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CASE REPORT

MRI-detected double low-intensity bands in osteonecrosis of the femoral head

Ryosuke Yamaguchi · Takuaki Yamamoto · Goro Motomura · Satoshi Ikemura · Yukihide Iwamoto

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Introduction

When treating osteonecrosis of the femoral head (ONFH), it is important to define the site and size of necrotic lesions, in general based on the detection of the demarcating area. Although a plain radiograph is routinely performed, it does not always make the lesion clear, especially in early stage cases. On the other hand, magnetic resonance (MR) imaging usually detects the necrotic lesion more clearly even at the early stage [1, 2], and therefore MR imaging is widely used in both the diagnosis and the selection of treatment for ONFH [3, 4].

A low-intensity band in the femoral head on T1-weighted MR imaging is one of the characteristic findings in ONFH [1, 5]. It is generally a single band, and the band was histopathologically proven to correlate with the reparative zone of osteonecrosis. Therefore, this band is recognized as the demarcation between the necrotic and viable area [6, 7].

This report describes a case of ONFH in which T1-weighted MR imaging showed double low-intensity bands in the femoral head.

The patient was fully informed that her data would be submitted for publication, and she consented.

R. Yamaguchi · T. Yamamoto (✉) · G. Motomura · S. Ikemura · Y. Iwamoto
Department of Orthopaedic Surgery, Graduate School of Medical Sciences, Kyushu University, 3-1-1 Maidashi, Higashi-ku, Fukuoka 812-8582, Japan
e-mail: yamataku@ortho.med.kyushu-u.ac.jp

Case report

A 41-year-old female (height: 161 cm, weight: 46 kg, BMI: 17.7) presented with mild pain in her left hip joint; the pain had gradually progressed. There was no history of antecedent trauma, but she had a history of alcoholic liver cirrhosis. Plain radiographs of the left hip obtained 6 months after the onset of the pain showed a slight collapse at the anterosuperior portion of the femoral head without joint space narrowing (Fig. 1a, b). Based on these radiographic findings, she was thought to have ONFH. Despite conservative treatment, she eventually had difficulty walking. Radiographs obtained 1.5 years after the onset of the pain showed a progression of the collapse at the anterosuperior portion of the femoral head as well as an irregular band-like sclerosis in the femoral head (Fig. 1c, d). She had restricted hip motion in all directions (flexion: 100°, extension: 0°, abduction: 10°, external rotation: 10°, internal rotation: 0°).

MR imaging (Vantage 1.5-T; Toshiba Medical Systems, Tochigi, Japan) performed 1.5 years after the onset of the pain showed double low-intensity bands in the femoral head on the T1-weighted spin-echo [repetition time/echo time (TR/TE) = 590/10 ms)] and T2-weighted spin-echo (TR/TE = 3,500/94) images (Fig. 2a, b). The bands were almost parallel, and their shapes were concave to the articular surface. The proximal low-intensity band was localized in the relatively small area at the anterosuperior portion of the femoral head, which did not extend to the acetabular edge, while the distal low-intensity band involved a wide region of the femoral head and exceeded the acetabular edge. On the gadolinium-enhanced fat-saturated T1-weighted imaging (TR/TE = 590/10), the proximal low-intensity band was not contrast-enhanced, but the distal low-intensity band was partially contrast enhanced, and the proximal segment from the distal low-intensity band was not contrast

