Sacroiliac BASRI		3.72±0.82	3.29±0.84	<0.001
Lumbar BASRI		2.90±1.38	2.18±1.51	0.001
Lumbar mSASSS		19.77±14.67	10.70±12.10	<0.001
bDMARD		34 (49.28)	41 (36.60)	0.127

Results are expressed as n (%) or mean±SD. Ages are expressed in years.
AS, ankylosing spondylitis; ASDAS-CRP, Ankylosing Spondylitis Disease Activity Score; axSpA, axial spondyloarthritis; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; BASFI, Bath Ankylosing Spondylitis Functional Index; BASRI, Bath Ankylosing Spondylitis Radiology Index; bDMARD, biological disease-modifying antirheumatic drug; BMI, body mass index; CS, cervical spine; EnA, entheropathic arthritis (IBD-associated spondyloarthritis); IBD, inflammatory bowel disease; mSASSS, modified Stoke Ankylosing Spondylitis Spinal Score; nr-axSpA, non-radiographic axial spondyloarthritis; Ps SpA, psoriatic spondyloarthritis; SpA, spondyloarthritis.

importance of systematically evaluating the CS, independent of the lumbar or sacroiliac joints, as not all instances of radiographic damage appear to progress from caudal to cranial.

The characteristics of cervical involvement vary between patients with AS and psoriatic arthritis (PsA). In AS, the prevalence has been reported to be around 50% and has been associated with male sex, age, disease duration and disease activity, as well as the presence of uveitis.[3 13] Cervical involvement can be asymptomatic, leading to serious complications, making its diagnosis vital.[4 5 14 15] On the other hand, the prevalence of cervical involvement in axial PsA is estimated to be between 35% and 75%.[16] It tends to be more extensive compared with AS[17] and does not always show concomitant involvement of the sacroiliac joints.[18] Some studies have linked it to the type of psoriasis (scalp), severe peripheral involvement, enthesopathy and disease duration.[6 10 15] However, in others, there has been no clear association with cutaneous involvement. Furthermore, an association between cervical damage and HLA-B39, DR4 and DR5 genes in patients with PsA has been described.[19] Conversely, in

our population, no differences were observed between patients with or without cervical involvement in terms of the prevalence of peripheral or extramusculoskeletal manifestations.

Only two patients (0.6%) exhibited spondylitis without sacroiliitis, both of them with psoriasis, an observation that differs from the rest of the literature, as other studies have reported a prevalence of spondylitis without sacroiliitis in up to 35% of patients with axial PsA.[18] This discrepancy with the literature could be explained by the different characteristics of the populations.

Regarding ZJ, their evaluation allows for the identification of radiographic damage in a larger number of patients. In our study, it was observed in almost one-third of the patients (n=99; 29.1%), with 20 of them having exclusive involvement (5.9% of the global cohort). This prevalence is similar to what has been observed in other studies.[6 8 12] The involvement of ZJ may be related to reduced mobility, decreased functionality and increased disease activity,[5 8–10] which our results support.

Regarding the relationship between posterior radiographic damage and vertebral bodies, some studies have shown a high prevalence of ZJ ankylosis in long-standing AS, even higher than that of vertebral bodies,[8 14] while others, with prospective design, have found that anterior radiographic damage is almost double.[6] On the other hand, a recent study analysing a large number of X-rays over 16 years suggests a close relationship between anterior and posterior cervical involvement, as patients with at least one syndesmophyte tend to have greater ZJ damage.[7] However, the prevalence of vertebral body involvement remains higher than that of ZJ, consistent with the results of our study.

In our work, the choice of the De Vlam method for evaluating ZJ deserves special consideration. Various scoring methods for ZJ assessment have been proposed and validated[10 20]; however, the De Vlam method is the most prevalent in the literature.[8] Nevertheless, there is no consensus regarding its grading, and the definition of ZJ involvement remains heterogeneous in the literature, which can lead to variability in its prevalence. Most studies are based on the presence of fusion, considered a fairly specific lesion of inflammatory pathology.[7 21 22] In our case, we have contemplated that a De Vlam method score ≥3 already implies significant posterior radiographic damage and increases the likelihood of fusion. This cut-off might be able to discriminate between changes due to disease activity or degenerative pathology. As for interobserver variability, our study achieved moderate agreement, consistent with other studies,[6] which suggests potential adequate reliability of this method for use in clinical practice and research.

The proportion of patients with CS involvement who also had enthesitis is significant in our cohort. This correlation could be interpreted in light of recent theories suggesting that the enthesis is the pathogenic epicentre in axSpA.[2 23] According to this theoretical framework, entheses serve as initial points for inflammation, which can later spread to adjacent structures, including the spine. This finding raises the need for further studies that explore the relationship between enthesitis and cervical involvement to better understand underlying mechanisms and guide more effective therapeutic strategies.

This study presents some limitations, such as the use of simple X-rays for the assessment of structural damage. Distinguishing between degenerative and disease-specific changes can be challenging using this technique. However, as mentioned before, the established cut-off points might be reliable for the discrimination between them. Furthermore, while other imaging modalities for evaluating radiographic damage have emerged,[9] the validated scoring methods are currently limited to plain radiographs.[7 8] The widespread clinical use of X-rays, owing to its accessibility, enables its application in a large patient population.

In conclusion, the performance of CS radiography should be considered routine in clinical practice, especially in men, who seem to constitute a higher-risk group for the development of radiographic damage, as should the evaluation of ZJ since their involvement is common in axSpA and is related to increased disease activity and decreased functionality. According to our results, it seems that there is a close relationship between anterior and posterior cervical involvement, and both can be affected simultaneously as the underlying disease progresses. However, further studies, especially prospective ones, are needed to determine potential risk factors associated with radiographic CS involvement in patients with axSpA.

Contributors All authors had access to the data and these meet the Uniform Requirements for Manuscripts Submitted to Biomedical Journals Criteria for authorship. LB-A—substantial contributions to study conception and design, substantial contributions to acquisition of data, substantial contributions to analysis and interpretation of data, drafting the article or revising it critically for important intellectual content, final approval of the version of the article to be published, author acting as guarantor. DB—substantial contributions to analysis and interpretation of data, drafting the article or revising it critically for important intellectual content, final approval of the version of the article to be published. XM—substantial contributions to analysis and interpretation of data, drafting the article or revising it critically for important intellectual content, final approval of the version of the article to be published. JAN—substantial contributions to acquisition of data, final approval of the version of the article to be published. JMN—drafting the article or revising it critically for important intellectual content, final approval of the version of the article to be published. XJ—substantial contributions to study conception and design, substantial contributions to acquisition of data, drafting the article or revising it critically for important intellectual content, final approval of the version of the article to be published.

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