Limitations of lumbar spine MRI in the diagnosis of ankylosing spondylitis

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Abstract

Objective

To assess the value of inflammatory and fatty lesions in the lumbar spine on magnetic resonance imaging (MRI) in differentiating ankylosing spondylitis (AS) from non-inflammatory chronic back pain.

Methods

We reviewed the lumbar spine MR images of 192 consecutive AS patients and 208 non-AS subjects with non-inflammatory chronic back pain. Lesions including vertebral corner inflammatory lesions (CIL), inflammation in posterior elements (PE) of the spine, and fatty deposition lesions (FDL) seen on lumbar spine MRI were scored in a blinded manner.

Results

The frequencies of CIL and FDL in AS patients were higher than that in non-AS patients (both $p<0.01$), but there was no significant difference in the positive rate of inflammation in PE of the spine between two groups. AS patients had higher scores of all three types of lesions than non-AS patients (all $p<0.01$). Positive likelihood ratio increased as the cut-off score for distinguishing AS from other diseases increased (ranged from 1.14 to 18.42). But the biggest value of area under the receiver operating characteristic curve of all types of lesions was only 62.58%. We also summarised some features of these lesions that may help to distinguish AS from non-inflammatory chronic back pain.

Conclusion

Our study found that the value of inflammatory and fatty lesions (including CIL, inflammation in PE and FDL) seen on lumbar spine MRI in the diagnosis of AS was limited. But the diagnosis of AS would be more convincing if patients had high scores of these three types of lesions (CIL ≥16, and/or inflammation in PE of the spine ≥5, and/or FDL ≥2).

Key words

ankylosing spondylitis, MRI, diagnostic imaging

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Introduction

In recent years, magnetic resonance imaging (MRI) has been widely used as a diagnostic tool for spondyloarthropathy (SpA) (1-3). Several features of SpA detected by spine MRI have been identified, such as the vertebral corner inflammatory lesions (CIL) and inflammatory lesions in posterior elements (PE) of the spine (4-10). Many scoring methods have also been established to evaluate these lesions in SpA (9-16). Fatty deposition lesion (FDL) is another type of lesion seen on spine MRI, which is recently found to be a characteristic of axial SpA, and may be useful when inflammatory changes are absent (17, 18).

Ankylosing spondylitis (AS) is the most typical type of disease of SpA, which usually has a delay of diagnosis for several years and a considerable socio-economic impact for the patients (19, 20). Patients with the symptom of chronic back pain often have radiologic examinations of their lumbar spine only. Whether the inflammatory lesions and FDL seen on lumbar spine MRI can be used to differentiate AS from other diseases has seldom been discussed. In this study, we try to assess the value of these specific types of lesions seen on lumbar spine MRI in the diagnosis of AS.

Materials and methods

Subjects

This retrospective study was performed at the Third Affiliated Hospital of Sun Yat-sen University in China, from year 2007 to year 2011. Four hundred consecutive Chinese patients who had MR examinations of the lumbar spine for chronic back pain were recruited. They were divided into two groups: 1. AS group (n=192), patients who fulfilled the modified New York diagnostic criteria for AS (21); 2. Non-AS group (n=208), patients with mechanical back pain but could not met the criteria for AS. The diagnoses of the non-AS patients included: disc herniation (n=125), osteoarthritis (n=47), tumour (n=20), tuberculosis (n=11), and spine deformity (n=5). The gold-standard of diagnosis of the patients in the non-AS group was given by the treating physician basing on history, examination, non-radiological/radiological investigations, histology (when available), and clinical outcome data.

MRI scoring

MRI was performed using a 1.5T scanner (Signa Excite II, GE Medical Systems). Scan protocols were standardised across different subjects. Images were obtained from the 12th thoracic vertebra (T12) to the 1st sacral vertebra (S1) level with 4mm thick consecutive slices. Lesions in MR images of T1-weighted and short inversion time inversion recovery (STIR) sequences in both sagittal and axial planes were assessed. A training session was arranged prior to the assessments, in which multiple scans were reviewed to illustrate different examples of specific type of lesions. Each image was rated by 2 independent readers (XHD, radiologist, 35 years of experience, with lots experience in reading MRI of the spine; ZYH, rheumatologist, 6 years of experience) who were blinded to the patients' identities. The mean of the 2 readers' scores was used for all data analyses.

