Computed tomography findings of subchondral insufficiency fractures of the femoral head

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ARTICLE INFO

Keywords:

Computed tomography
Subchondral insufficiency fracture of the femoral head
Magnetic resonance imaging

ABSTRACT

Objectives: The objective of this study was to describe the appearance of Subchondral insufficiency fracture (SIF) by computed tomography (CT).

Methods: Images of 52 consecutive patients diagnosed with SIF were retrospectively reviewed. CT was available for five patients (7 cases).

Results: Corresponding to a low-intensity band on MR images, a radiolucent or sclerotic band was observed on CT images.

Conclusion: The present study is the first to report CT findings of SIF. A radiolucent or sclerotic band was observed on CT images. The results of the present study provide useful information for diagnosis of SIF.

1. Introduction

Subchondral insufficiency fracture (SIF) of the femoral head has been reclassified as a cause of acute hip pain.^{1–3} Affected patients typically complain of acute hip pain with no obvious antecedent trauma.^{1,4–6} Radiographs obtained at the onset of hip pain show femoral head collapse or no obvious findings in the majority of cases. T1-weighted magnetic resonance (MR) images reveal low-intensity bands in the subchondral area of the femoral head, which tend to be irregular, disconnected, and convex to the articular surface.^{1,3,7} These low-intensity bands have been histologically shown to correspond to the fracture line of the associated repaired tissue.^{4,8} The low-intensity band is surrounded by a bone marrow edema pattern, which is observed as a homogenous and ill-delimited low-signal intensity area on T1-weighted MR images and high-signal intensity on T2-weighted MR images.⁹

Few studies have reported modalities other than MR imaging (MRI) for diagnosis of SIF. Of these, Miyanishi et al reported one case with transient osteoporosis of the hip, which had a subchondral fracture line of the femoral head on computed tomography (CT).¹⁰ However, the imaging appearance of SIF on CT has not been described in detail. Therefore, the aim of the current study was to describe the appearance of SIF on CT.

2. Methods

2.1. Patients

The protocol of the present retrospective study was approved by the local institutional review board. The medical records of 52 consecutive patients diagnosed with SIF between June 2007 and April 2014 at our institution were retrospectively reviewed. CT scans were available for five patients (two males and three females; mean age 57.2 years; age range, 23–81 years), which involved two bilateral cases. Of the five patients (seven cases), one had a history of corticosteroid therapy for asthma and one had a history of uterine cancer.

A diagnosis of SIF was based on the following published criteria^{1,8,11}: (1) hip pain with no apparent history of trauma; (2) radiographic findings that were normal or showed collapse of the femoral head, joint space narrowing, and/or linear patchy sclerotic areas in the superior portion of the femoral head; (3) a bone marrow edema pattern in the femoral head and/or neck on MR images; and (4) a subchondral low-signal intensity band on T1-weighted MR images that was serpiginous or paralleled the articular surface.

All patients were initially managed by conservative treatment, which consisted of rest and avoidance of weight-bearing activities for 6–8 weeks. Radiographically, the presence of a subchondral fracture,

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Table 1
Clinical characteristics and CT findings of the femoral head.

Case No.	Sex	Age	MRI (weeks) ^b	CT (weeks) ^c	Clinical Outcome	Collapse	Radiolucent band	Sclerotic band
1 ^a	Male	47	6.8	7.6	Conservative	–	–	+
2 ^a	Male	47	6.8	7.6	Conservative	–	–	+
3	Female	74	8.8	15.6	THA	+	+	–
4 ^a	Male	23	7.2	8.8	ARO	+	+	–
5 ^a	Male	23	7.2	8.8	ARO	+	+	–
6	Female	81	2.8	6.8	THA	+	+	–
7	Female	61	2.0	3.2	Conservative	–	–	+

^a Bilateral case.

^b From onset to MRI.

^c From onset to CT. THA, total hip arthroplasty; ARO, anterior rotational osteotomy of the femoral head.

Fig. 1. A 47-year-old male (Case 2 in Table 1): (a) T1-weighted MR image on coronal slice shows a low-signal intensity band (arrows). (b) CT (coronal slice) shows a sclerotic band corresponding to the band on the MR image (arrowheads). A 23-year-old male (Case 4 in Table 1): (c) T1-weighted MR image on coronal slice shows a low-signal intensity band (arrows), (d) CT (coronal slice) shows a radiolucent band corresponding to the band on the MR image (arrowheads) and collapse of the femoral head. No sclerotic band is observed.

patchy sclerosis, progression of collapse, and osteoarthritic change (joint space narrowing) were investigated on both the anteroposterior and lateral views, where progression of collapse was an indication of surgical treatment. For patients who did not undergo surgery, follow-up MRI was performed at approximately 6 or 12 months after the first visit.

2.2. MRI

MRI was performed using a 1.5-T or 3.0-T MR system. T1-weighted MR images (repetition time/echo time = 400–675/8–19 msec, field of view = 35–68 cm, matrix = 220–512 × 256–512, slice thickness = 3–5 mm) in the coronal plane were available for all patients. The hip position was neutral during MRI; namely, flexion, extension, abduction, adduction, internal rotation, and external rotation were each zero degrees.

2.3. CT scans

All CT images were obtained using a 64-detector-row CT scanner (Aquilion; Toshiba Medical Systems Corporation, Tokyo, Japan) with a 648 × 648 matrix, 2-mm section thickness, and field of view of 320 mm. Coronal CT slices were observed by two subspecialized hip joint surgeons with 4 and 7 years of experience, respectively. CT findings were compared with MR images.