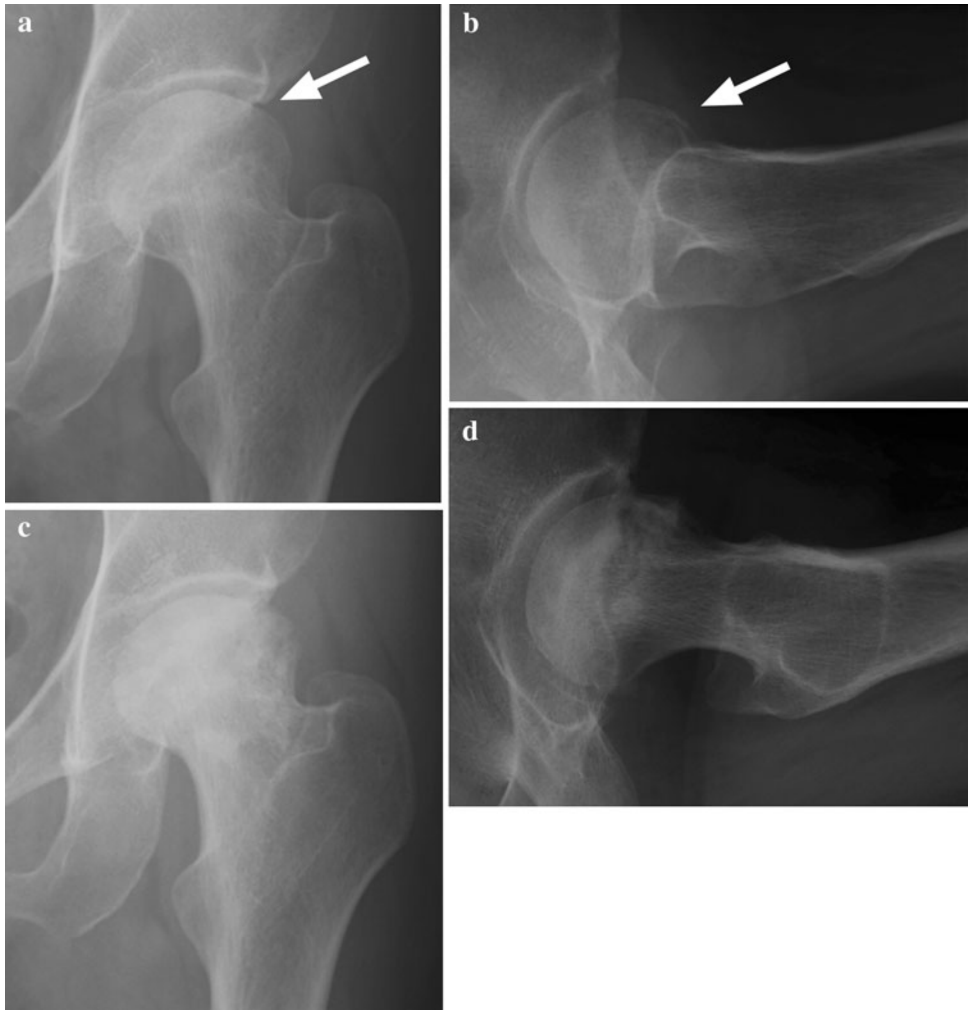

Fig. 1 Plain radiographs of the left hip joint. Radiographs of the anteroposterior view (**a**) and lateral view (**b**) at 6 months after the onset of the pain show a slight collapse at the anterosuperior portion of the femoral head (*arrow*) without joint space narrowing. Radiographs of the anteroposterior view (**c**) and lateral view (**d**) at 1.5 years after the onset of the pain show a progression of the collapse at the anterosuperior portion of the femoral head as well as an irregular band-like sclerosis in the femoral head

enhanced (Fig. 2c). The fat-saturated T2-weighted imaging (TR/TE = 5,000/18) showed similar findings to those on the contrast-enhanced T1-wighted imaging (Fig. 2d). Based on these findings, the distal low-intensity band was defined as the genuine demarcation between the living and necrotic area, and the proximal band as a fracture line. Since there were no indications for osteotomies, she underwent left arthroplasty.

A mid-coronal cut section of the resected femoral head showed a yellowish opaque, well-defined, wedge-shaped osteonecrosis (Fig. 3a). In addition, a fracture line was seen in the necrotic lesion, which corresponded to the proximal band detected on MR imaging. A specimen radiograph also showed the fracture line (Fig. 3b). An aggregation of bone debris was recognized as a sclerotic area along the fracture line. Microscopically, dead fractured bone trabeculae were observed around the fracture line with aggregation of bone debris, where there was no evidence of dead reparative tissue against osteonecrosis (Fig. 4a, b). On the other hand, around the distal band vascular-rich granulation tissues with appositional bone formation were observed (Fig. 4c). Histologically, the proximal band corresponded to the fracture line with aggregation of bone debris, while the distal band corresponded to the reparative tissue formed around the osteonecrosis.

