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SHORT COMMUNICATION

Clinical outcomes in relation to locations of bone marrow edema lesions in patients with a subchondral insufficiency fracture of the hip: a review of fifteen cases

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Objective: The prognosis of patients with a subchondral insufficiency fracture remains unclear. The purpose of this study was to investigate the correlation between locations of bone marrow edema (BME) lesions and clinical outcome in patients with a subchondral insufficiency fracture of the hip.

Methods: We retrospectively reviewed 15 consecutive hips in 14 patients who were diagnosed with subchondral insufficiency fracture of the hip at our institution between April 2013 and September 2014. This study included five males (six hips) and nine females (nine hips), ranging from 36 to 83 years of age (mean age: 66 years). The mean duration from the onset of hip pain to MRI examination was 1.8 months (range 0.5–5 months). Both clinical and imaging findings were investigated.

Results: Based on the findings of MR images, BME lesion in the femoral head alone was observed in six patients (six hips), BME lesion in the acetabulum alone was

observed in one patient (two hips) and BME lesions in both the femoral head and acetabulum were observed in seven patients (seven hips). 3 of 15 hips resulted in rapidly destructive arthrosis and their BME lesions were observed in both the femoral head and acetabulum. 8 of 15 hips successfully healed by conservative treatment and BME lesions in 7 of these 8 hips were observed in only the femoral head or acetabulum.

Conclusion: The results of this study indicate that the locations of BME lesions (femoral side alone, acetabular side alone or both) may be related to the clinical outcome in patients with a subchondral insufficiency fracture of the hip.

Advances in knowledge: Patients with subchondral insufficiency fracture of the hip in whom BME lesions were observed in both the femoral head and acetabulum may have a higher risk to need to undergo total hip arthroplasty.

INTRODUCTION

A subchondral insufficiency fracture of the femoral head occurs mainly in elderly females with osteoporosis. Radiographs obtained at the onset of hip pain often show no obvious findings in the majority of cases; however, MR images often reveal a bone marrow edema (BME) lesion in the femoral head with a diffuse low-intensity area on T_1 images and a high-intensity area on T_2 images in addition to an irregular serpiginous low-intensity band (fracture line) convex to the articular surface.^{1,2}

Rapidly destructive arthrosis (RDA) of the hip is also most commonly seen in elderly females with unilateral involvement. The radiographic characteristics include a disappearance of the joint space followed by rapid joint destruction within 6–12 months. Some cases of subchondral insufficiency fracture have been reported to cause

RDA.³ Recently, there has been a report on cases with RDA resulting from a subchondral insufficiency fracture in both the femoral head and acetabulum.⁴

Some cases of subchondral insufficiency fracture have been reported to undergo a progressive collapse necessitating surgery, while others have been reported to heal after conservative therapy.^{5,6} The prognosis of patients with subchondral insufficiency fracture remains unclear. The purposes of this study were to investigate (i) the MRI findings in both the femoral head and acetabulum and (ii) determine whether these findings correlated with clinical outcomes in patients with a subchondral insufficiency fracture of the hip.

PATIENTS AND METHODS

The institutional review board approved the study. This study retrospectively reviewed 15 consecutive hips in

14 patients who were diagnosed with a subchondral insufficiency fracture of the hip at our institution between April 2013 and September 2014. This study included five males (six hips) and nine females (nine hips), ranging from 36 to 83 years of age (mean age: 66 years). Of these 14 patients, 2 patients had histories of corticosteroid therapy and 3 patients had histories of alcohol intake. The body mass index (BMI) (in kilogram per square metre) was calculated and obesity was defined as a BMI of 26.4 or greater.⁷

