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# Distinguishing bone marrow edema patterns on MRI between spondyloarthritis and diffuse idiopathic skeletal hyperostosis

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## Abstract

**Background** Bone marrow edema (BME) in the vertebral body, a key feature of spondyloarthritis (SpA), is not uncommon in diffuse idiopathic skeletal hyperostosis (DISH). Our study aims to compare the vertebral BME patterns on MRI between DISH and SpA.

**Methods** This retrospective study included 273 patients with DISH and 132 patients with SpA who underwent whole-spine MRI. Two radiologists jointly assessed primary imaging features on radiographs and MRI of the spines, followed by independent evaluations of BME characteristics including the presence, location, signal intensity and associated finding of BME to distinguish between DISH and SpA groups. Imaging characteristics of BME were compared with univariate and multivariate logistic regression tests using Generalized Estimating Equations.

**Results** Patients with DISH were significantly older than those with SpA ( $68.3 \pm 9.3$  vs.  $38.9 \pm 13.5$  years,  $P < 0.001$ ). BME was more prevalent in SpA than in DISH (31.8% vs. 20.9%,  $P = 0.016$ ). In SpA, BME was significantly more likely to appear at the posterior corner (odds ratios (ORs) from multivariate logistic regression for reviewers 1 and 2: 46.01 and 38.95, respectively) or posterior band (ORs, 41.38 and 15.42), and demonstrate stronger hyperintensity (ORs, 7.66 and 7.99). BME with fatty changes was also associated with the diagnosis of SpA (ORs, 2.52 and 2.59).

**Conclusion** Characteristic BME patterns on spine MRI, particularly posterior location, marked hyperintensity, and accompanying fatty changes, could help distinguish SpA from DISH in diagnostically challenging cases with overlapping MRI manifestations.

**Keywords** Spine MRI, Diffuse idiopathic skeletal hyperostosis, Axial spondyloarthritis, Ankylosing spondylitis, Bone marrow edema

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## Background

Spondyloarthritis (SpA) is a group of inflammatory diseases affecting the spine and joints. Diagnosing SpA involves a combination of clinical symptoms, laboratory results, and imaging findings. Recently, MRI has become essential for early diagnosis of SpA by identifying bone marrow edema (BME) in the sacroiliac joints, a major criterion of Assessment of SpondyloArthritis International Society (ASAS) classification system [1]. However, it has also been reported that BME can occur exclusively in the spines [2]. Moreover, routine spine MRI does not include the sacroiliac joints. Therefore, the detection of BME in vertebral bodies can be crucial for suggesting SpA and prompting further investigation.

One diagnostic challenge in differentiating SpA on spine MRI is diffuse idiopathic skeletal hyperostosis (DISH), a common, non-inflammatory skeletal disorder marked by osseous bridging across vertebral bodies and ossification of entheses [3]. In contrast to SpA, which affects a relatively younger population, DISH is more commonly seen in older adults. Its prevalence varies from 2.9% to 27.2% [4–6], and can reach up to 42% in men older than 65 years [7]. Traditionally, DISH is diagnosed using the imaging criteria proposed by Resnick and Niwayama, which require the presence of characteristic ossifications across four contiguous vertebrae on radiographs [3], often mistaken for the non-marginal syndesmophytes of SpA [8]. Additionally, the BME in the vertebral bodies of patients with DISH patients is not uncommon, further complicating the differentiation from SpA [9–11]. To date, no study has specifically examined the BME patterns between DISH and SpA. Identifying distinct BME patterns on MRI between these conditions could aid in differentiating between them. Thus, our study aims to compare BME patterns on MRI in SpA versus DISH.

## Methods

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, and the protocol was approved by the Institutional Review Board (IRB) of [Chung-Ang University Hospital] (approval number: No. 2301-029-19455). The need of informed consent was waived by the committee due to its retrospective nature.

### Patients

First, we retrospectively reviewed the imaging and medical records of patients ( $n = 2595$ ) aged 20 to 85 years who underwent both spine MR and spine radiographs between January 2021 and August 2022 in a single institution to identify the DISH group. Two musculoskeletal radiologists (J.Y. J., and S. K., with 16 and 14 years of experience in musculoskeletal radiology, respectively)

reviewed the spine radiographs including the sacroiliac joints, and MR imaging and selected patients with flowing ossifications at least four contiguous vertebrae and the absence of sacroiliac joint erosions in accordance with the consensus criteria for DISH [3, 12, 13]. All discrepancies between the two readers were resolved by consensus after a joint review session. Among the 2595 patients with spine MR and spine radiographs, 573 patients were diagnosed with DISH. Furthermore, the medical record and laboratory results of 573 patients with DISH were reviewed to eliminate the possibility of other condition. The exclusion criteria were as follows: (1) postoperative state ( $n = 117$ ), (2) recent vertebral body fracture ( $n = 133$ ), (3) underlying malignancy ( $n = 27$ ), (4) infectious spondylitis ( $n = 21$ ), and (5) poor image quality ( $n = 2$ ). Finally, the DISH group consisted of 273 patients (Fig. 1).

Second, we reviewed the spine MRI and spine radiographs of patients aged 20 to 85 years who were diagnosed with SpA between January 2017 and August 2022 to identify the SpA group. The diagnosis was made by a rheumatologist based on the clinical findings, laboratory findings, and imaging studies including spine radiographs and MRI in accordance with the ASAS classification criteria [1]. Patients with psoriatic manifestations of the skin or nails were not included in our study. Among a total of 145 SpA patients with spine MRI, 13 patients were excluded due to postoperative state ( $n = 6$ ), recent vertebral body fracture ( $n = 4$ ), and underlying malignancy ( $n = 3$ ). Eventually, the SpA group comprised 132 patients (Fig. 1).

