Diagnostic and Interventional Imaging (2016) xxx, xxx—xxx

ORIGINAL ARTICLE /*Musculoskeletal imaging*

Assessment of anterior subcutaneous hypersignal on proton-density-weighted MR imaging of the knee and relationship with anterior knee pain

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KEYWORDS
Bursitis;
Bone edema;
Knee;
Magnetic resonance imaging (MRI)

Abstract
Purpose: The purpose of this study was to evaluate the prevalence of anterior subcutaneous hypersignal indicating edema on proton-density (PD)-weighted MRI of the knee and to determine whether reporting anterior edema is clinically relevant.
Materials and methods: One hundred and ninety-one knee MRIs from 162 patients were reviewed for anterior subcutaneous edema. There were 92 men and 70 women with a mean age of 41.72 years ± 13.92 (SD) (range, 15—80 years) years and a mean body weight of 75.94 kg ± 12.54 (SD) (range, 50—130 kg). The MRI findings were compared with patient age, gender, body weight, history of repetitive microtrauma and clinical findings. Patellar and trochlear chondropathy, medial plica, joint effusion, synovitis, infrapatellar fat-pad signal intensity, suprapatellar fat-pad signal intensity with mass effect, quadriceps and patellar tendon abnormalities were also reviewed.
Results: An anterior hypersignal on PD-weighted MRI was detected in 158/191 MR examinations (82.7%) and 104 (84.6%) of these cases had histories of anterior knee pain. No correlation between anterior pain and anterior edema was found ($P = 0.42$). Age ($P < 0.0001$), weight ($P < 0.0001$), and repetitive microtrauma ($P = 0.001$) were identified as significant variables associated with anterior edema.

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http://dx.doi.org/10.1016/j.diii.2016.08.008

Please cite this article in press as: Unlu EN, et al. Assessment of anterior subcutaneous hypersignal on proton-density-weighted MR imaging of the knee and relationship with anterior knee pain. Diagnostic and Interventional Imaging (2016), http://dx.doi.org/10.1016/j.diii.2016.08.008

Conclusion: Anterior edema may be a physiological phenomenon or degenerative change related to patient age, weight, and knee movement or mechanics. It should not be reported as a pathological finding on MRI unless clinical findings support regional infection or inflammation.

Anterior knee pain is the most common knee complaint and has various underlying causes, including patellar chondromalacia, anterior knee bursitis, quadriceps or patellar tendon abnormalities, plica syndromes, Hoffa's disease, bone abnormalities, and traction apophysitis syndromes [1—3]. Bursitis may mimic several peripheral joint and muscle abnormalities clinically. Thus, it is important for the radiologist to identify bursal pathology and provide direct management geared towards bursitis [4]. Anterior subcutaneous adipose tissue, including prepatellar and superficial infrapatellar bursae, may often show edematous high signal intensities on fat-suppressed proton-density (PD)-weighted images of the routine magnetic resonance imaging (MRI) of the knee, which may be misdiagnosed as anterior bursitis or inflammation radiologically. Some previous studies have shown that this finding is common on knee MRI [1,4]. It has been also reported that the peripatellar lesions involving prepatellar and superficial infrapatellar bursae demonstrated on MRI are common in older individuals with equal prevalence in both symptomatic and asymptomatic patients with osteoarthritis [5].

The purpose of this study was to evaluate the prevalence of anterior subcutaneous hypersignal indicating edema on PD-weighted MRI of the knee and to determine whether reporting anterior edema is clinically relevant.

Materials and methods

Patients

We retrospectively evaluated consecutive routine knee MRI examinations performed between June 2014 and February 2015. MRI examinations were selected from the picture archiving and communication system (PACS) of our hospital. Patients with a history of regional radiotherapy, generalized edema, acute sports injury, history of an operation within 6 months, prosthesis and metallic artefacts and regional soft tissue or bone infection were excluded from the study. Also for patients undergoing several MRI examinations during this period, only the first examination was included in our study. Therefore, 94 examinations of 80 patients were excluded. A total of 191 knee MRIs of 162 patients were included in the study. In total, 92 (56.8%) of the patients were males, and 70 (43.2%) were females. Their mean age was 41.72 years ± 13.92 (SD) (range, 15—80) and the mean weight was 75.94 kg ± 12.54 (SD) (range, 50—130) kg. The examined knee was the right knee in 68 (42%), left in 65 (40.1%), and bilateral in 29 (17.9%) patients.