Bone marrow oedema (BME) was defined as a hyperintense signal on STIR image, corresponding to a hypointense signal on T1-weighted image with irregular contour, when compared to normal bone marrow signals coming from the centre of an unaffected vertebra (11, 12).

CIL was defined as sharply marginated BME lesion (Fig. 1). We used a scoring method similar to the Spondyloarthritis Research Consortium of Canada (SPARCC) spinal inflammation scoring method (13) to score the CIL. In brief, we calculated all the 6 spinal levels from the lower T12 to the upper S1. We assessed 3 consecutive slices that were most affected for each spinal level. Then, each spinal level was divided into 4 quadrants and scored on a dichotomous basis: 1 = increased signal, 0 = normal signal. Three consecutive slices results in a maximum score of 12 per spinal level. On each spinal level, an additional score of 1 was given for the presence of a lesion exhibiting intense in any quadrant on a single slice. Similarly, the presence of a lesion exhibiting depth ≥1 cm in any quadrant of a spinal

level was also given an additional score of 1. Therefore, the maximum additional score was 6 per spinal level. And our total score of lumbar spine CIL ranged from 0 to 108.

PE of the spine consists of 3 components: pedicles, facet joints, and the transverse and spinous processes. BME lesions present in these 3 components from the 1st lumbar vertebra (L1) to the 5th lumbar vertebra (L5) on sagittal or axial slices were scored in a dichotomous manner (Fig. 2). Any presence of inflammation in a component of a spinal level got a score of 1. Each spinal level had a total score ranged from 0 to 3, and the maximum score of 5 lumbar spine levels was 15.

FDL was the lesion present on any sagittal slices in vertebral corners, which had a high signal on T1-weighted images and a corresponding suppressed signal on STIR sequences (Fig. 3). Dichotomous method was also used to score FDL: 1 = presence of lesion in one corner, 0 = normal. The total score of FDL for 6 spinal levels from the lower T12 to the upper S1 ranged from 0 to 24 (each spinal level had 4 corners). Changes that extended diffusely along endplate which were Modic endplate changes (22) were excluded.

Reliability of scoring

Twenty cases of each group were selected randomly to be rescored again after all scoring was finished to allow the calculation of intrareader variability. Another twenty cases of each group were randomly selected to calculate the interreader reliability. Intraclass correlation coefficients (ICCs) of intrareader and interreader were calculated using analysis of variance (ANOVA). Both of the intrareader and interreader reliabilities of all three types of lesions were high. For intrareader reliabilities, ICCs of CIL, inflammation in PE of the spine, and FDL were 0.83, 0.82, and 0.90 respectively; for interreader reliabilities, ICCs were 0.88, 0.84, and 0.92 for CIL, inflammation in PE of the spine, and FDL, respectively.

Statistical analysis

The scores of three kinds of lesions in two groups were compared using ANOVA. Pearson's chi-square test was used to compare the prevalence of different types of lesions in two groups. Two-tail *p*-values of less than 0.05 were considered to be statistical significance. The sensitivity, specificity, and positive likelihood ratios (pLR) of each type of lesions in diagnosing AS were calculated by cross-table analysis. Receiver operating characteristic (ROC) curves and areas under the curve (AUC) were used (23, 24) to assess the diagnostic capacity of each kind of lesion. All statistical analyses were carried out in SPSS version 15.0.