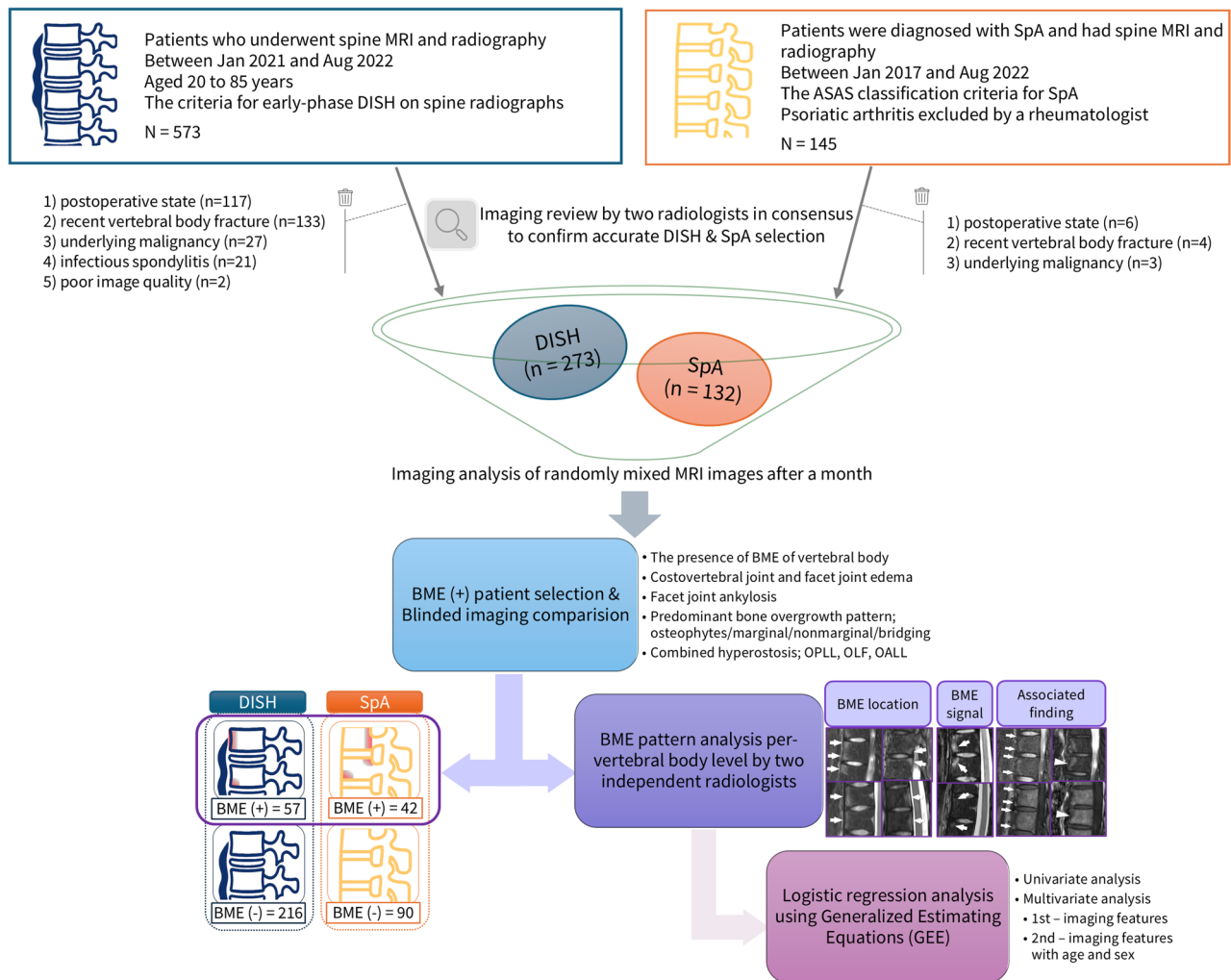
### MR imaging

Spine MR imaging was performed in the supine position. All patients were scanned with a 3T MR scanner (MAGNETOM Skyra, Siemens Healthcare) with a 32-channel spine matrix coil and a body matrix coil. Whole spine MR imaging from the skull base to the coccyx was obtained using three imaging steps of sagittal T2-weighted Dixon TSE sequence including one in-phase and the other water-phase. The detailed imaging parameters were as follows: TR: 3960 ms, TE: 87.00 ms, echo train length: 16, FOV: 250 × 289 mm, matrix: 256 × 278, NEX: 1, acquisition time: 1 min 50 s, slice thickness: 3.0 mm, gap: 0.3 mm, flip angle: 133 deg, PAT factor: 2, and PAT mode GRAPPA (generalized autocalibrating partially parallel acquisition).

### Image analysis

#### *Preassessment for the inclusion of BME-positive patients and comparison of classical imaging characteristics*

While the classification criteria for SpA are well established, the diagnosis of DISH relies primarily on imaging features. Therefore, two radiologists (J.Y. J., and S. K., with 16 and 14 years of experience in musculoskeletal

