SCIENTIFIC ARTICLE

Prevalence and frequency of subchondral bone marrow edema in the lumbar facet joints of asymptomatic and symptomatic individuals

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Abstract

Objective To prospectively compare the prevalence and frequency of subchondral bone marrow edema (BME) in the lumbar facet joints of low back pain patients and healthy subjects.

Materials and methods Lumbar magnetic resonance imaging (MRI) examinations were performed on 55 asymptomatic participants (18 men; age range 21–63; mean 36 ± 12 years; body mass index (BMI) range 16–31; mean 22.6 ± 3.2 kg/m^2) and 79 low back pain patients (36 men; age range 18–77; mean 47 ± 14 years; BMI range 18–40; mean 27.8 ± 4.4 kg/m^2). In both groups, facet joint subchondral BME signal was evaluated using T2-weighted STIR imaging, and facet joint osteoarthritis was characterized as mild, moderate, and severe.

Results The BME signal was found in seven asymptomatic participants (12.7%) and 28 low back pain patients (35.4%) ($P = 0.003$). A significant portion of the patients (15.2%) presented more than one BME signal ($P = 0.011$). By pooling the ten facet joints of all subjects in each group, a significant difference in osteoarthritis grade distribution was observed between the two groups ($P < 0.001$). When adjusted for low back pain status, age, BMI, Modic type 1, disk herniation, and facet joint osteoarthritis maximal grade, only the latter was significantly associated with the facet joint BME signal ($P < 0.001$).

Conclusion Despite the higher prevalence and frequency of the BME signal in facet joints of low back pain patients compared to that in healthy subjects, the signal was found to be associated with the severity of the patients' osteoarthritis and not with their low back pain status.

Keywords MRI · Spine · Bone marrow edema · Facet joint · Osteoarthritis · Low back pain

Introduction

Low back pain is the leading cause of disability, and it is most commonly related to disk-related disease, including disk herniation, and/or facet joint osteoarthritis [1, 2]. The symptoms of facet joint osteoarthritis can mimic those associated with disk herniation through the so-called "pseudo-radicular"

referral pattern, which often makes it difficult to distinguish between the two conditions [2–4]. Magnetic resonance imaging (MRI) is a useful technique to assess disk and facet joint abnormalities, though it lacks specificity regarding the determination of the causes of low back pain because these abnormalities are also common in asymptomatic subjects [4–7].

On MR images, bone marrow edema (BME) patterns manifest with moderately low signal intensity on T1-weighted images and high signal intensity on T2-weighted images without sharp abnormal to normal marrow interfaces [8]. In the subchondral vertebral end plates, this signal, known as Modic type 1, and its resolution are both associated with low back pain and its relief [8–14]. By contrast, these abnormalities are not as common in healthy subjects [10]. In their retrospective study, Friedrich et al. [15] reported this type of BME signal within the facet joint subchondral bone in 14% of patients with low back pain, though their results were not compared to those of healthy subjects. If this signal is indeed more

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frequent in low back pain patients than in asymptomatic subjects, its detection would be useful in the development and implementation of effective treatment plans (e.g., selecting a particular facet joint level for facet block therapy).

This study aimed to compare the prevalence and frequency of the facet joints BME signal between symptomatic patients and healthy subjects.

Materials and methods

Subjects

This study was conducted at two hospitals (Centre Hospitalier Universitaire Ambroise Paré, Mons; Hôpital Universitaire des Enfants Reine Fabiola, H.U.D.E.R.F., Brussels, Belgium), and the study methodology and procedures were approved by the local ethics committee of each institution, and written informed consent was obtained from all participants.