A diagnosis of subchondral insufficiency fracture of the hip was made based on the following published criteria:^{1–4,6} hip pain that began without any apparent history of trauma; radiographs that were normal or that showed the collapse of the femoral head or acetabulum and/or linear patchy sclerotic areas in the superior portion of the femoral head or acetabulum; MR images that showed BME lesions in the femoral head and/or acetabulum; and subchondral low-signal-intensity bands on the T_1 or T_2 weighted MR images that were serpiginous or paralleled the articular surface. In the patients receiving total hip arthroplasty (THA), the diagnosis of a subchondral insufficiency fracture was made based on the histopathological findings; macroscopically, a linear fracture with a whitish-grey appearance paralleling the subchondral bone endplate was observed. Microscopically, the whitish-grey area consisted of irregularly arranged fracture callus, reactive cartilage and granulation tissue. It should be noted that small areas of necrotic bone trabeculae and bone marrow may be observed in subchondral insufficiency fracture; however, such necrosis is confined to the area around the fracture line

without any evidence of antecedent bone infarction. Patients treated with conservative treatments underwent follow-up MRI in order to confirm that the fracture lines (subchondral low-signal-intensity bands) had disappeared, as well as to differentiate the subchondral insufficiency fracture from osteonecrosis of the femoral head.

All patients initially underwent conservative treatment, which consisted of rest and the avoidance of weight-bearing activities for 4–6 weeks. Radiographically, the presence of a subchondral fracture, patchy sclerosis, a progression of collapse and osteoarthritic change (joint space narrowing) were investigated on both the anteroposterior and lateral views. Bone mineral density (BMD) measurements of the proximal femur were obtained in all 14 patients using dual-energy X-ray absorptiometry.

The MR examinations were performed by a 1.5-T system (Siemens; Erlangen, Germany) under 5-mm slice thickness. The T_1 weighted spin-echo images (repetition time/echo time = 430–616/10–14 ms) and fat-saturated T_2 weighted spin-echo images (repetition time/echo time = 3500–5000/82–90) in the coronal and axial (and/or oblique axial: paralleling the femoral neck axis) planes were available in all cases.

The interobserver variability of the locations of the BME lesions, fracture lines (low-intensity band) and histopathological findings between two observers (SI and TM) using the kappa statistic were 0.8649 (almost perfect), 0.7321 (substantial agreement) and 0.6957 (substantial agreement), respectively.⁸

Table 1. Clinical characteristics in patients with a subchondral insufficiency fracture of the hip

Patients	Age (years)	Gender	BMI (kg m^{-2})	Steroid therapy	Alcohol intake	BMD (t -score)	Onset MRI (months)	MRI final (months)	Follow-up MRI (months)	Clinical outcome
1	83	Male	26.5	–	+	–0.9 SD	1	3	–	THA
2	43	Male	26.4	–	–	–1.1 SD	2	18	5	Conservative
3	79	Female	20.2	+	–	–2.2 SD	2	8	–	THA
4	80	Female	29.8	–	–	–2.8 SD	5	6	–	THA
5	67	Female	32.5	–	+	–2.5 SD	4	5	–	THA
6	80	Female	28.9	–	–	–2.7 SD	2	3	–	THA
7	58	Male	19.6	–	–	–3.5 SD	2	3	–	THA
8	36	Female	16.4	–	–	–3.1 SD	2	19	–	Conservative
9	69	Female	21.0	–	–	–2.1 SD	2	21	3	Conservative
10	78	Male	24.2	+	+	–3.0 SD	1	17	3	Conservative
						–3.0 SD	1	17	3	Conservative
11	59	Female	20.2	–	–	–3.5 SD	0.5	13	4	Conservative
12	61	Female	25.2	–	–	–1.4 SD	0.5	13	4	Conservative
13	68	Female	24.5	–	–	–1.8 SD	1	4	–	THA
14	61	Male	22.5	–	–	–2.3 SD	1	12	5	Conservative

BMD, bone mineral density; BMI, body mass index; SD, standard deviation; THA, total hip arthroplasty.

MRI final: duration from the initial MRI examination to the final follow-up (end point: THA).

Follow-up MRI, duration from the initial MRI to the follow-up MRI.

RESULTS

The clinical and imaging findings are summarized in [Tables 1](#) and [2](#). Clinically, 5 of 14 patients were categorized as being obese (BMI > 26.4) and 7 of 14 patients were categorized as having osteoporosis (BMD < -2.5 standard deviation). The mean duration from the time of onset of hip pain to the MRI examination was 1.8 months (range 0.5–5 months). The mean duration from the MRI examination to the final follow-up was 16.3 months (range 12–21 months) in patients healed by conservative treatment. On the other hand, the mean duration from the MRI examination to the final follow-up was 4.6 months (range 3–8 months) in patients treated with THA owing to both the persistence of hip pain and the radiological progression of collapse of the femoral head or osteoarthritic change (end point: THA).