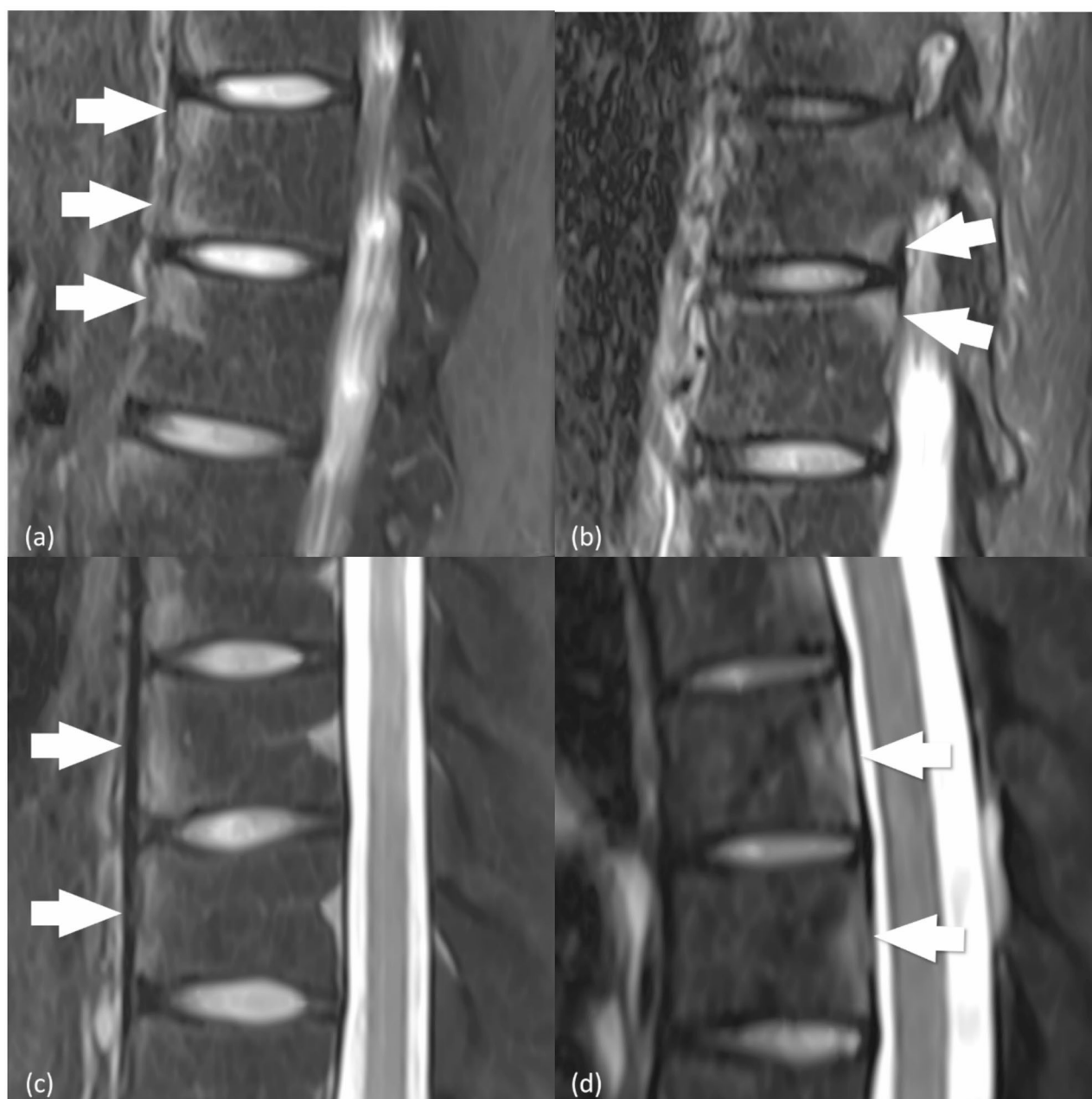


**Fig. 1** The schematic diagram of this study. DISH=diffuse idiopathic skeletal hyperostosis, SpA=spondyloarthritis, BME=bone marrow edema, ASAS classification=the Assessment of SpondyloArthritis international Society classification, OPLL=ossification of the posterior longitudinal ligament, OLF=ossification of the ligamentum flavum, OALL=ossification of the anterior longitudinal ligament

imaging, respectively) jointly assessed and compared primary imaging features to ensure that the DISH group was properly selected in contrast to the SpA group. Following the initial assessment, MR imaging of the DISH and SpA groups were randomly mixed, and two groups were assessed after a one-month washout period in a blinded manner with respect to the diagnosis. The assessed imaging features encompassed costovertebral joint and facet joint edema, facet joint ankylosis, predominant bone overgrowth pattern, and combined hyperostosis, including ossification of the posterior longitudinal ligament (OPLL), ligamentum flavum (OLF), and anterior longitudinal ligament (OALL). The bone overgrowth pattern was categorised into four types: (1) osteophytes, (2) marginal osteophytes, (3) nonmarginal osteophytes, and (4) bridging osteophytes [12] (Fig. 1). All discrepancies between the two readers were resolved by consensus after joint review.

#### Analysis of BME per-vertebral body level

Two reviewers (J.Y. J., and S. K.) assessed MRI first to identify the presence of BME in any of the vertebral bodies. In cases where BME was found, the two radiologists independently analysed the MRI for each level of the spine (Fig. 1). The assessed features on each BME-positive vertebral body included the location, intensity, and pattern of the lesions on T2-weighted and fat-suppressed T2-weighted images. The BME location in the vertebral body was categorised as the anterior corner, posterior corner, anterior band, or posterior band (Fig. 2). The signal intensity (SI) of BME was categorised as weak or strong, using SI of cerebrospinal fluid as a reference (Fig. 3); a strong SI indicated that the SI of BME was higher than that of cerebrospinal fluid, while a weak SI denoted that the SI of BME was lower than that of cerebrospinal fluid. The associated findings of BME were also categorised as BME only, BME with fat deposition, or