Two subject groups were considered in this study. The first group of 55 healthy volunteer participants (i.e., healthy group) included 18 men and 37 women, aged from 21 to 63 years old (mean ± standard deviation (SD), 36 years ±12) with a body mass index (BMI) ranging from 16 to 31 kg/m^2 (mean ± standard deviation (SD), 22.6 kg/m^2 ± 3.2). These subjects were recruited from the medical and paramedical staffs of both institutions subject to the following inclusion criteria: more than 18 years old; never having consulted a physician, physiotherapist, or osteopath for low back pain; never been absent from work for low back pain; no history of spine trauma, spine infection, spine surgery, lumbar spine infiltration, neoplasia, or rheumatic disease; and no MRI contraindications. The second group of 79 symptomatic patients (i.e., low back pain group) included 36 men and 43 women, aged from 18 to 77 years old (mean ± SD, 47 years ± 14) with a BMI ranging from 18 to 40 kg/m^2 (mean ± SD, 27.8 kg/m^2 ± 4.4). These participants were consecutively recruited among patients who consulted with their physician and underwent a lumbar MRI examination subject to the following inclusion criteria: more than 18 years old with persistent low back pain for more than 3 months; no history of spine trauma, spine infection, spine surgery, neoplasia, or rheumatic disease; and no MRI contraindications. All participants completed the Nordic Musculoskeletal Questionnaire (NMQ) that consisted of questions regarding the participants' gender, age, weight, height, physical activities, possible symptoms, and/or treatments [16].

Fig. 1 Axial short tau inversion recovery (STIR) T2-weighted sequence (**a**) at the L5-S1 level showing left grade I facet joint osteoarthritis with bone marrow edema (BME) signal (white arrow); (**b**) at the L5-S1 level, showing right grade II facet joint osteoarthritis with BME signal (white arrow) and left grade III facet joint osteoarthritis without significant BME signal; (**c**) at the L4-L5 level, showing right grade II and left grade III facet joint osteoarthritis with BME signal (white arrows); (**d**) at the L4-L5 level, showing bilateral grade III facet joint osteoarthritis with subchondral bone cysts (black arrow). No BME signal was observed
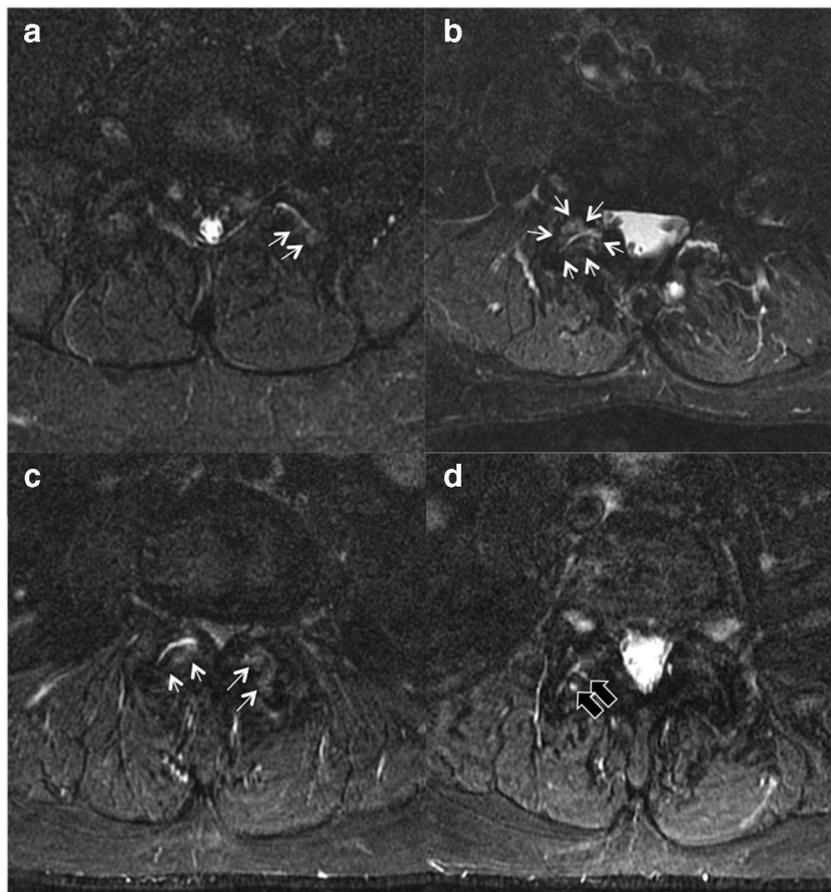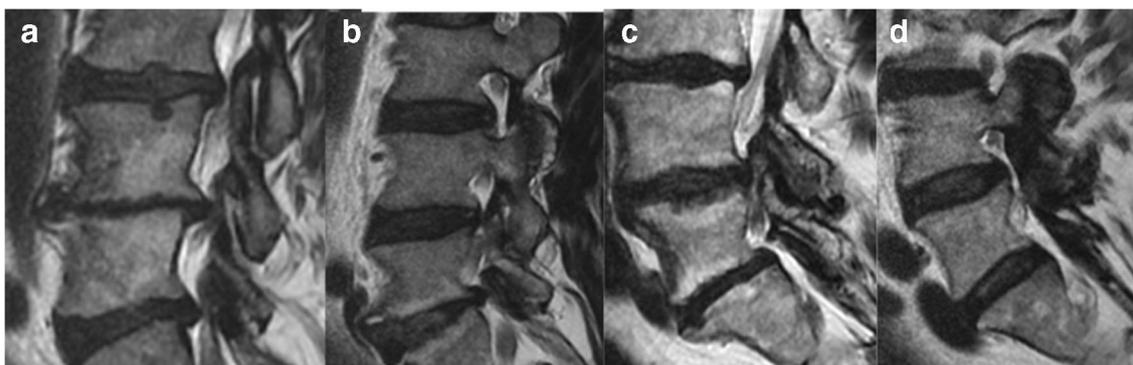
Fig. 2 Sagittal T2-weighted sequences at the level of L4-L5: **a** normal facet joint; **b** grade I facet joint osteoarthritis; **c** grade II facet joint osteoarthritis; **d** grade III facet joint osteoarthritis