The patients were classified according to age, gender, bodyweight, and the presence of repetitive microtrauma or chronic irritation (e.g., occupational kneeling, activities requiring a significant amount of kneeling, such as house cleaning or praying in Islamic culture). The clinical presentations of all patients were clearly documented.

Local ethics committee approval was obtained for this retrospective study and the requirement for patient informed consent was waived.

MRI protocol

MRI was performed using a 1.5-T scanner (Echelon®, Hitachi, Tokyo, Japan) with dedicated extremity coil. Body coil was used for overweight patients. MRI protocol included T1-weighted spin-echo-sequences in the transverse and sagittal planes (TR/TE: 400-450/11-12), fat-suppressed fast spin-echo PD-weighted sequences in the transverse and sagittal planes (TR/TE: 1550—2000/12—24), and gradient-echo sequence in the sagittal and coronal planes (TR/TE: 500—550/20, flip angle 20°C). The field of view (FOV) was 20 cm, the slice thickness was 4—4.5 mm, and the intersection gap was from 4 to 5 mm. The number of acquisition was either one or two and the matrix ranged 256 × 320, 224 × 320, 256 × 384 and 320 × 320.

Intravenous administration of a gadolinium chelate was performed in 4 patients at a dose of 0.1 mmol/kg of body weight because of a suspicion of synovitis or arthritis. T1-weighted spin-echo or fat-suppressed T1-weighted spin-echo imaging (TR/TE: 450—600/12—20) in the transverse, sagittal and/or coronal planes were added to the protocol for these patients.

Imaging analysis

MR images were analyzed in consensus by two radiologists with 8 and 10 years of experience in musculoskeletal imaging. MRI images were evaluated in terms of the signal of the anterior subcutaneous adipose tissue, cystic lesions related to bursitis, patellar and/or trochlear chondropathy, medial plica, effusion and synovitis in the joint, a signal from the infrapatellar (Hoffa) fat-pad, the signal and mass effect of the suprapatellar (quadriceps) fat-pad, and patellar and quadriceps tendinopathies. The complaints of patients were classified as anterior pain, regional inflammation (pain, increased temperature, swelling, and redness), and a palpable mass.

Reticular fluid intensities or diffuse ill-defined edematous signal changes on the fat-suppressed PD-weighted sequence at the anterior subcutaneous adipose tissue, affecting the prepatellar and superficial infrapatellar regions, were noted as ''anterior subcutaneous PD-weighted high signal

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intensity''. Encapsulated fluid collection at the prepatellar and/or superficial infrapatellar regions is defined as bursitis.

Patellar and trochlear chondropathy was noted (grade 0, normal, grade 1, signal abnormality without defect, grade 2, less than 50% cartilage defect, grade 3, more than 50% cartilage defect, grade 4, full-thickness cartilage defect with subchondral bony changes). The presence of medial patellar plica was noted.

Less than 5 mm widening at the suprapatellar recess on sagittal PD-weighted image was accepted as normal joint fluid, whereas more than 5 mm widening was deemed effusion.

The suprapatellar or quadriceps fat-pad lies on the patellar base and fills the gap between superior aspect of the patellar cartilage and posterior aspect of the insertion of the quadriceps tendon. The pre-femoral fat-pad is located immediately anterior to the femur, and the suprapatellar joint recess separates the suprapatellar fat-pad from the pre-femoral fat-pad. Truncation or scalloping of the pre-femoral fat-pad, defects or displacement or irregularity of the infrapatellar fat-pad (Hoffa), and thickening and/or enhancement of synovial surfaces were recorded as synovitis. Hoffa intensity equal to fat was considered as normal. Focal, linear or diffuse increased intensity, heterogeneity and fluid intensities were noted as pathological findings. Suprapatellar fat-pad intensity equal to that of fat was considered as normal. Higher signal than fat or fluid intensity with mass effect (evident by convex posterior contour) were noted as pathological findings.