Discussion

There have been few reports of MR imaging in ONFH showing double low-intensity bands on the T1-weighted imaging. Macroscopically and microscopically, the proximal low-intensity band on the T1-weighted imaging in the current case corresponded to a fracture line in the necrotic lesion, while the distal one corresponded to the previously characterized "low-intensity band" [1, 5], which demarcates the necrotic lesion from the viable area. The proximal low-intensity band was considered to be a fracture line and aggregation of bone debris, which were recognized as a sclerotic area along the fracture line.

In general, both non-enhanced T1-weighted and T2-weighted MR imaging can differentiate hypervascularized

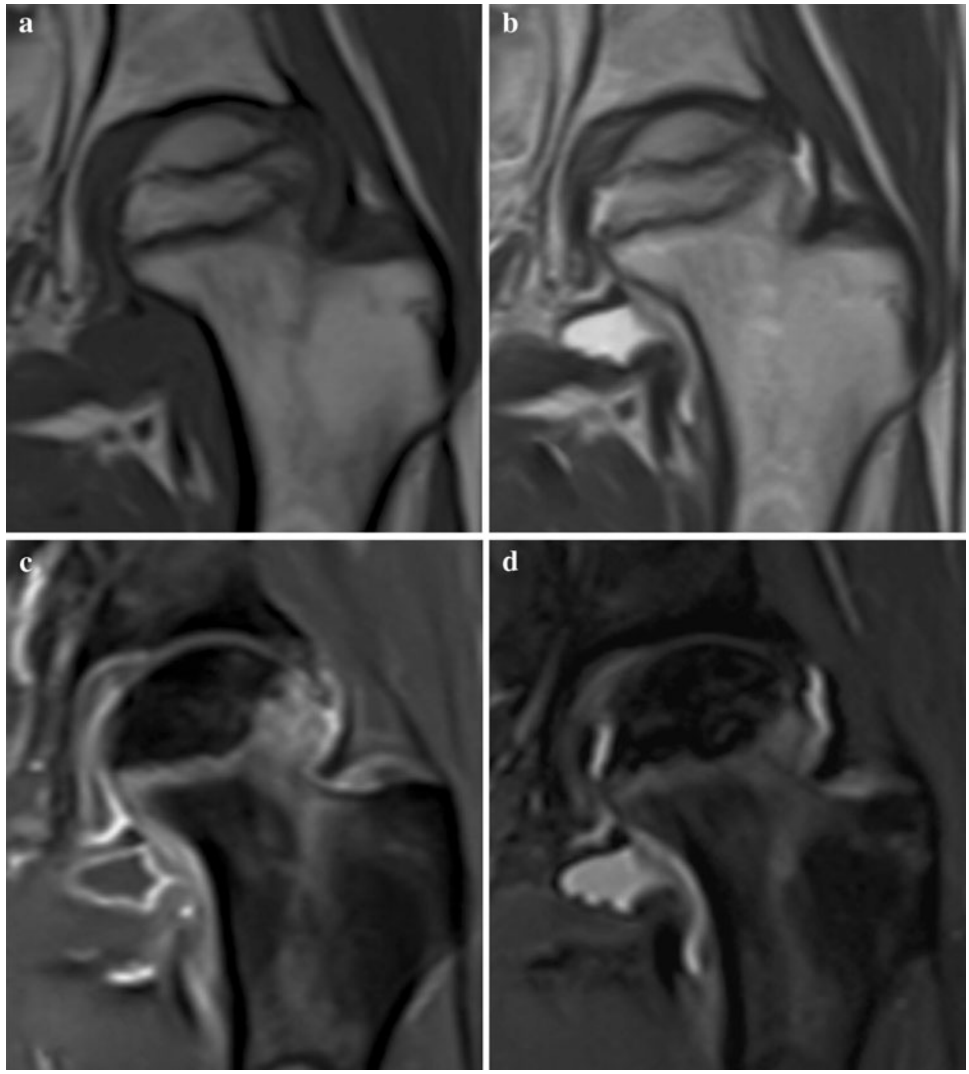

Fig. 2 MR imaging at 1.5 years after the onset of the pain. **a** Coronal T1-weighted spin-echo [repetition time/echo time (TR/TE) = 590/10 ms] and **b** coronal T2-weighted spin-echo (TR/TE = 3,500/94) images show double low-intensity bands in the femoral head. The bands are almost parallel, and their shapes are concave to the articular surface. **c** Coronal contrast-enhanced fat-saturated T1-weighted imaging (TR/TE = 590/10) shows no contrast-enhancement in the proximal segment from the distal low-intensity band. The proximal low-intensity band is not contrast-enhanced, but the distal low-intensity band is partially contrast-enhanced. **d** Fat-saturated T2-weighted imaging (TR/TE = 5,000/18) shows a high intensity in the area distal from the distal low-intensity band