MRI imaging

The MRI examinations were performed with a 1.5 T MRI scanner (Intera®, Philips Healthcare, Best, the Netherlands; Signal HDxt, GE Healthcare, Fairfield, CT). The standardized protocol was applied to both groups, which included sagittal spin-echo T1-weighted sequence (repetition time msec/echo time msec, 550–600/10–11; section thickness, 4 mm; 512 × 512 matrix), sagittal turbo spin T2-weighted sequence (repetition time msec/echo time msec, 4400–4600/80–120; slice thickness, 4 mm; matrix 512 × 512 mm), and axial short tau inversion recovery (STIR) T2-weighted sequence (repetition time msec/echo time msec, 4400–9600/45–80; inversion recovery msec, 130–150; slice thickness, 4 mm; 512 × 512 matrix).

Image analysis

Two radiologists (AM, CN) with 15 and 16 years of experience in neuroradiology and musculoskeletal MRI scanning and interpretation were blinded to the subject data that were based on the parameters listed below and then asked to independently grade facet joint osteoarthritis according to the Weishaupt's grading system [10] on both sides of each lumbar level. This grading system organizes joint conditions in the following manner: grade 0 corresponds to participants with a normal facet joint space; grade 1 corresponds to participants exhibiting a narrowing of the facet joint space thinner than 2 mm, small osteophytes, and/or mild hypertrophy of the articular process; grade 2 corresponds to participants with narrowing of the facet joint space, moderate osteophyte, moderate hypertrophy of the articular process, and/or mild subarticular bone erosion; and grade 3 corresponds to

participants with narrowing of the facet joint space, large osteophyte, severe hypertrophy of the articular process, severe subarticular bone erosion, and/or subchondral cysts. For this study, the BME signal of the facet joint subchondral bone was defined as a region of high signal intensity with ill-defined margins on the T2-weighted STIR images (Figs. 1 and 2). If present, facet joint effusion was also coded for both sides of each lumbar level. To resolve discrepancies between the radiologists' interpretations, they reviewed the images together to reach a consensus.