7 patients (7 hips) of 14 patients (15 hips) underwent THA owing to the persistence of hip pain. Radiologically, the progression of collapse of the femoral head and/or osteoarthritic change was observed. Three of seven patients treated by THA resulted in RDA ([Figure 1](#)). All seven patients treated by THA were histopathologically diagnosed to have a subchondral insufficiency fracture. A cut section of the resected femoral heads showed a notched linear shaped zone of white and grey tissue, paralleling the subchondral bone endplate ([Figure 1e](#)). The whitish-grey regions consisted of fracture callus, reactive cartilage and granulation tissue ([Figure 1f](#)). These reparative tissues corresponded to the band on the MR image in all seven cases ([Figure 1b](#)). Abundant bone and cartilage debris within the reparative tissue were observed in cases which resulted in RDA

([Figure 1f](#)). 7 patients (8 hips) of 14 patients (15 hips) successfully healed by conservative treatment ([Figure 2](#)).

Based on the MRI findings, the BME lesion in the femoral head alone was observed in six patients (six hips), BME lesion in the acetabulum alone was observed in one patient (two hips) and BME lesions in both the femoral head and acetabulum were observed in seven patients (seven hips). A subchondral low-intensity band (fracture line) in the femoral head was observed in 12 patients (12 hips) and low-intensity band in the acetabulum was observed in 1 patient (1 hip). No cases showed a subchondral low-signal-intensity band in both the femoral head and acetabulum. The presence of a subchondral low-intensity band was unclear in two cases. These two cases were diagnosed as having a subchondral fracture, since a subchondral fracture line or patchy sclerosis was observed on radiographs during the follow-up periods.

The BME lesions in 6 (86%) of 7 hips treated by surgical treatment (THA) were observed in both the femoral head and acetabulum. Among them, the BME lesions in all three hips with RDA resulting from a subchondral insufficiency fracture were observed in both the femoral head and acetabulum. The BME lesions in 7 (88%) of 8 hips that successfully healed by conservative treatment were observed in only the femoral head or acetabulum ([Figure 2](#)).

Seven of eight hips healed by conservative treatment underwent a follow-up MRI ranging from 3 to 5 months after the initial MRI in order to confirm that the fracture lines (subchondral low-signal-intensity bands) had disappeared ([Figure 2](#)).

Table 2. Imaging findings in patients with a subchondral insufficiency fracture of the hip

Patients	BME		L-I-B		Radiological outcomes			AHI (%)	BLR	Histopathological findings		Clinical outcome
	FH	A	FH	A	Collapse	OA	RDA			Callus formation	Cartilage debris	
1	+	+	+	–	–	+	+	70.6	65.5	+	+	THA
2	+	+	+	–	–	–	–	87.0	69.4	N/A	N/A	Conservative
3	+	+	+	–	+	–	–	78.3	63.3	+	–	THA
4	+	+	+	–	–	–	+	67.5	78.3	+	+	THA
5	+	+	+	–	–	+	+	83.3	63.0	+	+	THA
6	+	+	+	–	–	–	–	85.1	63.2	+	–	THA
7	+	–	+	–	–	–	–	77.6	62.2	+	–	THA
8	+	–	U/C	–	–	–	–	75.6	50.0	N/A	N/A	Conservative
9	+	–	+	–	–	–	–	73.3	31.3	N/A	N/A	Conservative
10	–	+	–	U/C	+	+	–	80.8	42.5	N/A	N/A	Conservative
	–	+	–	+	–	–	–	84.9	60.0	N/A	N/A	Conservative
11	+	–	+	–	–	–	–	75.9	42.1	N/A	N/A	Conservative
12	+	–	+	–	–	–	–	74.8	50.8	N/A	N/A	Conservative
13	+	+	+	–	–	–	–	71.7	40.7	+	–	THA
14	+	–	+	–	–	–	–	81.2	52.8	N/A	N/A	Conservative

A, acetabulum; AHI, acetabular head index; BLR, band length ratio; BME, bone marrow edema; FH, femoral head; L-I-B, low-intensity band on MR images; N/A, not applicable; OA, osteoarthritic change; RDA, rapid destructive arthrosis of the hip; THA, total hip arthroplasty; U/C, unclear (radiological subchondral fracture line or linear patchy sclerotic area was confirmed in these two cases).