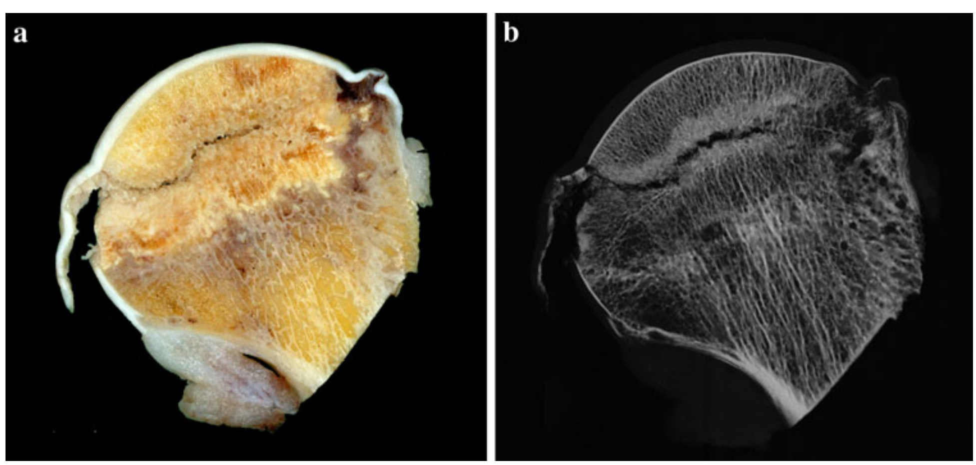

Fig. 3 A mid-coronal cut section of the resected femoral head and a specimen radiograph. **a** A mid-coronal cut section of the femoral head shows a yellowish, opaque, well-defined, wedge-shaped osteonecrosis. A fracture line is seen in the necrotic lesion. **b** A specimen radiograph also shows the fracture line clearly. The aggregation of bone debris is recognized as a sclerotic area along the fracture line

viable tissue from hypovascularized necrotic tissue in ONFH, and therefore contrast-enhanced MR imaging is not necessarily adopted [9]. However, contrast-enhanced MR imaging has been used to identify a necrotic lesion for ONFH cases that show a bone marrow edema pattern on non-enhanced MR imaging, because the pattern complicates the demarcation between the living and necrotic lesions [10, 11]. In the current case, the contrast-enhanced