The quadriceps and patellar tendons were characterized as having partial or full-thickness tears, thickening, and increased signal intensities that indicated focal or diffuse tendinitis. Hyperintense striations related to adipose tissue of the quadriceps tendons were evaluated as normal. Focal insertional increased signals in a regular and homogenous tendon without thickening or irregularity of the tendon and without adjacent bone marrow edema were not considered a tendon abnormality.

Statistical analysis

Kolmogorov—Smirnov test was used to evaluate the normality of the distribution of quantitative variables. Mann—Whitney *U*-test was used to compare quantitative variables. Continuous variables were given as mean ± standard deviation (SD) and range (min—max). Categorical variables were expressed as raw numbers, proportions and percentages, and analyzed with Fisher exact test. Statistical analyses were performed using SPSS for Windows software (ver 15.0, SPSS Inc., Chicago, IL, USA) package and P values < 0.05 were considered to indicate statistical significance.

Results

Reticular or ill-defined hyperintense signals were detected in the anterior subcutaneous adipose tissue of 158 (82.7%) knees on fat-suppressed PD-weighted sagittal and transverse MRI images. The signal was extended from the level of the patella to the tuberosity of the tibia longitudinally (Figs. 1 and 2). Adipose tissue intensity was normal in 33

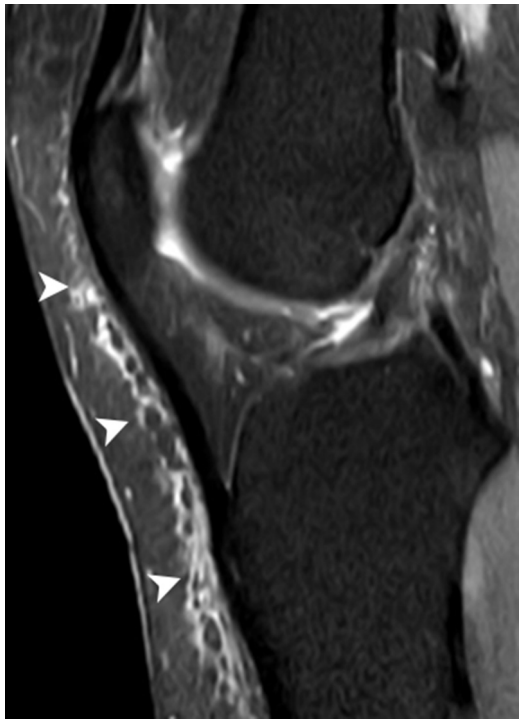

Figure 1. Forty-nine-year-old woman weighing 105 kg without anterior knee pain or regional inflammation on physical examination. Fat-suppressed PD-weighted MR image in the sagittal plane shows prepatellar and superficial infrapatellar reticular fluid intensities (arrowheads).

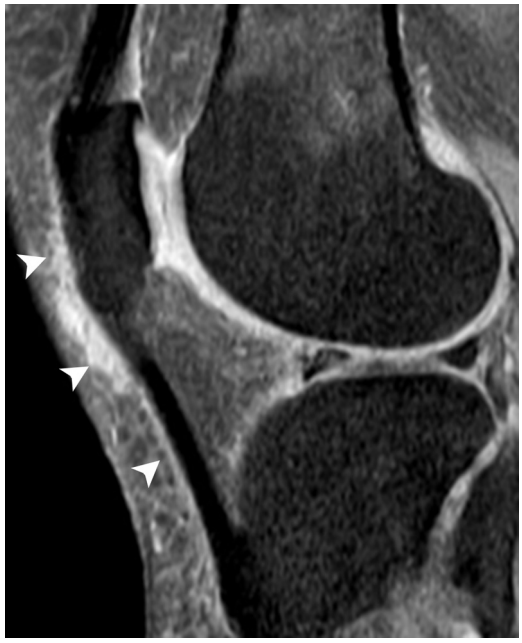

Figure 2. A 56-year-old woman weighing 90 kg without anterior knee pain and clinical evidence of bursitis. Fat-suppressed PD-weighted MR image in the sagittal plane shows anterior edema prominent in the prepatellar region (arrowheads).