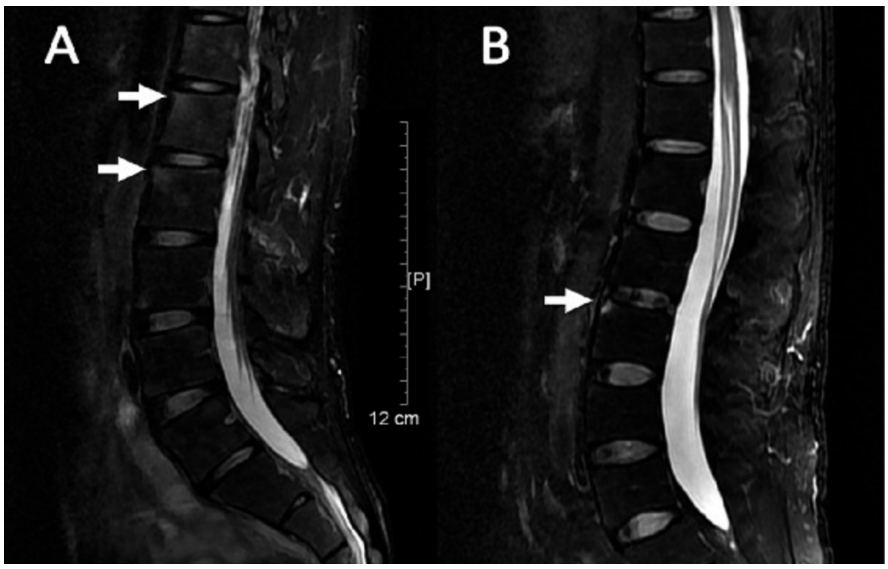

Fig. 1. A, A 23-year-old male patient with AS. The upper anterior corner of the first and second lumbar vertebral shows CIL with depth >1cm (shown by arrows) on a STIR sequences. The score of CIL of this patient is 6. **B**, A 34-year old male patient with AS. The upper anterior corner of the third lumbar vertebral shows CIL with intensity (shown by arrow) on sagittal STIR sequences.

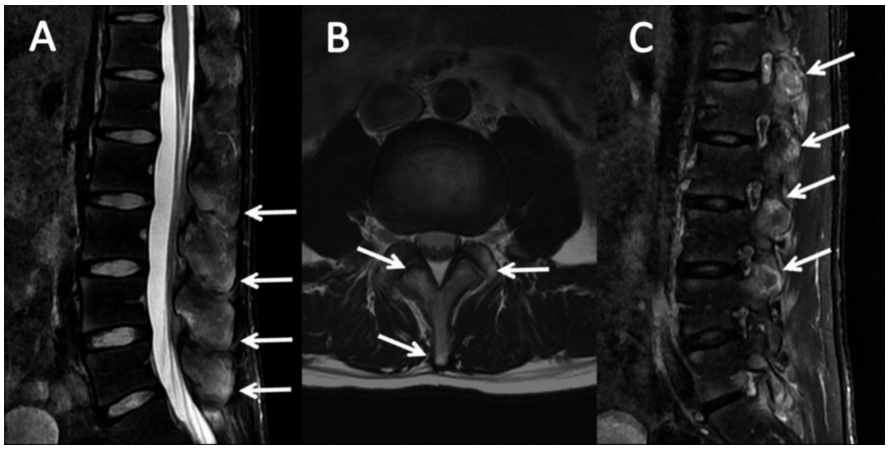

Fig. 2. A 19-year-old male patient with AS showed inflammation in PE of the spine on STIR sequences. **A**, inflammation in the spinous processes of the second to the fifth lumbar spine levels on sagittal plane (shown by arrows). **B**, inflammation in the facet joints and spinous process of the third lumbar spine level on axial plane (shown by arrows). **C**, inflammation in the pedicles of the first to the fifth lumbar spine levels on sagittal plane (shown by arrows).

Results

Characteristics of the subjects

Four hundred subjects, including 192 AS patients and 208 non-AS patients were included in this study. In the AS group, 150 were male, 153 (79.7%) were B27 positive, the age was 28.4±6.7 years (ranged from 12 to 51 years), and the disease duration was 5.6±7.2 years. 170 (88.5%) AS patients were treated with non-steroidal anti-inflammatory drugs or disease-modifying anti-rheumatic drugs or did not take any medicine at all. Only 11.5% of them (n=22) had been treated with biological agents.