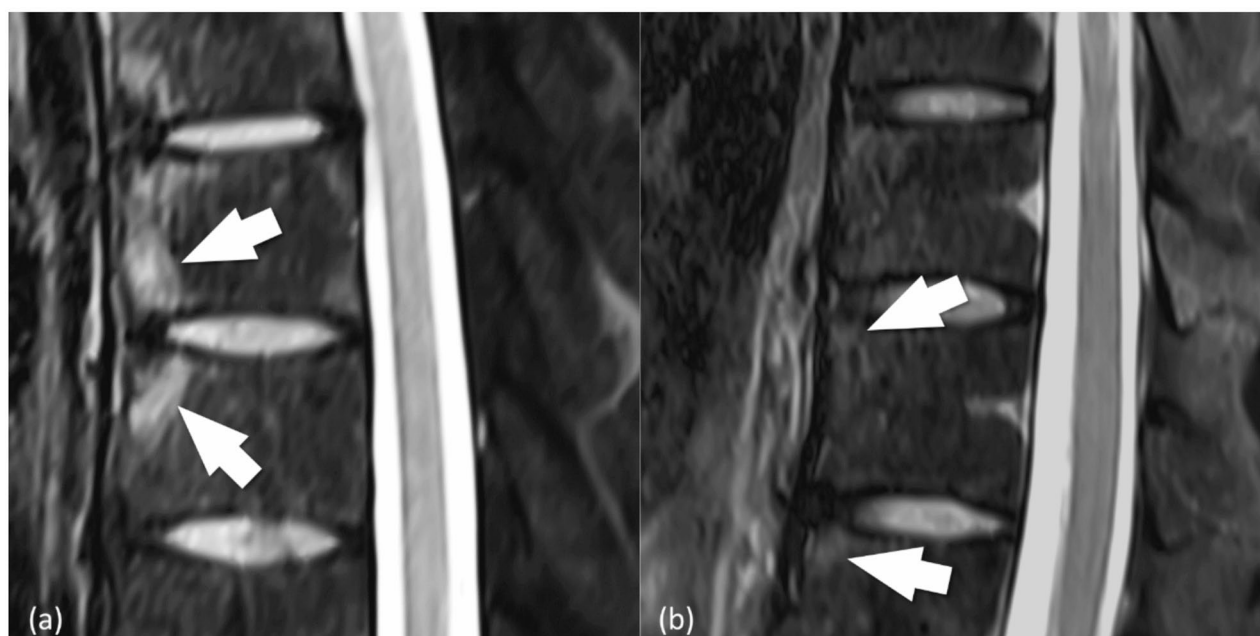


**Fig. 2** The representative MR images of the location of bone marrow edema in the vertebral body. **(a)** Anterior corner location and **(c)** anterior band location of bone marrow edema in a patient with axial spondyloarthritis. **(b)** Posterior corner location and **(d)** posterior band location of bone marrow edema in a patient with axial spondyloarthritis. Bone marrow edema showing a triangular shape at the anterior superior or inferior corner of vertebral body is categorised as anterior corner location (**a**, arrows). Triangular bone marrow edema at the posterior superior or inferior corner of vertebral body is categorised as posterior corner location (**b**, arrows). Bone marrow edema which appears as a band along the anterior or posterior wall is classified as anterior band (**c**, arrows) or posterior band location (**d**, arrows), respectively

BME with sclerosis (Fig. 4). When more than one site of BME was present in a single vertebral body, the predominant BME was selected as the representative lesion. All MR images were evaluated on a DICOM viewer (Zetta PACS, Taeyoung Soft Co. Ltd.).

#### Statistical analysis

A *t*-test was used to compare age, and Fisher's exact test or the Chi-square test was used to compare sex, the presence of BME, and established features, including costovertebral joint edema, facet joint edema, the predominant and most common bone overgrowth pattern and the presence of OPLL, OLF, and OALL, between the



**Fig. 3** The representative MR images of the signal intensity of bone marrow edema. **(a)** A fat suppressed T2-weighted image shows a bone marrow edema categorised as strong, with signal intensity similar to that of cerebrospinal fluid (arrows) in a patient with SpA. **(b)** On fat suppressed T2-weighted image, vertebral bodies display bone marrow edema with weak hyperintensity (arrows) in a patient with DISH

two groups. Interreader agreement was determined using Cohen's kappa statistics.

To identify the imaging features of BME to differentiate SpA and DISH, we performed logistic regression using Generalized Estimating Equations (GEE) with an exchangeable correlation structure to account for intra-subject clustering. For univariate analysis, separate GEE models were applied to each BME characteristic. For multivariate analysis, two models were constructed: one adjusting for all imaging features to assess their independent contributions, and another further adjusting for age and sex to control for demographic confounders. All statistical analyses were performed using R software (v. 4.1.0; <http://www.Rproject.org>), and a  $p$  value of  $< 0.05$  was considered statistically significant. Cohen's kappa statistics were graded as fair ( $< 0.40$ ), moderate ( $0.40$ – $0.60$ ), substantial ( $0.61$ – $0.80$ ), and almost perfect ( $> 0.80$ ) [14].