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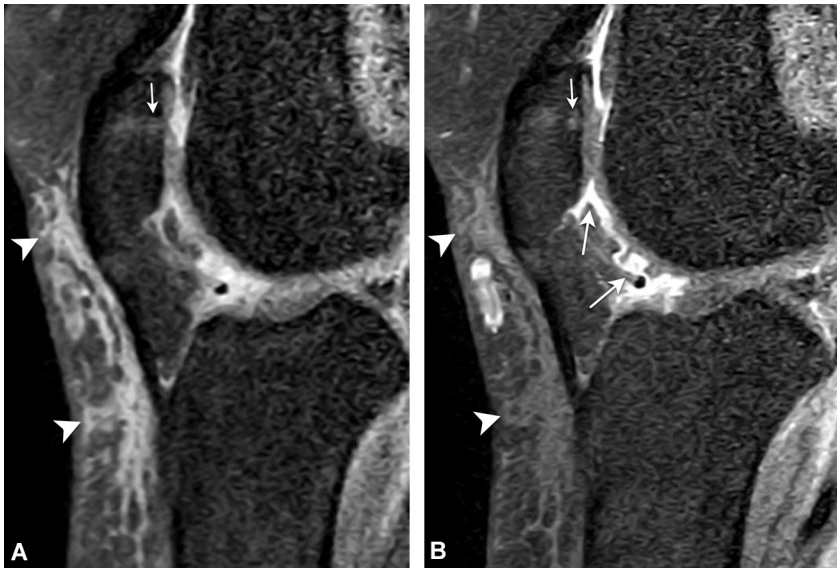

Figure 3. A 71-year-old and overweighted (130 kg) woman without anterior knee pain. A. Fat-suppressed PD-weighted MR image in the sagittal plane shows moderate anterior edema (arrowheads). B. No enhancement on post-contrast fat-suppressed T1-weighted image is visible in this region. Note the subchondral changes of patellar chondropathy (small arrows, A and B), and enhancement of synovial surfaces consistent with synovitis (large arrows, B).

(17.9%) knees. An anterior PD-weighted high signal intensity without enhancement was detected in all of the contrast-enhanced studies ($n = 4$) (Fig. 3).

The relationship between mean age and the anterior PD-weighted high signal intensity was statistically significant ($P < 0.0001$). There was no significant gender or side (right-left) difference between the groups with and without anterior PD-weighted high signal intensity ($P = 0.24$ and 0.99, respectively). The relationship between the mean weight and the anterior PD-weighted high signal intensity was statistically significant ($P < 0.0001$).

Within the subgroup of patients for whom both knees were examined, bilateral anterior PD-weighted high signal intensity was detected in 23/29 (79%) patients (Fig. 4). Four of them (14%) had no PD-weighted high signal intensity bilaterally, and 2 (7%) had hyperintensity in only one knee.

A history of repetitive microtrauma was noted in 92 (48.2%) knees. The association between anterior PD-weighted high signal intensity and repetitive microtrauma was statistically significant ($P = 0.001$).

Anterior knee pain was present in 123 (64.4%) knees. Anterior PD-weighted high signal intensity was detected in 104 (84.6%) of knees with pain, and in 54 (79.4%) of knees without pain; the difference was not statistically significant ($P = 0.42$).

Only 2 (1%) patients had signs of regional anterior subcutaneous inflammation clinically. The signal was similar to the other cases (Fig. 5). No finding related to regional inflammation was found in other patients on physical examination.

While patellar and/or trochlear chondropathy were seen in 92 (74.8%) of the patients with anterior knee pain, 31 (45.6%) of the knees without pain had chondropathy; the difference was statistically significant ($P < 0.001$). The association between patellofemoral chondropathy and anterior PD-weighted high signal intensity was also statistically significant ($P = 0.046$).

A medial plica was identified in 43 (35.0%) of knees with anterior pain and in 16 (23.5%) of knees without pain; the difference was not statistically significant ($P = 0.14$). There was also no significant association between anterior edema and medial plica ($P = 0.83$).

Effusion was detected in 65 (52.8%) of the knees with anterior pain and in 24 (35.3%) of the knees without pain. The relationship between anterior pain and effusion was statistically significant ($P = 0.02$). However, there was no significant association between anterior edema and joint effusion ($P = 0.12$).

While synovitis was seen in 84 (44%) of all knees, of whom anterior pain was detected in 64 (76.2%), 59/107 (55.1%) of the knees without synovitis had anterior pain; the difference was statistically significant ($P = 0.003$). But there was no significant association between anterior PD-weighted high signal intensity and synovitis ($P = 0.33$).