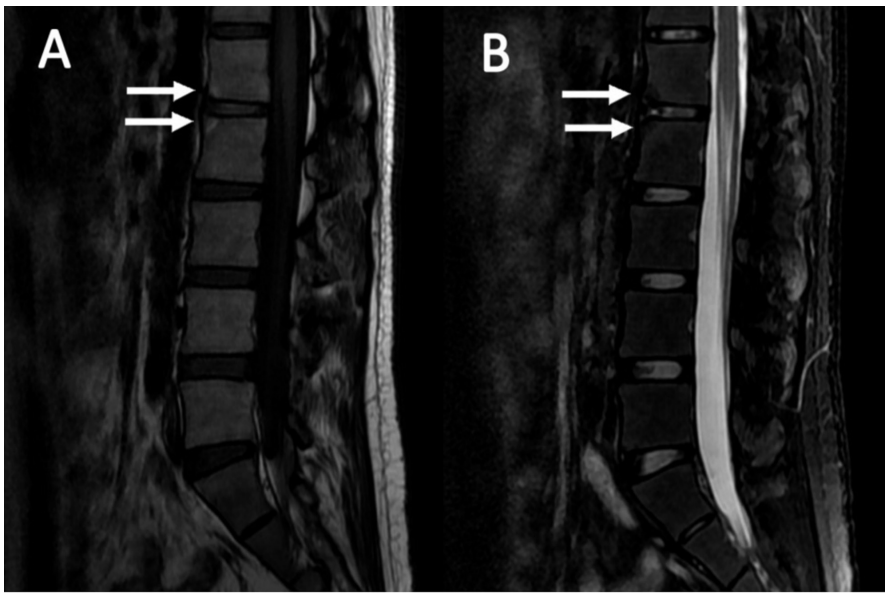

Fig. 3. FDL on lumbar spine MRI found in a 26-year-old male patient with AS. A, high signals in the lower anterior corner of the first lumbar vertebral and upper anterior corner of the second lumbar vertebral on T1-weighted image (shown by arrows). B, suppressed signals on STIR sequence in the corresponding sites (shown by arrows).

Table I. The scores of CIL, inflammation in PE of the spine, and FDL of AS and non-AS patients seen on lumbar spine MRI.

MRI characteristic	AS Group (mean ± SD)	non-AS Group (mean ± SD)	*p*-value*
CIL	11.3 ± 6.4	4.2 ± 2.7	0.002
Inflammation in PE of the spine	2.6 ± 2.8	1.8 ± 1.9	0.009
FDL	0.5 ± 1.2	0.1 ± 0.4	0.000

*p-value for the difference between AS and non-AS groups. AS: ankylosing spondylitis; CIL: vertebral corner inflammatory lesions; PE: posterior elements; FDL: fatty deposition lesions.

In the non-AS group, 158 were male, 13 tested for HLA-B27 and all were negative. The age of the non-AS group was 45.9±9.2 years (ranged from 13 to 72 years), which was significantly older than the AS group (p<0.05).

Features of individual lesions

The scores of CIL, inflammation in PE of the spine, and FDL are shown in Table I. The distributions of specific type of lesions are listed in Table II.

i. *Vertebral corner inflammatory lesions*

CIL was the most frequently recorded pattern of lesions in both groups. The total number of corners with CIL was 2659 (27.7%). The positive rate of CIL in AS group (the percentage of patients who had one or more corners with CIL) was significantly higher than that in non-AS group (51.6% *vs*. 44.7%, p<0.01). 64 AS patients and 17 non-AS patients reached the score of 16, which has a specificity of 0.92 in diagnosing AS (shown in Table III). The mean score of CIL in the AS group was remarkably greater than that in the non-AS group (p<0.01). Anterior vertebral were much more commonly affected with CIL than posterior vertebral in both groups (both p<0.05). The most and least affected sites with CIL were different between two groups (shown in Table II).

ii. Inflammation in PE of the spine

Compared to the non-AS group, the AS group showed a remarkably greater mean score of inflammation in PE of the spine, and a significantly higher positive rate of inflammation in pedicle (both p<0.01). The most and least affected sites of inflammation in PE of the spine were also different between two groups (shown in Table II), while, the positive rates of inflammation in PE were similar in two groups (31.8% in

Table II. Features of CIL, inflammation in PE of the spine, and FDL in AS and non-AS patients.