The radiologists were also asked to classify disk abnormalities, such as bulging, protruding, or extruding at each lumbar level according to the North American Spine Society's (NASS) Clinical Guidelines [17]. Finally, they were asked to code end plate and adjacent bone marrow abnormalities on sagittal MR images according to the definitions provided in Modic et al. [10] for each category: no abnormality, type I (low signal intensity on T1-weighted images and high signal intensity on T2-weighted images compared to fatty bone marrow), type II (high signal intensity with both images), and type III (low signal intensity on both images). When two types were simultaneously present on both sides of the intervertebral space, only one diagnosis was applied in the following manner: first priority, type I; second priority, type II; and last priority, type III.

Statistical analysis

Proportion comparisons were performed by exact Fisher tests. The factors that influence the probability of observing BME signal were assessed with multivariate logistic regression using R (version 3.3.2) software [18]. The level of significance was 0.05.

Table 1 Frequency distribution of facet joint bone marrow edema (BME) in the whole lumbar spine in each group

	0 BME signal	1 BME signal	≥2 BME signal
Healthy group ($n = 55$)	87.2%	5.5%	7.3%
Low back pain group ($n = 79$)	64.5%	20.3%	15.2%

Table 2 Grade distribution of facet joint osteoarthritis

	Grade 0	Grade 1	Grade 2	Grade 3
Healthy group	314/550 (57.1%)	195/550 (35.5%)	40/550 (7.2%)	1/550 (0.2%)
Low back pain group	454/790 (57.5%)	235/790 (29.8%)	71/790 (9.0%)	29/790 (3.7%)

Results

BME signals were present in 13 facet joints in seven healthy participants (12.7%) and 50 facet joints in 28 patients with low back pain (35.4%) ($P = 0.003$). The frequency of facet joint BME in each subject is presented in Table 1, and notably, the frequency of subjects with 2 or more areas of BME signals in the whole spine was significantly higher in the low back pain group than in the healthy group ($P = 0.011$).

The frequency and grades of lumbar facet joint osteoarthritis are presented in Table 2.

By pooling the facet joint levels of all subjects, the osteoarthritis grade distributions for each were found to be statistically significantly different ($P < 0.001$), and notably, there was a higher proportion of grade 3 in the low back pain group. The prevalences of BME signals according to the maximal grade of facet joint osteoarthritis in all subjects are presented in Fig. 3. The distribution of disk abnormalities and vertebral end plate abnormalities according to Modic are shown in Table 3. The groups were statistically different in terms of age and BMI ($P < 0.001$). The factors that influence the probability of observing more than one BME signal are provided in Table 4. Based on the results of logistic regression analysis adjusted for confounding factors, which included low back pain status, age, BMI, Modic type 1 vertebral end plate, disk herniation, and facet joint osteoarthritis maximal grade, only the latter was found to be significantly associated with the facet joint BME signal.

Discussion

This study results revealed the following: (1) the facet joint BME signals were more prevalent and frequent in the low back pain patients than they were in healthy subjects and (2) the BME signal was associated with the severity of facet joint osteoarthritis regardless of the pain status.

Although the prevalence and frequency of the facet joint BME signals were higher in the low back pain group than in the healthy group, 12% of the facet joints of healthy participants presented a BME signal, which indicated that relationship to low back pain was inconsistent, which may have been due to BME signals' association with a wide variety of diseases, including trauma-induced lesions and degenerative and inflammatory osteoarthropathies with various histopathological substrates [9, 19, 20]. BME signals in vertebral end plates, known as Modic type 1 signals, are commonly related to a particular chain of events. Specifically, an initial mechanical phenomenon is followed by microfractures of the cancellous bone and end plate. An inflammatory response characterized by edema in the end plates and/or adjacent bone marrow is followed by the onset of fibrovascular marrow replacement and the diffusion of low-virulence anaerobic bacteria, which can further propagate peridiscal marrow inflammation [21, 22]. In the knee, such signal corresponds histologically to medullary necrosis, fibrosis, or trabecular abnormalities, whereas edema is a minor consideration in this study [20, 23]. Histopathological analyses in rheumatoid arthritis patients have shown that the BME signal is related to lymphocyte and osteoclast infiltrates and is predictive of erosive lesions [24].