Hoffa pathologies were seen in 59 (30.9%) of the knees, and 43 (72.9%) had anterior pain. Pain was detected in 80/132 (60.6%) knees with normal Hoffa. The pain rates were similar ($P = 0.102$). The relationship between pathological Hoffa intensity and anterior PD-weighted high signal intensity was not statistically significant ($P = 0.082$).

A quadriceps fat-pad mass effect was seen in 16 (8.4%) of all knees, of whom pain was detected in 10 (62.5%). Also, 113/175 (64.6%) of the knees without mass effects had anterior pain. The relationship between anterior pain and quadriceps fat-pad mass effect was not statistically significant ($P = 0.868$). There was also no statistically significant association between anterior PD-weighted high signal intensity and quadriceps mass effect ($P = 0.314$).

Patellar tendon abnormalities were seen in 3 (2.4%) knees. Two knees with proximal patellar tendinitis and adjacent bone marrow edema had pain in this region. They were also accompanied by chronic Osgood-Schlatter disease. One patient had a postoperative defect and tendinosis due to

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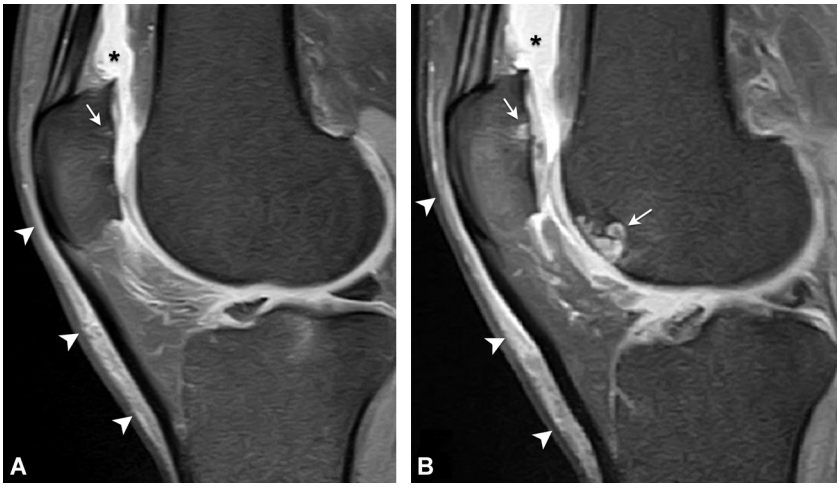

Figure 4. Fourty-five-year-old, 87 kg weighted man with bilateral anterior knee pain and clinical findings of patellofemoral osteoarthritis. Fat-suppressed PD-weighted MR images in the sagittal plane of the right (A) and the left (B) knee show anterior edema (arrowheads) and end-stage patellofemoral chondropathy (arrows) prominent on the left side. Note the joint effusion bilaterally (*).

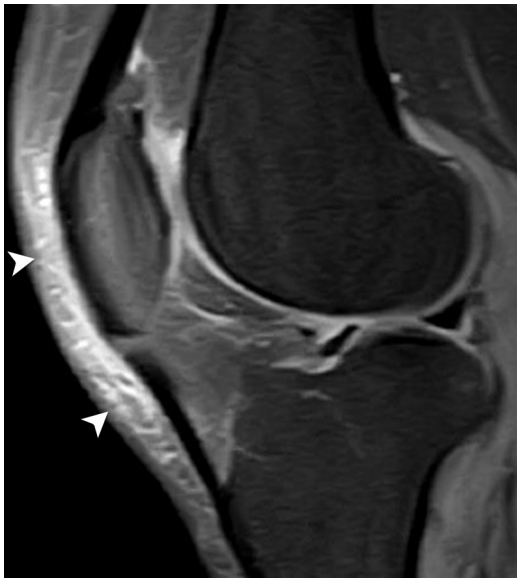

Figure 5. Thirty-three-year-old, 55 kg weighted woman presenting with anterior knee pain, swelling, redness and increased temperature (regional inflammation). Fat-suppressed PD-weighted MR image in the sagittal plane shows prepatellar edema (arrowheads) with ill-defined borders. No fluid collection consistent with anterior bursitis is visible.

a previous (~ 1 year ago) anterior cruciate ligament reconstruction surgery. This patient had no anterior knee pain. Anterior PD-weighted high signal intensity was detected in all of these patients. No quadriceps tendon tear or tendinitis was seen in any patient.