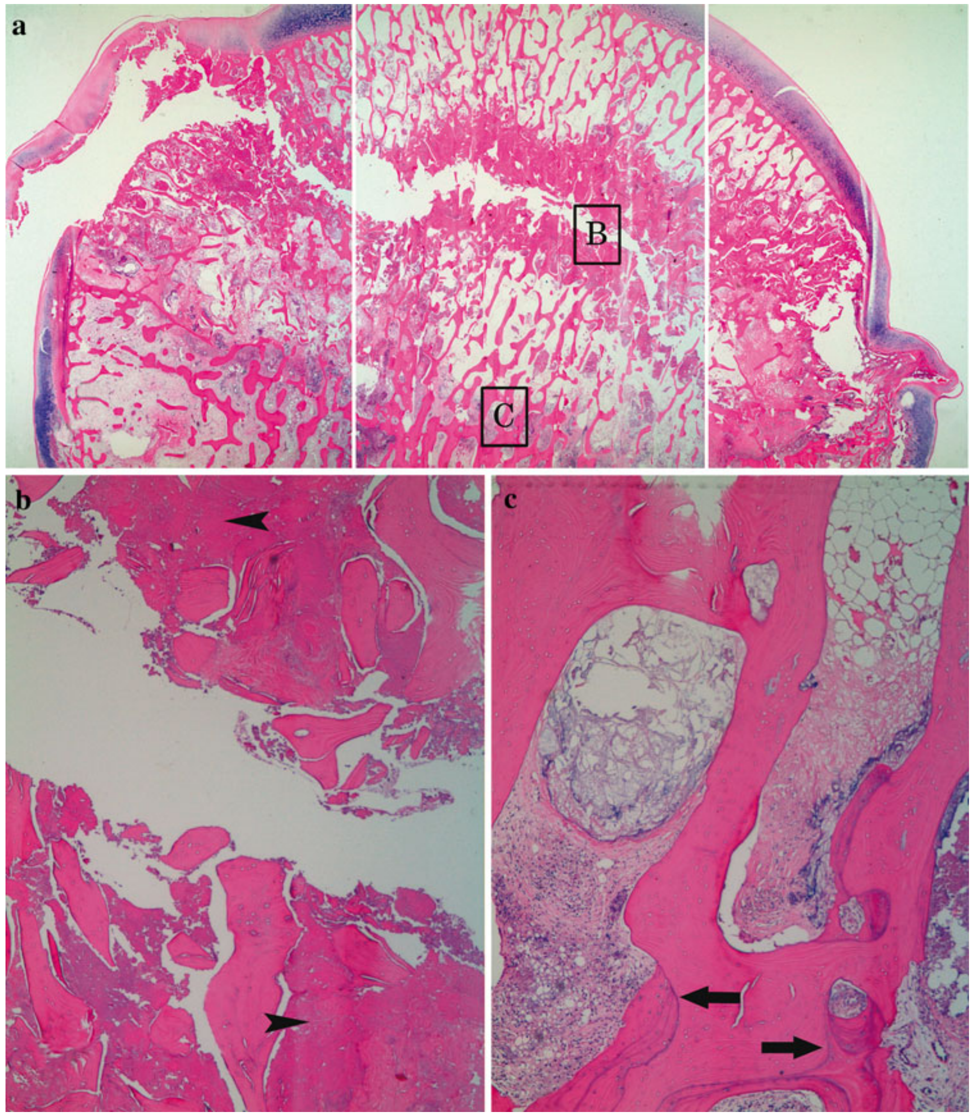

Fig. 4 Histological appearance in the femoral head (hematoxylin and eosin staining, 1× for **a** and 50× for **b** and **c**). **a** A fracture line is observed in the middle portion of the necrotic lesion. Expanded images below (*B*, *C*) correspond to *black-lined squares* in this image. **b** Dead fractured bone trabeculae are observed along a fracture line with bone debris (*arrow head*). This area corresponds to the proximal band detected by MRI, which thus indicates the fracture line. **c** Vascular rich granulation tissues with appositional bone formation (*arrow*) are observed. This area corresponds to the distal band detected by MRI, which thus indicates the reparative zone of osteonecrosis

T1-weighted imaging and fat-saturated T2-weighted imaging were useful to clarify the necrotic lesion and select the surgical treatment. However, some studies reported that CT revealed more subchondral fractures in osteonecrosis of the femoral head than unenhanced radiography or MR imaging [12, 13]. Therefore, CT may be useful for detecting a subchondral fracture if plain MR imaging shows ambiguous low-intensity band lesions in the femoral head with osteonecrosis.

In a case of recurrent osteonecrosis, similar double low intensity bands may be observed on MR imaging. However, in this case no evidence of dead repair tissue was histologically observed around the proximal low intensity area, which indicates that double bands in the current case were not the result of recurrent osteonecrosis. In addition, a histopathological study revealed that the prevalence of recurrent osteonecrosis was extremely rare (0.3%; 2 of 606 femoral heads) [14].

Bullough et al. [15] noted that focal concentrations of stress at the junctions between the thickened sclerotic trabeculae of the reparative zone and the necrotic trabeculae may be important in the formation of deep fractures within the necrotic legion. Yang et al. [8] reported that a fracture in the necrotic lesion appeared in two major locations: the subchondral region and the deep necrotic region near the underlying necrotic-viable interface. Also, the site and size of the necrotic area in the femoral head was suggested to determine the risk of a fracture and subsequent collapse. In the current case, the fracture was seen in the middle of the necrotic tissue concavely with a partial subchondral fracture, and both ends of the fracture were confirmed in the junctions. It is possible that, in addition to the sites of both ends of the fracture, the shape, the depth, and the width of the necrotic lesion may also be associated with the morphology of such fractures.

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