Case Report

Longitudinal Stress Fracture of the Humerus

Imaging Features and Pitfalls

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Abstract Longitudinal stress fractures are an uncommon injury in which a diaphyseal fracture line occurs parallel to the long axis of a bone in the absence of direct trauma. They have been described in the tibia and less commonly in the femur but apparently not in the upper limb. We report a longitudinal stress fracture occurring in the humerus of a 62-year-old woman who had a history of osteoporosis and had undergone recent surgery of the contralateral wrist. We present the radiographic, MRI, and CT features of the case and emphasize the difficulties in diagnosis caused by negative findings on early radiographs and by nonspecific bone marrow edema pattern on MRI. The risk of a contralateral upper extremity stress fracture from activities of daily living in a patient with osteoporosis whose other upper extremity is immobilized also is highlighted.

Introduction

Longitudinal stress fractures are uncommon injuries in which a diaphyseal fracture line occurs parallel to the long axis of a bone in the absence of direct trauma. They are distinguished from the more common pattern of horizontal stress fractures, which run perpendicular to the diaphyseal cortex of a long bone. Longitudinal stress fractures have been reported exclusively in the lower limb. There are several reports of longitudinal stress fractures in the tibia [4, 8, 10, 11] and a small number of reported cases in the femur [22, 23]. The diagnosis is important, as some of the imaging features can overlap with inflammatory and neoplastic entities and therefore awareness of the diagnosis and its specific imaging signs is needed. We are unaware of any reported case in the current literature of this pattern of stress fracture in the upper limb. We describe the radiographic, MRI, and CT findings in a patient with a longitudinal stress fracture affecting the patient's right proximal humeral diaphysis.

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Each author certifies that his or her institution has approved the reporting of this case report and that all investigations were conducted in conformity with ethical principles of research.

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Case Report

A 62-year-old woman presented with right upper arm pain that began 2 months after injury to her contralateral left wrist. The earlier injury to her left wrist was caused when she tripped on a cement porch, resulting in a deep laceration to the palm of her left hand. She sustained a laceration to the flexor digitorum profundus of the left long and ring fingers and of the flexor digitorum superficialis of the left ring finger. Both injured flexor digitorum profundus tendons were surgically repaired 4 days after injury. The left ring finger flexor digitorum superficialis was resected. Postoperatively, the left hand and wrist had been

immobilized in a dorsal block splint. The patient then presented with right upper arm pain, which was gradual in onset, beginning 6 weeks after her left wrist surgery. The pain was progressively more severe and present at rest but exacerbated by use of the right arm.

The patient's medical history included hypothyroidism (well controlled on levothyroxine sodium 50 µg per day) and mild hypertension (treated with atenolol 200 mg twice daily). The patient also was diagnosed with osteoporosis 8 years before her left wrist injury and was treated with risedronate sodium 35 mg weekly. At baseline, her lumbar spine T-score was -0.7 and femoral neck T-score was -2 . Her most recent bone densitometry performed 6 months before the onset of right upper limb symptoms showed lumbar spine osteopenia (T-score = -1.9) and femoral neck osteoporosis (T-score = -2.5). The patient was not active in any sporting activity and was retired from her former work as a teacher. She lived alone, and after her left hand surgery, she performed all activities of daily living without assistance. During the first 2 to 3 weeks of the patient's right upper limb pain, she initially attributed the symptoms to simply "overdoing it," but she sought medical attention when the pain became progressively worse and restricted her activity.

Radiographs of the right shoulder were performed 2 to 3 weeks after onset of symptoms (9 weeks postoperatively). These were interpreted as normal, showing no evidence of bone lesion, lucent fracture line, arthritis, or definite periosteal new bone formation. Retrospective review of these radiographs showed a subtle abnormal linear area of increased density in the right proximal humeral metadiaphysis parallel to its long axis (Fig. 1). At that time, the patient was presumed to have right rotator cuff tendinopathy. She received treatment with a right shoulder cortisone injection, with relief lasting less than 1 day.

Because of persistent severe pain, MRI of the right shoulder and humerus was performed 12 weeks postoperatively (Hitachi 0.3-T AIRIS® II open MRI; Hitachi Medical Corp, Tokyo, Japan) (Fig. 2). The MR images showed extensive abnormal bone marrow signal intensity throughout the right humeral medullary cavity, with abnormal low signal intensity on T1-weighted spin echo images (TR, 530 ms; TE, 14 ms; slice thickness, 4 mm) and high signal intensity on short tau inversion recovery (STIR) sequence (TR, 2200 ms; TE, 25 ms; inversion time, 100 ms; slice thickness, 4 mm). This combination of signal intensity abnormality was consistent with a bone marrow edema pattern. In addition to marrow edema, axial T1-weighted and STIR sequences showed focal endosteal and periosteal thickening at the posterolateral aspect of the proximal humeral shaft, extending longitudinally from the proximal right humeral metaphysis to the distal humeral