Feature	CIL (positive rate)		Inflammation in PE of the spine (positive rate)		FDL (positive rate)	
	AS	non-AS	AS	non-AS	AS	non-AS
Male *vs*. Female	52.0% *vs*. 50.0%	45.6% *vs*. 42.0%	31.3% *vs*. 33.3%	27.2% *vs*. 30.0%	12.7% *vs*. 11.9%	5.7% *vs*. 8.0%
Anterior *vs*. Posterior vertebral	48.1% *vs*. 23.9%*	29.1% *vs*.11.0 %*	NA	NA	2.5% *vs*. 1.7%*	0.5% *vs*. 0.4%
Superior *vs*. Inferior vertebral	36.2% *vs*. 35.8%	19.5% *vs*. 20.6%	NA	NA	2.2% *vs*. 2.0%	0.6% *vs*. 0.2%*
Pedicle	NA	NA	14.3%*	7.9%*	NA	NA
Facet joints	NA	NA	18.8%	15.2%	NA	NA
Transverse and spinous process	NA	NA	19.0%	15.7%	NA	NA
Most affected site	upper-anterior L1 (42.3%)	upper-anterior L4 (25.5%)	L2 level (31.4%)	L4 level (26.5%)	upper-anterior L2 (6.6%)	upper-anterior L4 (2.3%)
Least affected site	lower-posterior L5 (9.6%)	lower-posterior T12 (2.9%)	L5 level (14.9%)	L1 level (8.0%)	lower-posterior L4 (0.0%)	many sites# (0.0%)

*Significantly different (p<0.05) between AS and non-AS patients. NA: not applicable. AS: ankylosing spondylitis; CIL: vertebral corner inflammatory lesions; PE: posterior elements; FDL: fatty deposition lesions. #The sites included: upper- anterior of S1, upper- posterior of L1 and L2, lower- anterior of L4 and L5, lower-posterior of T12, L1, L4 and L5.

AS group, and 27.9% in non-AS group, p=0.103).

iii. Fatty deposition lesions

FDL was rarely present, which was only found in 24 AS patients and 13 non-AS patients. Besides, in the non-AS group, only 3 patients had a score of 2, and all the others scored less than 2. Both the positive rate and the mean score of FDL of the AS group were significantly higher than those of the non-AS group (12.5% *vs*. 6.3%, and 0.5 *vs*. 0.1, both p<0.01). The most commonly affected site of FDL was also different between two groups (shown in Table II). In AS patients, anterior vertebral was much more commonly affected than posterior vertebral (p<0.05); while, in non-AS patients, the superior half vertebral was more commonly affected than the inferior half vertebral (p<0.05).

Analysis of diagnostic utility

The sensitivity, specificity, pLR and AUC of different scores of the three types of lesions in diagnosing AS are listed in Table III. PLR increased as the cut-off score for distinguishing AS from other diseases increased (ranged from 1.14 to 18.42). High scores of lesions (including CIL ≥16, inflammation in PE of the spine ≥5 and FDL ≥2) had high specificity (≥0.89). However, due to the relatively low sensitivity, the biggest AUC value was quite low (62.58%). We also tested the diagnostic value of different combinations of the three types of lesions, for example, CIL plus FDL. But none of them had a better AUC value (data not shown). Besides, we counted the score of CIL without weight on the intense and depth, and assessed the diagnostic value of this separate CIL score. But it could not reach a better AUC value either (data not shown).

Table III. Sensitivity, specificity, positive LR and AUC for different scores of CIL, inflammation in PE of the spine, and FDL in diagnosing AS.

MRI characteristic	Sensitivity	Specificity	Positive LR	AUC (%)
Score of CIL				
≥1	0.52	0.55	1.15	53.43
≥6	0.45	0.66	1.33	55.59
≥11	0.40	0.78	1.83	59.46
≥16	0.33	0.92	4.08	62.58
≥21	0.22	0.97	7.58	59.50
≥31	0.09	1.00	18.42	54.19
Score of inflammation in PE of the spine				
≥1	0.32	0.72	1.14	51.94
≥5	0.24	0.89	2.27	56.69
≥9	0.15	0.96	3.37	55.13
≥13	0.08	1.00	16.25	53.67
Score of FDL				
≥1	0.13	0.94	2.00	53.13
≥2	0.09	0.99	6.14	53.71

LR: likelihood ratio; AUC: area under receiver operating characteristic curve; AS: ankylosing spondylitis; CIL: vertebral corner inflammatory lesions; PE: posterior elements; FDL: fatty deposition lesions.