## Results

### The clinical evaluation of patients

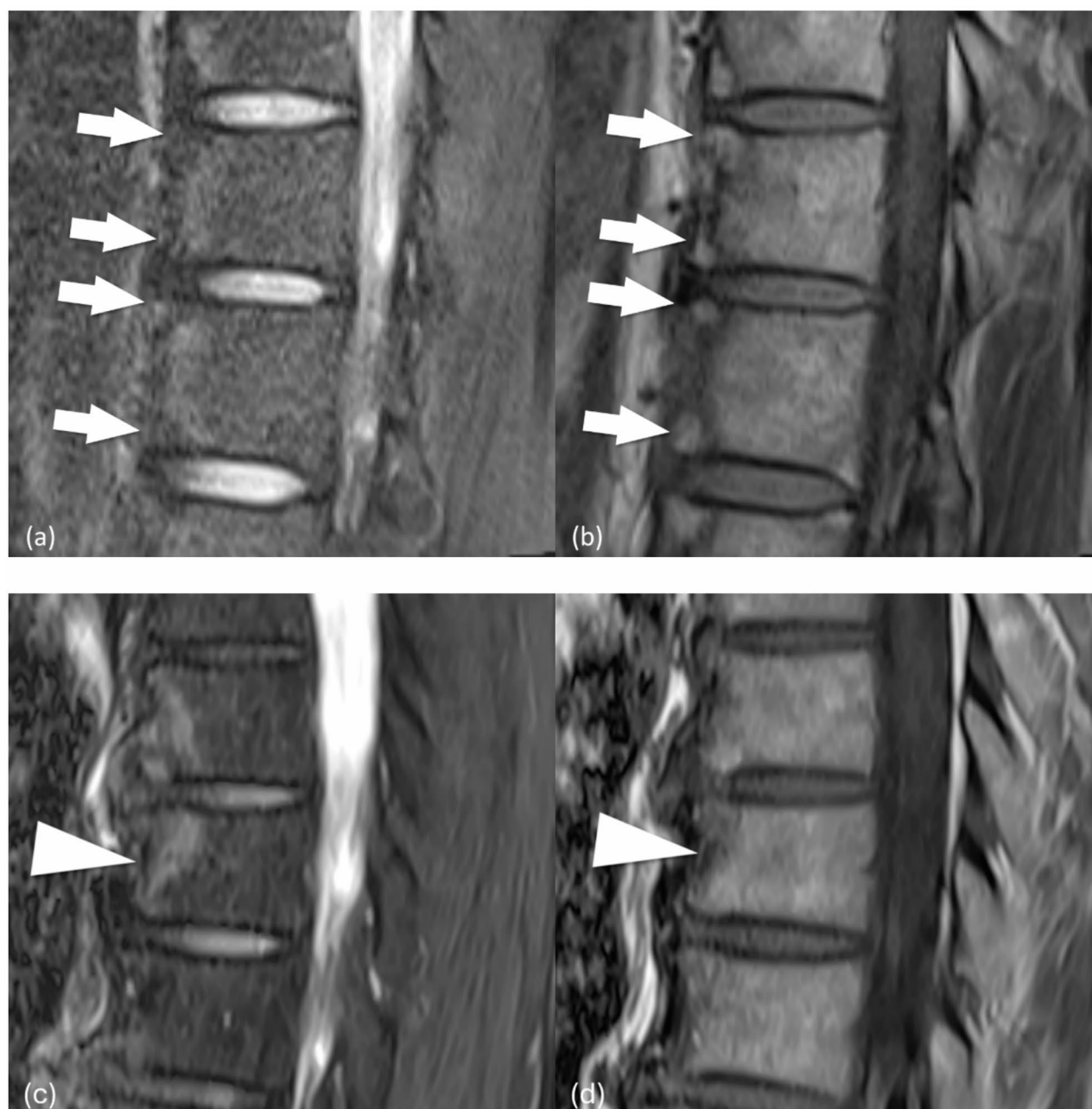
Table 1 shows the demographic and imaging features of the patients in both the DISH and SpA groups. DISH patients were older than SpA patients (mean age  $\pm$  standard deviation;  $68.3 \pm 9.3$  years in DISH versus  $38.9 \pm 13.5$  years in SpA,  $P < 0.001$ ) and the DISH group included a higher proportion of males than the SpA group ( $n = 196/273$  [71.8%] versus  $n = 88/132$  [66.7%],  $P = 0.299$ ). Regarding radiographic findings, DISH patients more frequently exhibited nonmarginal (49.8% versus 3.8%) or

bridging osteophytes (49.5% versus 9.1%) compared to SpA patients ( $P < 0.001$ ), whereas facet ankylosis (0.4% versus 9.1%,  $P < 0.001$ ) were more common in the SpA group. BME identified on MRI in the vertebral body (20.9% in DISH versus 31.8% in SpA,  $P = 0.016$ ) was less frequently observed in the DISH group than in the SpA group, and no costovertebral joint edema (0% versus 18.2%,  $P < 0.001$ ) was observed in the DISH group.

### Analysis of bone marrow edema pattern

Table 2 demonstrates the patterns of BME in the vertebral body, independently assessed by both reviewer 1 and reviewer 2. There were substantial interrater agreements for the presence of BME in the vertebral body ( $\kappa = 0.798$ ), lesion location ( $\kappa = 0.768$ ), and the associated finding of BME ( $\kappa = 0.610$ ). There was almost perfect agreement for the intensity of BME ( $\kappa = 0.850$ ). All BME patterns analysis demonstrated significant differences between the two groups ( $P < 0.001$ ). In the SpA group, BME was more frequently observed in the posterior corner (9.5–13.2% vs. 0.3–0.6% in DISH) or band (3.3–3.7% vs. 0.3–0.8% in DISH) location ( $P < 0.001$ ), and exhibited strong signal intensity of BME (11.9–12.6% vs. 2.5–3.0% in DISH) more often ( $P < 0.001$ ). Furthermore, BME with fatty change (14.6–22.9% in SpA vs. 6.7–9.8% in DISH) was more commonly seen in SpA, whereas BME with sclerosis (8.3–13.7% in SpA vs. 23.1–36.0% in DISH) was more common in the DISH group ( $P < 0.001$ ).

In multivariate logistic regression analysis of both reviewers, regardless of the inclusion of demographic