Fluid collection consistent with anterior bursitis, acute Osgood-Schlatter disease, or traction apophysitis was not seen in any case.

The association between anterior knee pain and anterior edema, and the significant and non-significant variables associated with an anterior PD-weighted high signal intensity are shown in Table 1.

Discussion

We found a high prevalence of anterior subcutaneous edema (82.7%) in our study, and there was no significant association between this signal and anterior knee pain. We also found no significant association between subcutaneous edema and other possible causes of anterior pain, such as medial plica, effusion, synovitis, Hoffa fat-pad and quadriceps fat-pad abnormalities, and patellar tendon pathologies. We found significant associations between patient age, body weight, and history of repetitive microtrauma or chronic irritation, and patellofemoral chondropathy.

Anterior subcutaneous edema is a common finding on routine knee MRI studies, and we noticed that this finding may confused with bursitis or local inflammation by radiologists, especially when they are inexperienced in musculoskeletal imaging or not sufficiently informed about the clinical findings. In addition, clinicians who want to evaluate the MR images of their patients may consider this finding as an inflammatory change in patients with anterior knee pain. Thus, an incorrect assessment of this finding may lead to unnecessary anti-inflammatory treatment of patients by clinicians.

The prepatellar bursa is located between the patella and overlying subcutaneous tissue. The superficial infrapatellar bursa is located in the subcutaneous fat between the distal third of the patellar tendon, the tibial tubercle, and the overlying skin, and this bursa was found in 55% of cases in a cadaveric investigation [4,6]. Most of the bursae in the body are not normally visualized on imaging, and the term ''bursitis'' refers to pathological enlargement of the bursa [4,7]. Bursitis can be caused by excessive local friction, infection, arthritides, or direct trauma. Inflammation of prepatellar and superficial infrapatellar bursae usually occurs from chronic repetitive trauma due to occupational kneeling or activities requiring a significant amount of kneeling, e.g., housemaids, clergy (clergyman's knee), carpet-layers, and wrestlers [4]. The effusion and edema of prepatellar bursitis may extend and communicate with the superficial infrapatellar bursa [8]. Bursitis should be

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Table 1 Correlation between anterior pain and anterior edema, and the significant and non-significant variables associated with an anterior PD high signal intensity on MR imaging of the knee.

	Anterior PD high signal intensity [+] $n = 158$ (82.7%)	Anterior PD high signal intensity [−] $n = 33$ (17.3%)	P
Anterior pain			
Yes, *n* (%)	104 (84.6)	19 (15.4)	0.42
No, *n* (%)	54 (79.4)	14 (20.6)	
Age mean, SD [min−max], years	44.76 ± 13.35 [15−80]	28.48 ± 6.82 [16−45]	**< 0.0001**
Gender			
Female, *n* (%)	73 (86.9)	11 (13.1)	0.24
Male, *n* (%)	85 (79.4)	22 (20.6)	
Side			
Right, *n* (%)	82 (82.8)	17 (17.2)	0.99
Left, *n* (%)	76 (82.6)	16 (17.4)	
Weight mean, SD [min−max], kg	77.25 ± 12.39 [50−130]	67.82 ± 9.89 [50−86]	**< 0.0001**
Repetitive microtrauma			**0.001**
Yes, *n* (%)	85 (92.4)	7 (7.6)	
No, *n* (%)	73 (73.7)	26 (26.3)	
Patellofemoral chondropathy			
Yes, *n* (%)	107 (87.0)	16 (13.0)	**0.046**
No, *n* (%)	51 (75.0)	17 (25.0)	
Medial plica			
Yes, *n* (%)	48 (81.4)	11 (18.6)	
No, *n* (%)	110 (83.3)	22 (16.7)	0.83
Effusion			
Yes, *n* (%)	78 (87.6)	11 (12.4)	0.12
No, *n* (%)	80 (78.4)	22 (21.6)	
Synovitis			
Yes, *n* (%)	69 (86.2)	15 (13.8)	
No, *n* (%)	89 (80.2)	18 (19.8)	0.33
Hoffa pathology			
Yes, *n* (%)	53 (89.8)	6 (10.2)	0.082
No, *n* (%)	105 (79.5)	27 (20.5)	
Quadriceps fat-pad mass effect			
Yes, *n* (%)	15 (93.8)	1 (6.2)	0.314
No, *n* (%)	143 (81.7)	32 (18.3)	

Numbers in brackets are ranges; SD indicates standard deviation. Bold indicates significant differences ($P < 0.05$).

differentiated from subcutaneous edema on imaging. In contrast to edema, bursitis appears as a localized fluid collection with well-defined borders [7].