2.4. Histopathological findings

For patients receiving total hip arthroplasty, a diagnosis of a subchondral insufficiency fracture was based on histopathological findings. Macroscopically, a linear fracture with a whitish-gray appearance paralleling the subchondral bone endplate was observed. Microscopically, the whitish-gray area consisted of irregularly arranged fracture calli and granulation tissue. It should be noted that small areas

Fig. 2. An 81-year-old female (Case 6 in Table 1): (a) T1-weighted MR image (coronal slice) shows a low-signal intensity band (white arrows). (b) CT (coronal slice) shows a radiolucent band corresponding to the band on the MR image (white arrowheads) and collapse of the femoral head. No sclerotic band is observed. (c) A cut section of the resected femoral head shows a whitish linear-shaped area beneath the articular cartilage. (d) Fracture calli (black arrows) and granulation tissue (black arrowheads) are observed (hematoxylin and eosin staining; magnification, $\times 100$).

of necrotic bone trabeculae and bone marrow may be observed in SIF; however, such necrosis is confined to the area around the fracture line with no evidence of antecedent bone infarction.^{1,12}

3. Results

The clinical characteristics and CT findings of the femoral head are summarized in Table 1. The mean duration from the time of hip pain onset to MRI examination was 5.9 (range, 2.0–8.8) weeks. The mean duration from the time of hip pain onset to CT examination was 8.3 (range, 3.2–15.6) weeks. Three cases (two patients) resolved after conservative treatment, while four cases (three patients) required surgical intervention due to progression of femoral head collapse (total hip arthroplasty and transtrochanteric anterior rotational osteotomy for two patients each). The mean duration from the time of hip pain onset to surgery was 17.9 (range, 6.0–27.2) weeks.

All hips showed a low-intensity band on T1 and/or T2-weighted MR images, which tended to be irregular, disconnected, and convex to the articular surface. Corresponding to the low-intensity band on MR images, a radiolucent or sclerotic band was observed on CT images (Table 1). Three cases with a sclerotic band showed no collapse of the femoral head and resolved by conservative treatment. Four cases with a radiolucent band showed collapse of the femoral head and required surgery (Fig. 1).

Two cases treated by total hip arthroplasty were histopathologically diagnosed as SIF. A cut section of the resected femoral heads showed a notched linear-shaped zone of white tissue, paralleling the subchondral bone endplate. The whitish regions consisted of fracture calli, reactive cartilage, and granulation tissue (Fig. 2). These reparative tissues corresponded to the bands on the MR images.

4. Discussion

T1-weighted MR images of SIF reveal low-intensity bands in the subchondral area of the femoral head, which tend to be irregular, disconnected, and convex to the articular surface.^{1,3,7} These low-intensity bands have been histologically shown to correspond to the fracture line of the associated repaired tissue.^{4,8} In the present study, the CT findings of SIF were compared with the MRI and histopathological findings. Corresponding to the low-intensity band on MR images, a radiolucent or sclerotic band was observed on CT images. Histopathologically, the bands consisted of fracture calli and granulation tissue. Although MRI remains the most useful modality for diagnosis of SIF, the present results of CT findings can contribute to a more precise diagnosis of SIF.

Conservative therapy, consisting of rest and the avoidance of weight-bearing activities, is the first choice of treatment for SIF. However, some SIF patients require surgical treatment due to the progression of femoral head collapse after conservative treatment.¹³ Careful follow-up is important for the treatment of SIF. Follow-up radiographs have been applied to investigate the progression of collapse and osteoarthritic change (joint space narrowing). Both the low-intensity band and bone marrow edema pattern on MRI exist more than several months after hip pain onset. Neither radiography nor MRI is able to detect the process of fracture healing. No studies have reported the CT findings of SIF, although many studies of other fractures reported the contribution of CT for the detection of fracture healing. CT can detect healing of femoral fractures earlier than radiography (3 vs. 6 weeks, respectively).¹⁴ In the present study, a radiolucent or sclerotic band was observed on CT images. Three cases with a sclerotic band showed no collapse and resolved by conservative treatment, while four cases with a radiolucent band showed collapse of the femoral head that required surgery. These CT findings may be associated with the course

of SIF. It is considered that many cases with a sclerotic band achieve fracture healing. Some studies have reported prognostic factors for SIF. The first reported prognostic factors of SIF were band length and band length ratio.¹⁴ Other factors, including acetabular head coverage,¹³ bone marrow edema lesion,¹² two types (central type and lateral type),¹⁵ and subchondral intensity on fat-suppressed T2-weighted Images,¹⁶ have also been reported. However, these previous studies focused on the association between MRI and the clinical results of SIF, while the present study is the first to report CT findings of SIF, which may be useful for follow-up imaging of SIF.

The main limitation to this study was the small sample size. Second, SIF is a rare fracture and CT is not routinely performed for all patients before initiating treatment. Third, the patients in this study underwent CT for preoperative evaluation or examination of other diseases, thus selection bias may have occurred. Hence, further studies of larger numbers of cases are needed. Lastly, the time of CT examination from pain onset varied. Therefore, prospective studies using routine planned CT are necessary to establish the most useful follow-up CT plan for SIF treatment.

5. Conclusion

The present study is the first to report CT findings of SIF. Corresponding to a low-intensity band on MR images, a radiolucent or sclerotic band was observed on CT images. The results of the present study provide useful information for diagnosis of SIF.

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