**Fig. 4** The representative MR images of associated findings of bone marrow edema. **(a)** fat suppressed T2-weighted image, and **(b)** T1-weighted image) MR images in a patient with SpA shows bone marrow edema with fat deposition (arrows) in the vertebral bodies. **(c)** fat suppressed T2-weighted image, and **(d)** T1-weighted image) MR images of a patient with DISH show bone marrow edema with sclerosis in a vertebral body, showing low signal intensity on both T2 and T1 weighted images (arrow-heads)

factors, the posterior corner location (odds ratio (OR), 9.99–46.01), the posterior band location (OR, 4.24–41.38), strong hyperintensity (OR, 4.58–7.99), and associated fatty change (OR, 2.00–2.59) were more strongly associated with SpA than DISH as indicated by the odds ratio. In contrast, the anterior band (OR, 0.33–1.18) and associated sclerosis (OR, 0.34–0.48) were more suggestive of DISH (Table 3). In the adjusted 2nd model including the imaging features, age and sex, BME at the

posterior corner location remained significantly associated with SpA, with an OR [95% confidence interval] of 46.01 [4.58–462.36] for Reviewer 1 ( $P=0.001$ ) and 38.95 [6.91–219.48] for Reviewer 2 ( $P<0.001$ ). Similarly, BME at the posterior band location was associated with SpA (41.38 [3.19–536.20],  $P=0.004$  for Reviewer 1; 15.42 [1.32–179.88],  $P=0.029$  for Reviewer 2). Additionally, stronger hyperintensity (7.66 [2.05–28.64],  $P=0.002$  for Reviewer 1; 7.99 [2.00–31.86],  $P=0.003$  for Reviewer 2)

**Table 1** Clinical and overall imaging characteristics in DISH and SpA groups

|                                         | DISH<br>(n = 273) | SpA<br>(n = 132) | P-value |
|-----------------------------------------|-------------------|------------------|---------|
| Sex                                     |                   |                  | 0.299   |
| Male                                    | 196 (71.8%)       | 88 (66.7%)       |         |
| Female                                  | 77 (28.2%)        | 44 (33.3%)       |         |
| Age (years)                             | 68.3 ± 9.3        | 38.9 ± 13.5      | < 0.001 |
| Bone marrow edema in vertebral body (+) | 57 (20.9%)        | 42 (31.8%)       | 0.016   |
| Costovertebral joint edema (+)          | 0 (0%)            | 24 (18.2%)       | < 0.001 |
| Facet edema (+)                         | 23 (8.4%)         | 7 (5.3%)         | 0.261   |
| Predominant bone overgrowth pattern     |                   |                  | < 0.001 |
| No overgrowth                           | 0 (0%)            | 89 (67.4%)       |         |
| Osteophytes                             | 2 (0.7%)          | 8 (6.1%)         |         |
| Marginal osteophytes                    | 0 (0%)            | 18 (13.6%)       |         |
| Non-marginal osteophytes                | 136 (49.8%)       | 5 (3.8%)         |         |
| Bridging osteophytes                    | 135 (49.5%)       | 12 (9.1%)        |         |
| OPLL (+)                                | 23 (8.4%)         | 9 (6.8%)         | 0.574   |
| OLF (+)                                 | 60 (22.0%)        | 18 (13.6%)       | 0.046   |
| OALL (+)                                | 75 (27.5%)        | 15 (11.4%)       | < 0.001 |
| Facet ankyloses (+)                     | 1 (0.4%)          | 12 (9.1%)        | < 0.001 |

OPLL = ossification of the posterior longitudinal ligament, OLF = ossification of the ligamentum flavum, OALL = ossification of the anterior longitudinal ligament

**Table 2** Patterns of bone marrow edema in vertebral bodies with interobserver agreements

|                                                                         | Reviewer 1          |                    | Reviewer 2          |                    | kappa |
|-------------------------------------------------------------------------|---------------------|--------------------|---------------------|--------------------|-------|
|                                                                         | DISH                | SpA                | DISH                | SpA                |       |
| Number of vertebral bodies with edema /Total number of vertebral bodies | 328/1311<br>(25.0%) | 336/966<br>(34.8%) | 360/1311<br>(27.5%) | 349/966<br>(36.1%) | 0.798 |
| Location                                                                | < 0.001             |                    | < 0.001             |                    | 0.768 |
| Anterior corner                                                         | 159<br>(48.5%)      | 216<br>(64.3%)     | 217<br>(60.3%)      | 209<br>(59.9%)     |       |
| Posterior corner                                                        | 1<br>(0.3%)         | 32<br>(9.5%)       | 2<br>(0.6%)         | 46<br>(13.2%)      |       |
| Anterior band                                                           | 167<br>(50.9%)      | 77<br>(22.9%)      | 138<br>(38.3%)      | 81<br>(23.2%)      |       |
| Posterior band                                                          | 1<br>(0.3%)         | 11<br>(3.3%)       | 3<br>(0.8%)         | 13<br>(3.7%)       |       |
| Intensity                                                               | < 0.001             |                    | < 0.001             |                    | 0.850 |
| Weak                                                                    | 318<br>(97.0%)      | 296<br>(88.1%)     | 351<br>(97.5%)      | 305<br>(87.4%)     |       |
| Strong                                                                  | 10<br>(3.0%)        | 40<br>(11.9%)      | 9<br>(2.5%)         | 44<br>(12.6%)      |       |
| Associated finding                                                      | < 0.001             |                    | < 0.001             |                    | 0.610 |
| Only edema                                                              | 178<br>(54.3%)      | 213<br>(63.4%)     | 253<br>(70.3%)      | 269<br>(77.1%)     |       |
| With fat                                                                | 32<br>(9.8%)        | 77<br>(22.9%)      | 24<br>(6.7%)        | 51<br>(14.6%)      |       |
| With sclerosis                                                          | 118<br>(36.0%)      | 46<br>(13.7%)      | 83<br>(23.1%)       | 29<br>(8.3%)       |       |

and fatty change (2.52 [1.31–4.87],  $P = 0.006$  for Reviewer 1; 2.59 [1.03–6.47],  $P = 0.043$  for Reviewer 2) were significantly associated with SpA.

## Discussion

DISH is generally considered a non-inflammatory condition, diagnosed based on characteristic radiographic findings of new bone formation along the anterolateral aspect

of contiguous vertebral bodies. However, BME or osteitis-like signals, which signify inflammatory components, have been increasingly reported in DISH, not only due to the improved signal-to-noise ratio and robust fat suppression of recent MRI machines but also due to growing recognition of these findings in recent literature [10, 11, 15, 16]. In our study, more than 20% of patients diagnosed with DISH demonstrated BME in vertebral bodies.