Without histopathological analysis, the significance of the facet joint BME signal in low back pain patients is therefore unclear. Our results revealed that the facet joint BME signal was related to the severity of the facet joint osteoarthritis in both low back pain patients and healthy subjects, with BME signal and osteoarthritis predominating in the overloaded L4/L5 and L5/S1 lumbar levels. Similar signal intensity was reported by Morrison et al. in lumbar pedicles associated with adjacent facet degenerative joint disease [25]. Nevertheless, the BME signal does not appear to be by itself the causal process of subchondral bone marrow disease. On the contrary, the causal process is typically associated with biomechanical stress, joint instability, or a degenerative disease, with the extent and severity of the BME signal being linked to cartilage loss [9, 19, 23, 26, 27].
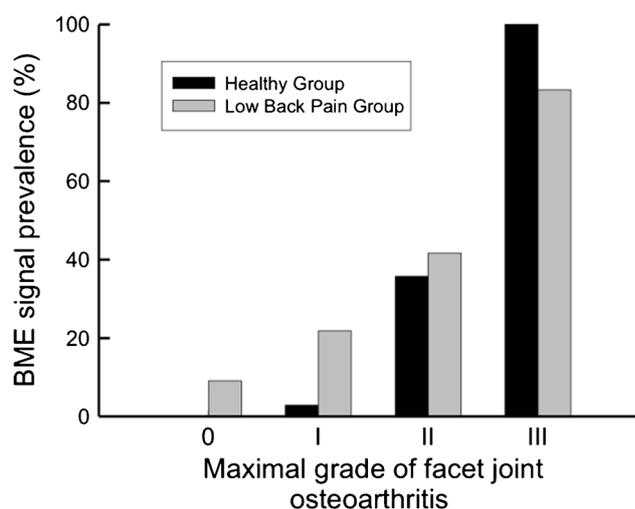
Fig. 3 Distribution of facet joint bone marrow edema (BME) signal according to the grade of facet joint osteoarthritis in each group

Table 3 Frequencies of disk abnormalities and Modic end plate at each level in the healthy group and the low back pain group

Level	Healthy group ($n = 55$)					
	Bulging	Protrusion	Extrusion	Modic I	Modic II	Modic III
L1-L2	2 (3.6%)	0	0	0	3 (5.4%)	0
L2-L3	2 (3.6%)	0	0	0	2 (3.6%)	0
L3-L4	5 (9.1%)	0	0	2 (3.6%)	0	0
L4-L5	9 (16.3%)	0	0	4 (7.2%)	0	0
L5-S1	13 (23.6%)	0	0	6 (10.9%)	11 (20%)	1 (1.8%)
	Low back pain group ($n = 79$)					
Level	Bulging	Protrusion	Extrusion	Modic I	Modic II	Modic III
L1-L2	16 (20.2%)	0	0	5 (6.3%)	15 (19%)	0
L2-L3	15 (19.0%)	2 (2.5%)	2 (2.5%)	9 (11.4%)	23 (29.1%)	0
L3-L4	23 (29.1%)	7 (8.8%)	1 (1.2%)	18 (22.8%)	24 (30.4%)	0
L4-L5	31 (39.2%)	17 (21.5%)	2 (2.5%)	27 (34.2%)	37 (46.8%)	1 (1.2%)
L5-S1	38 (48.1%)	14 (17.7%)	5 (6.3%)	24 (30.4%)	42 (53.2%)	0