Figure 1. An 83-year-old male (Patient no. 1 in [Tables 1](#) and [2](#)): (a) an anteroposterior (AP) radiograph of the right hip at the onset of pain. (b) On the coronal T_1 weighted image [repetition time (TR)/echo time (TE) = 474/14 ms], a low-intensity band is observed beneath the articular cartilage at the superolateral portion of the femoral head (arrows). (c) On the coronal T_2 fat-saturated image (TR/TE = 3500/87), bone marrow edema lesion is observed at the anterior portion of the acetabulum (arrow). (d) 3 months after onset, an AP radiograph is showing the progressive collapse of the femoral head and disappearance of the joint space. (e) A cut section of the resected femoral head is showing a reddish and whitish linear shaped area beneath the articular cartilage (arrows). (f) A photomicrograph obtained from the collapsed region [reddish and whitish linear shaped area in (e)]. Fracture callus (arrows), reactive cartilage and granulation tissue are observed. Granulomatous foci of fragmented bone and cartilage debris (arrowheads) are seen in the bone marrow space, indicating rapid joint destruction (haematoxylin and eosin X40).

DISCUSSION

Generally, the presence of a BME lesion on MR images is consistent with edematous changes and mild fibrosis, which are often associated with the observation of fat cell destruction, vascular congestion and/or interstitial haemorrhage in histopathology specimens.⁹ These findings can be seen in patients with osteoarthritis of the hip.¹⁰ In the present study, 7 (47%) of 15 hips showed the BME lesions in both the femoral head and acetabulum. In contrast, no cases showed a low-intensity band (fracture line) on MR images in both the femoral head and acetabulum. We consider these results to indicate the following: first, the subchondral fracture line, especially in the acetabulum, was not observed owing to either the slice thickness or slice direction of MR images. Second, the subchondral fracture line was not observed owing to the presence of extensive BME lesions. The subchondral fracture lines are more apparent on the follow-up MRI than those on the initial MRI in some cases of subchondral insufficiency fracture owing to the presence of extensive BME lesions. In the present study, 2 of 15 cases were diagnosed as having the subchondral insufficiency fracture by plain radiography. In the seven hips for which a second MRI examination was performed, the disappearance of the subchondral fracture was confirmed at 3–5 months after the initial MRI examination ([Table 1](#)). We therefore consider that it is reasonable to perform a follow-up MRI examination after an interval of 1 month from the initial MRI for an accurate diagnosis of a subchondral insufficiency fracture. Finally, BME lesion can be observed as osteoarthritic changes. A recent study

showed that cartilage defect size is associated with a clinical subchondral insufficiency fracture of the femoral head progression.¹¹ Further investigations with histopathological assessments at both the femoral head and acetabulum are necessary to clarify the impact of comorbid BME lesions on the prognosis of subchondral insufficiency fracture of the hip.

Some cases of a subchondral insufficiency fracture have been reported to undergo a progressive collapse necessitating surgery, while others have been reported to heal after conservative therapy.^{5,6} The prognosis of patients with subchondral insufficiency fracture remains unclear. Recently, several possible factors have been identified to be associated with the prognosis and need for surgery of patients with a subchondral insufficiency fracture. Clinically, it has been reported that more elderly patients (>71 years) and female patients with subchondral insufficiency fracture of the femoral head are at higher risk of undergoing surgical treatment.^{12,13} Radiologically, the acetabular head index and the length of T_1 low-intensity band (subchondral fracture line) of MR images to the weight-bearing portion ratio (band length ratio) have been shown to be important prognostic factors in patients with a subchondral insufficiency fracture of the femoral head.¹⁴ The authors concluded that the adequacy of acetabular coverage (acetabular head index < 76.8) and a band length ratio of >57.9 were associated with a higher risk of the progression of collapse of the femoral head and the need for surgery,¹⁴ which were consistent with the majority of our cases ([Table 2](#)). As a new finding of the prognosis of patients with