Discussion

This study systematically assessed the value of inflammatory and fatty lesions in the lumbar spine seen on MRI in differentiating AS from other diseases with chronic back pain. The features of CIL, inflammation in PE of the spine, and FDL in AS and non-AS patients were summarised. We found that, AS patients had higher scores of all these three types of lesions than non-AS patients. CIL and FDL were more commonly found in AS patients than non-AS patients, while there was no significant difference in the positive rate of inflammation in PE of the spine between two groups. In the diagnosis of AS, the higher cut-off score of the lesions we used, the greater pLR was obtained, and more convincing the diagnosis would be. Although they had relatively low sensitivity, which resulted in low AUC value, the high specificity of specified types of MRI lesions might be helpful in diagnosing AS when they are present in individual cases.

CIL was the most frequently recorded pattern of lesions in this study, which was commonly seen in both AS and non-AS patients. This was in accordance with other studies (8, 15). The most commonly affected site of CIL was the upper-anterior L1 in AS patients, and the upper-anterior L4 in non-AS patients. This finding was similar to the previous study (15). Although AS patients had significantly higher scores of CIL than non-AS patients, the sensitivity and the corresponding pLR of CIL was not high enough to diagnose AS. Since the AUC value takes both the sensitivity and specificity into account (24), it may be a better index to assess the diagnostic value than pLR. CIL had the biggest AUC value (62.58%) among the three types of lesions in this study, but such AUC value was still not high enough to make it a new diagnostic criteria. Nevertheless, high score CIL (≥16) showed a high specificity (0.92), which indicates that once they are found the diagnosis of AS is highly suspected.

Some researchers reported that the assessment of posterior structures was important in AS, since the inflammation in this location was present in the majority of AS patients (9). Pathologic studies also showed inflammations within facet joints in AS (25). However, the positive rate of this type of lesion was not statistically different between AS and non-AS patients in our study, and the sensitivity, pLR and AUC value of it were not satisfactory, either. This may due to the fact that the thoracic spine was more commonly affected with BME than the lumbar spine in AS (8). When we assessed the lumbar spine only, the positive rate of inflammatory lesion in AS patients might be reduced. Nonetheless, high specificity was found in score of inflammation in PE of the spine of ≥5. This may be useful in differentiating individual cases of AS from other diseases.

FDL was relatively seldom recorded. As the name of FDL based on the hypothesis that in the natural history of AS, inflammatory vertebral corners may be followed by fatty replacement before sclerotic bone formation (26, 27), FDL thus may represent a post-inflammatory stage prior to the bone sclerosis which often takes up to 10 years (28). The mean age of our AS patients was 28.4 years, and the mean disease duration was 5.6 years. These patients were prob-

ably in the post-inflammatory stage of AS, and showed a significantly higher positive rate of FDL than the non-AS patients. However, this positive rate of FDL was lower than that in a previous study (17), in which the majority of FDL in AS was present in the thoracic spine but not the lumbar spine. We only scored the lumbar spine; this may be the main reason for the lower positive rate in our study. Besides, 11.5% of the AS patients in this study had been treated with biological agents. Receiving early biological treatment theoretically may prevent the development of inflammation and their subsequent evolution into fatty deposition lesions. This may also be a reason why the positive rate of FDL we observed was lower. In this study, FDL was found in only 13 non-AS patients, and none of them had a score of more than 2. Thus, we proposed that if a FDL score of more than 2 was seen on lumbar spine MRI, the diagnosis of AS should be considered.

Patients with chronic back pain usually take the examination of lumbar spine MRI without having x-rays or MRI of the sacroiliac joints done. Some experts pointed out that inflammation could be confined to the spine and do not involve the sacroiliac joints in AS (29). Therefore, in this study, we assessed the diagnostic value of lumbar spine MRI in AS. We found that the greater scores of lesions we used as the cut-off value to distinguish AS from other diseases, the higher specificity and pLR were obtained. Due to its low sensitivity, the three types of lesions in lumbar spine MRI had a limited role in diagnosing AS in the majority of cases. However, thanks to the high specificity, very high scores of inflammatory lesions (CIL ≥16, inflammation in PE of the spine ≥5), fatty lesions (FDL ≥2), might be helpful in the diagnosis of individual cases.

In conclusion, we had conducted a systematic assessment of inflammatory and fatty deposition lesions seen on lumbar spine MRI in AS and non-AS patients with chronic back pain. We found that the diagnostic value of those lesions in lumbar spine MRI to AS was limited. However, a high specificity of high scores of lesions found in lumbar spine MRI may be of diagnostic value in selected cases.

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