**Table 3** Univariate and multivariate analysis of MR and clinical findings of bone marrow edema in the vertebral body between DISH and SpA

|                    | Reviewer 1 |                    |         |                    |         |                     | Reviewer 2 |                    |         |                   |         |                     |
|--------------------|------------|--------------------|---------|--------------------|---------|---------------------|------------|--------------------|---------|-------------------|---------|---------------------|
|                    | Unadjusted |                    |         | Adjusted 1st       |         |                     | Unadjusted |                    |         | Adjusted 1st      |         |                     |
|                    | P-value    | *OR (2.5–97.5% CI) | P-value | OR (2.5–97.5% CI)  | P-value | OR (2.5–97.5% CI)   | P-value    | OR (2.5–97.5% CI)  | P-value | OR (2.5–97.5% CI) | P-value | OR (2.5–97.5% CI)   |
| MR characteristics |            |                    |         |                    |         |                     |            |                    |         |                   |         |                     |
| Location           |            |                    |         |                    |         |                     |            |                    |         |                   |         |                     |
| Anterior corner    | 0.002      | 11.46 (2.51–52.5)  | 0.002   | 11.26 (2.35–54.05) | 0.001   | 46.01 (4.58–462.36) | <0.001     | 1                  | <0.001  | 9.99 (3.50–28.57) | <0.001  | 38.95 (6.91–219.48) |
| Posterior corner   |            |                    |         |                    |         |                     |            | 10.91 (3.95–30.10) |         |                   |         |                     |
| Anterior band      | <0.001     | 0.33 (0.20–0.55)   | <0.001  | 0.36 (0.21–0.61)   | 0.056   | 0.57 (0.32–1.01)    | 0.507      | 0.86 (0.54–1.35)   | 0.447   | 0.83 (0.52–1.33)  | 0.617   | 1.18 (0.61–2.29)    |
| Posterior band     | 0.054      | 8.14 (0.96–68.70)  | 0.052   | 8.42 (0.99–71.91)  | 0.004   | 41.38 (3.19–536.20) | 0.021      | 4.24 (1.25–14.45)  | 0.014   | 4.76 (1.37–16.57) | 0.029   | 15.42 (1.32–179.88) |
| Intensity          |            |                    |         |                    |         |                     |            |                    |         |                   |         |                     |
| Weak               | 1          |                    |         |                    |         |                     |            | 1                  |         |                   |         |                     |
| Strong             | <0.001     | 4.58 (2.24–9.35)   | <0.001  | 6.72 (2.77–16.30)  | 0.002   | 7.66 (2.05–28.64)   | <0.001     | 6.67 (2.83–15.71)  | <0.001  | 5.89 (2.42–14.34) | 0.003   | 7.99 (2.00–31.86)   |
| Associated finding |            |                    |         |                    |         |                     |            |                    |         |                   |         |                     |
| Edema              | 1          |                    |         |                    |         |                     |            | 1                  |         |                   |         |                     |
| Fat                | 0.050      | 2.08 (1.00–4.33)   | 0.029   | 2.23 (1.09–4.58)   | 0.006   | 2.52 (1.31–4.87)    | 0.052      | 2.00 (1.00–4.01)   | 0.010   | 2.48 (1.25–4.95)  | 0.043   | 2.59 (1.03–6.47)    |
| Sclerosis          | 0.003      | 0.34 (0.17–0.68)   | 0.052   | 0.48 (0.23–1.01)   | 0.186   | 0.46 (0.15–1.45)    | 0.002      | 0.38 (0.21–0.70)   | 0.006   | 0.42 (0.22–0.78)  | 0.011   | 0.40 (0.20–0.81)    |
| Clinical finding   |            |                    |         |                    |         |                     |            |                    |         |                   |         |                     |
| Age                |            |                    |         |                    | <0.001  | 0.83 (0.77–0.89)    |            |                    |         |                   | <0.001  | 0.82 (0.76–0.89)    |
| Sex; female        |            |                    |         |                    | 0.155   | 3.95 (0.59–26.31)   |            |                    |         |                   | 0.005   | 3.06 (0.55–17.10)   |

\* OR = odds ratio, represents the odds of having SpA over DISH. CI = confidence interval. Adjusted<sup>1st</sup> for imaging features only, adjusted<sup>2nd</sup> for imaging features, age and sex

Similarly, depending on the spinal level, BME has been reported on MRI in 18.2–41.7% of patients with DISH [16]. Furthermore, Latourte et al. reported that more than half of DISH patients had BME, and many of them met the ASAS criteria for SpA [9]. However, we hypothesised that the BME patterns in DISH and SpA could be distinguished from one another. Our study identified specific BME patterns that were more characteristic of DISH or SpA. BME in DISH patients predominantly showed an exclusive anterior location, weak hyperintensity, and a frequent association with sclerotic changes. In contrast, BME in SpA patients appeared at the posterior vertebral body, had strong hyperintensity and was commonly associated with fatty changes. Among these findings, the location of BME showed high odds ratios, with posterior corner or posterior band locations strongly suggestive of SpA. Similarly, Weiss et al. also reported that posterior acute inflammatory or fatty lesions were not commonly found in patients with DISH [10], while Maksymowych et al. found inflammatory lesions in the posterior elements were frequently present in AS [17]. Posteriorly located BME can also occur in DISH as a result of mechanical or degenerative stress reactions. However, in DISH, posteriorly located BME is typically confined to areas adjacent to the endplate and resembles BME related to endplate or disc degeneration, whereas in SpA it reflects inflammatory BME at ligamentous attachment sites.