Figure 2. A 78-year-old male (Patient no. 10 in [Tables 1](#) and [2](#)): (a) an anteroposterior radiograph of the bilateral hip at the onset of pain. (b, c) MRI findings at the onset of pain. A coronal T_1 weighted image [repetition time (TR)/echo time (TE) = 430/14] (b) is demonstrating diffuse low signal intensity in the acetabulum and a corresponding high signal intensity on the fat-saturated T_2 image (TR/TE = 3800/90) (c). (c) A fracture line is observed beneath the articular cartilage at the left side of acetabulum (arrows). (d) 3 weeks after the onset of pain, patchy areas of osteosclerosis are seen in the acetabulum (arrows). (e, f) MRI findings 3 months after the onset of pain (T_1 weighted image, TR/TE = 550/10; fat-saturated T_2 image, TR/TE = 5000/82). Bone marrow edema lesions have decreased and the low-intensity band previously seen in (c) has disappeared (f).

a subchondral insufficiency fracture, the results of our study indicate that patients with a subchondral insufficiency fracture of the hip in whom BME lesions were observed in both the femoral head and acetabulum are at a higher risk to require THA.

Clinically, several morbid conditions have been reported to be associated with RDA, including articular chondrocalcinosis, apatite crystal deposition, heterotopic ossification, neuropathy, infection, drug-induced arthropathy and a variant of osteonecrosis and rheumatoid arthritis.¹⁵ However, the precise aetiology of RDA remains unclear. Some cases of subchondral insufficiency fracture have been reported to show the rapid disappearance of the hip joint space and rapid joint destruction, such as that seen in RDA.³ Recently, there has been a report on cases with RDA resulting from a subchondral insufficiency fracture in both the femoral head and acetabulum.⁴ In the present study, BME lesions in both the femoral head and acetabulum were observed in all three patients with RDA (Patient no. 1, 4 and 5 in [Tables 1](#) and [2](#)) resulting from subchondral insufficiency fracture, although the fracture lines of the acetabulum were unclear based on the MRI findings.

The present study is associated with some major limitations. The first is the small number of cases examined (15 hips of 14 patients). Therefore, our results have limited validity and statistical analyses were not performed owing to the small number of cases. Further studies with a large number of cases where the correlation between the locations of BME lesions and the prognosis for a subchondral insufficiency fracture of the hip are evaluated are therefore necessary. The second limitation is that the duration from the onset of hip pain to the MRI examination was different in each case (ranging from 0.5 to 5 months). Timely MRI examinations are necessary to clarify the comorbidity of the locations of BME lesions in order to make an accurate prognosis in patients with a subchondral insufficiency fracture of the hip.

Several atypical cases involving subchondral insufficiency fractures of the hip were included in the present study. Patient no. 10 ([Tables 1](#) and [2](#) and [Figure 2](#)) showed bilateral subchondral insufficiency fractures of the acetabulum. To our knowledge, there have been no reports on bilateral subchondral insufficiency fractures of the acetabulum. Our case indicates that we need to

evaluate not only the femoral head, but also the acetabulum on MR images in patients with subchondral insufficiency fracture of the hip. Regarding the initial treatment for patients with acetabular insufficiency fractures without a femoral head fracture, we consider that resting and avoidance of weight bearing (similarly to patients with subchondral insufficiency fractures of the femoral head (SIF)) are needed in order to avoid surgical treatment, since a previous case report described a unilateral acetabular subchondral insufficiency fracture without a femoral head fracture that resulted in rapid acetabular osteolysis (protrusio acetabuli).¹⁶ Patient no. 2 (Tables 1 and 2) was a 43-year-old male patient with SIF in whom no evidence of osteoporosis, hyperparathyroidism or calcium/phosphate metabolism abnormalities other than the exception of BMD (t -score: -1.1 standard deviation) were observed. Although a recent study reported

that subchondral insufficiency fracture of the femoral head occasionally occurs in healthy adults,¹⁷ our case indicates that physicians should consider the possibility of subchondral insufficiency fractures in patients presenting with hip pain, even in young male patients.

In conclusion, the locations of BME lesions (femoral side alone, acetabular side alone or both) based on MRI findings may be related to the clinical outcome in patients with subchondral insufficiency fracture of the hip.

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