Moreover, our multivariate logistic regression analyses revealed that pain status does not influence the probability of observing a facet joint BME signal. This observation stands in contrast to the retrospective study by Friedrich et al., who reported that the prevalence of facet joint BME signal in low back patients is only 14%, which is much lower than that found in the low back pain group and close to that observed in our healthy group, although these authors did suggest that this signal may be relevant to the planning of facet joint treatment [15]. The prevalence of facet joints osteoarthritis has differed from one study group to another [7, 10, 28]. Jensen et al. and Weishaupt et al. reported that this prevalence varied from 8 to 12% in asymptomatic subjects between the ages of 35 and 42 [10, 28], while it reached 90% in young asymptomatic tennis players [7]. Although our healthy group are very different in terms of sport activities, 83% of our asymptomatic subjects showed mild facet joint osteoarthritis.

Disk abnormalities, particularly extrusion, also commonly cause low back pain. In our healthy participants, no one presented with disk protrusion or extrusion. These results differed somewhat from those in Weishaupt et al. who reported prevalences of protrusion and extrusion in 38% and 18% of their asymptomatic subjects, respectively [10]. The incidentally low prevalence of disk abnormalities in our healthy participants

allowed us to focus on a uniform study group of patients with facet joint osteoarthritis.

Our study had several limitations. First, our healthy participants were younger than our low back pain patients, and the prevalence of low back pain increased with age, making it difficult to recruit older healthy participants. However, the logistic regression analysis took this difference into account, and it did not influence the probability of observing a facet joint BME signal. Secondly, a vast majority of our patients complained of chronic low back pain, so it was not possible to evaluate the impact of low back pain duration on the BME signal. Investigating its prevalence in patients suffering from acute low back pain and its evolution over time would provide important insight regarding this relationship. Thirdly, the MRI scans could have underestimated the severity of facet joint osteoarthritis compared to CT scans [29]. However, in their study, comparing MRI and CT scanning results obtained in the assessment of lumbar facet joint osteoarthritis, Weishaupt et al. observed moderate to good agreement between both techniques, and excellent agreement was found when differences of one grade were omitted [30]. Fourthly, selective facet joint block testing was not performed on our low back pain group to distinguish facet joint syndrome from other confounding factors that can cause low back pain. However, even

Table 4 Factors influencing the probability of ≥ 1 facet joint BME signal

	Adjusted Odds ratio [CI 95%]	P value
Low back pain group/healthy group	2.013 [0.571–7.69]	0.286
Age	1.010 [0.968–1.054]	0.642
BMI	1.080 [0.953–1.234]	0.240
Vertebral end plate Modic 1	1.572 [0.47–5.152]	0.453
Disk herniation	0.231 [0.01–2.002]	0.241
Maximal grade of facet joint osteoarthritis	4.546 [2.261–10.11]	< 0.001

when properly conducted, false-positive rates of 25–44% have been reported for lumbar facet joint nerve blocks [31]. Moreover, multivariate logistic regression analyses have taken certain other factors into account, including age, BMI, Modic type 1 vertebral end plate, and disk herniation, which have also been found to contribute to low back pain. Finally, maybe our MR protocol including axial T2-weighted STIR sequences was not optimal to assess small facet joint osteoarthritis especially in vertebral alignment deformities such as scoliosis or spondylolisthesis, and we should probably have used additional sagittal T2-weighted STIR combined with axial T2-weighted sequences. Nevertheless, the aim of our study was to evaluate the presence of even small areas of bone marrow edema and to differentiate them from partial volume effect of the joint fluid or subchondral bone cysts. Moreover, we took into account all MR sequences to grade osteoarthritis.

In conclusion, the prevalence and frequency of the BME signal of the facet joint in low back pain patients were higher compared to the signal in healthy subjects, and this signal appears to be related to the severity of the osteoarthritis, but not to the low back pain status.

Compliance with ethical standards

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