In the study by Roth et al., which evaluated the quadriceps fat-pad signal intensity and enlargement on MRI, prepatellar edema was present in 90/92 (98%) patients [1]. They reported that, although the cause of this finding was unclear, the high prevalence and lack of significant correlation with anterior knee pain suggested that it is a physiological phenomenon related to knee movement or mechanics. Our results were similar, and we agree with Roth et al. We also think that this finding may be a degenerative change, which becomes prominent with aging and overuse of the knee. Although Roth et al. [1] and Shabshin et al. [9] reported that quadriceps fat-pad edema with mass effect is significantly associated with anterior knee pain, Tsavalas and Karantanas concluded that this finding is common on MRI and rarely associated with anterior pain [10]. We also did not find significant correlation between quadriceps fat-pad edema with mass effect and anterior knee pain in our study. We found a significant correlation between subcutaneous edema and patellofemoral chondropathy. We suggest that this correlation may depend on the similarity of predisposing factors of both processes, including age (for osteoarthritis), weight and repetitive microtrauma [11,12].

There are some studies about edematous signal changes in other parts of the body, which may be related. Haliloglu et al. evaluated the prevalence of peritrochanteric high T2 signal (peritendinitis, peritrochanteric edema) on routine hip MRI [13]. They reported that bilateral peritrochanteric edema was a common finding on MRI in those over 40 years

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of age and was not always related to the clinical findings. They suggested that this finding may be a part of degenerative process and may not be reported necessarily if the clinical findings do not also support greater trochanteric pain syndrome. Genu et al. evaluated the T2-STIR high signal intensity in the lumbosacral adipose tissue and found a significant relationship between non-inflammatory infiltration and overweight, age, and hospitalized status [14]. They suggested that this phenomenon seemed to be an interstitial edema, related to subcutaneous stasis, and should not be confused with local inflammation, unless there is no local underlying pathology, such as interspinous infectious diseases, myositis, or a recent surgery. Shi et al. also reported that posterior lumbar soft-tissue edema or fluid is frequently noted and more commonly seen in obese patients [15]. Kunin defined bridging septa in the perirenal adipose tissue, which are fibrous lamellae that can act as barriers to limit distribution of disease processes [16]. Thickening of the perinephric bridging septa is a non-specific imaging finding, and septa may be thickened due to edema or fibrosis, as a result of large parapelvic cysts causing chronic, tense capsular congestion [17]. Thickened bridging septa should also not be considered pathological if there is any underlying cause, such as inflammation, hemorrhage, or a tumor. In light of these studies, anterior subcutaneous edema seems to be a physiological and/or degenerative phenomenon, which may be related to age, weight, knee movements and repetitive microtrauma. It is important to distinguish this imaging finding from pathological conditions to protect patients from unnecessary anti-inflammatory treatments.

Our study has some limitations: its retrospective nature, the use of contrast material for a few patients, absence of anterior bursitis cases, and unknown past histories of anti-inflammatory therapy before the MRI examination in all patients. Also, our MRI protocol did not include fat-suppressed T2-weighted and/or STIR sequences, and we could not compare the difference of sequences. In addition, we did not have histological or pathological data; however, biopsy or surgery is not necessary for this very common and asymptomatic finding. Further investigations with larger series would be useful.

In conclusion, an edematous signal in the anterior subcutaneous adipose tissue of the knee is a very common finding on PD-weighted MRI and seems to be a physiological phenomenon or degenerative change related to patient age, weight, and knee movement or mechanics. It should not be reported as a pathological finding on MRI unless the clinical findings also support regional infection or inflammation.

Financial support

No financial support was received for this submission.

Disclosure of interest

The authors declare that they have no competing interest.

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