The signal intensity of BME in DISH patients was generally weaker than that in SpA patients in our study. The pathophysiologic mechanisms of DISH remain poorly understood, but it is believed to result from a combination of factors such as inflammation, mechanical stress or metabolic conditions [15, 18, 19]. The inflammation, if present, in DISH is generally milder compared to SpA, potentially representing a subclinical inflammatory condition with rare elevations in inflammatory markers such as erythrocyte sedimentation rate or C-reactive protein [15, 19]. Additionally, we observed differences in associated findings with edema between DISH and SpA. Chronic inflammation in SpA is known to contribute to the development of fat metaplasia in the areas of inflammation [20, 21]. In contrast, DISH, which is characterised by excessive bone formation, may present as sclerotic changes on MRI [18].

The widely used diagnostic criteria for DISH, which require flowing osteophytes over four vertebral bodies and the preservation of intervertebral disk space, mainly represent the advanced stage of DISH [3]. However, these original criteria may exclude early-stage DISH since longitudinal studies have shown that flowing type bone bridging across multiple spinal segments evolved from incomplete bone bridges [22, 23]. Furthermore, recent studies have reported that bridging syndesmophytes can also be observed in patients with DISH [16, 24].

In addition, the preservation of intervertebral disk space and the absence of apophyseal or sacroiliac joint changes in the original criteria also exclude DISH superimposed on disc degenerative disease or SpA. Based on these concerns, revised criteria have been proposed to address the limitations. Utsinger et al. introduced a grading system for DISH, categorizing it as definite, probable, or possible based on the number of vertebral bodies connected by bony bridges [25]. More recently, Kuperus et al. developed criteria for early DISH using longitudinal data [12]. These new criteria can be useful for research into the etiology, pathophysiology and treatment of DISH. However, there is still insufficient consensus for these proposed criteria to be established as standard classification criteria for DISH. Against this background, our study focused on the BME patterns between DISH and SpA on spine MRI, which are often difficult to distinguish using conventional imaging criteria. In contrast to the previous reports that has only briefly addressed inflammatory changes in DISH, we present a focused comparison of BME characteristics—location, signal intensity, and associated features such as fat deposition and sclerosis—providing enhanced insight into MR imaging-based differential diagnosis.

Our study had several limitations. First, the retrospective case-control design of our study led to selection bias. Specifically, non-symptomatic cases of DISH might be less likely to be included since MRI exams are typically performed when symptoms are present. Also, given that radiographs and MRIs were the imaging modalities employed for diagnosing DISH, the sensitivity of DISH diagnosis may be comparatively lower than that achieved with CT scans. To address this limitation, future studies applying dual-energy CT (DECT) with virtual non-calcium (VNCa) reconstructions may be considered. Recent studies have suggested that DECT provides high sensitivity for detecting ossified lesions while enabling the assessment of BME [26, 27], thus representing a promising imaging technique that combines the advantages of both MRI and CT. Second, while BME features were not referenced during the initial assessment for confirming proper group selection, the selection process itself may have introduced bias in the main imaging analysis. Since radiologists could not be entirely blinded to DISH-related imaging characteristics beyond BME on MRI, the possibility of implicit recognition of DISH-like features remains a limitation. Third, we did not account for the degree of disease activity in patients with SpA, which may influence the presence and severity of BME on MRI. Most patients in the SpA group underwent imaging due to clinically significant symptoms or recent symptom aggravation, suggesting that many were in an active disease state at the time of MRI acquisition. This may, in part, explain why the intensity of BME was generally

greater in SpA than in DISH. Fourth, we did not apply a patient-wise model, which could have provided direct diagnostic insights. However, due to the limitations of our case-control study design and sparsity of certain variables, patient-level analysis was not feasible. Future studies with prospective cohorts and balanced distributions will be needed to validate patient-level diagnostic performance. Fifth, the variables in our model were limited to BME characteristics, age, and sex of patients, whereas including patient symptoms and laboratory findings could potentially enhance the diagnostic performance of the model. Additional patient symptoms such as peripheral arthritis, uveitis, and psoriasis, as well as laboratory findings such as positive HLA-B27 and elevated inflammatory markers like erythrocyte sedimentation rate and C-reactive protein are expected to significantly improve the performance of the SpA diagnostic model. Therefore, future prospective multicenter studies integrating imaging findings with relevant clinical parameters are warranted to improve diagnostic specificity and accuracy. Finally, this study relied on a qualitative analysis of MR characteristics, and further studies are needed to assess the performance of diagnostic models with quantitative MR analysis.

## Conclusions

In conclusion, the posterior location, strong hyperintensity, and associated fat component of BME may provide helpful imaging clues for distinguishing SpA from DISH on spine MRI, particularly in diagnostically challenging cases.

## Abbreviations

|      |                                          |
|------|------------------------------------------|
| DISH | Diffuse idiopathic skeletal hyperostosis |
| SpA  | Axial spondyloarthritis                  |
| BME  | Bone marrow edema                        |

## Author contributions

Conceptualization: Joon-Yong Jung- Data curation: Sujin Kim, Joon-Yong Jung- Formal analysis: Joon-Yong Jung, Sujin Kim, Soyun Jeon, Bo Mi Chung- Investigation: Sujin Kim, Bo Mi Chung- Methodology: Joon-Yong Jung- Project administration: Joon-Yong Jung- Resources: Sujin Kim, Joon-Yong Jung- Software: Joon-Yong Jung, Soyun Jeon- Supervision: Joon-Yong Jung- Validation: Joon-Yong Jung- Visualization: Soyun Jeon, Sujin Kim- Writing-original draft: Sujin Kim, Joon-Yong Jung- Writing-review & editing: Joon-Yong Jung, Bo Mi Chung.

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## Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

## Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, and the protocol was approved by the Institutional Review Board (IRB) of [Chung-Ang University Hospital] (approval

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## Consent for publication

Not applicable.

## Competing interests

The authors declare no competing interests.

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