Fig. 1 A radiograph of the right proximal humerus obtained in internal rotation, which initially was interpreted as normal, shows, on retrospective review, subtle longitudinal sclerosis in the right proximal humerus metadiaphysis (arrowheads).

diaphysis. This endosteal and periosteal abnormality extended over a length of approximately 15 cm and were parallel to the long axis of the humerus. There was mild soft tissue edema adjacent to the region of periosteal reaction, evidenced by high signal on STIR sequence. The marrow signal abnormality prompted the readers of the initial MR images to include neoplasia and infection in the differential diagnosis, and at this point, the patient was referred to an orthopaedic oncologist for further assessment.

We then obtained a repeat radiograph of the right humerus (12 weeks postoperatively and 6 weeks after onset of symptoms) (Fig. 3). The radiograph showed a subtle linear area of periosteal reaction along the posterolateral aspect of the proximal right humerus, extending longitudinally from the proximal metaphysis to the diaphysis. Of three radiographic views taken at that time, the periosteal reaction was seen only on an anteroposterior projection of the humerus with the arm in internal rotation. Although the presence of the periosteal new bone formation represented a nonspecific finding, the linear configuration of the periosteal reaction, in conjunction with the clinical history, suggested a diagnosis of stress fracture.

Fig. 2A–B (A) An axial STIR sequence MR image (TR, 2200 ms; TE, 25 ms; inversion time, 100 ms; number of excitations, two; slice thickness, 4 mm) through the proximal right humeral shaft shows increased marrow signal intensity consistent with bone marrow edema pattern (arrow) and focal endosteal and periosteal reaction (arrowhead). No fracture line is evident. (B) A sagittal STIR sequence MR image (TR, 3326 ms; TE, 25 ms; inversion time, 90 ms; number of excitations, two; slice thickness, 4 mm) shows extensive signal abnormality in the right humeral shaft (arrows) consistent with bone marrow edema pattern.

Fig. 3 A radiograph of the right proximal humerus in internal rotation taken 6 weeks after symptom onset shows ill-defined linear sclerosis (arrowheads) and periosteal reaction (arrow).

We obtained a CT scan of the right upper limb (Light-Speed 64-slice MDCT; GE Medical Systems, Milwaukee, WI) 15 weeks postoperative and confirmed the presence of

a nondisplaced longitudinal fracture through the posterolateral cortex of the proximal humerus (Fig. 4). The fracture extended longitudinally from the proximal right humeral metaphysis to the distal humeral diaphysis over a 15-cm length, parallel to the long axis of the humerus (Fig. 5). There was associated periosteal and endosteal new bone formation.

The patient was treated nonoperatively with activity modification, but she declined immobilization. She received analgesia with oral tramadol and an acetaminophen-hydrocodone combined oral analgesic. Two months later, 23 weeks postoperatively, the patient had become asymptomatic with respect to her right upper arm and remains asymptomatic on followup 1 year later.

Discussion

Longitudinal stress fractures were first described by Devas in 1960 [10]. The key element of this diagnosis is a fracture

Fig. 4A–B Axial noncontrast CT scans of (A) the right proximal humerus and (B) the right midhumeral shaft (axial slice thickness, 2.5 mm; bone kernel) show endosteal and periosteal reaction and a lucent transcortical fracture line (arrows), longitudinally orientated, parallel to the long axis of the humerus. This finding continued from the proximal metaphysis to the distal right humeral shaft.

Fig. 5 A three-dimensional volume rendered reformation of CT of the right humerus shows the longitudinal orientation of the periosteal reaction at the right humeral longitudinal stress fracture (arrows), running approximately parallel to the long axis of the humerus.

line that occurs parallel to the long axis of a bone, but the fracture is an incomplete fracture, involving the cortex on one side only. In the original description of this entity [10], five of the six cases involved the tibia; the sixth case involved the femur. There have since been numerous additional reports of longitudinal stress fractures involving the tibia or femur [7, 8, 11, 12, 19, 20, 22, 23]. To our knowledge, this is the first reported case of a longitudinal stress fracture occurring in the upper extremity. Longitudinal stress fracture has been described in the lower limb in athletes, where it represents a manifestation of fatigue fracture [8, 10], and also in older patients with reduced bone mineral density, where it occurs in association with normal activities and represents a manifestation of insufficiency fracture [4, 23]. The mechanism of longitudinal stress fracture is poorly understood, but rotational stress was suggested as an etiologic factor in the original report of this entity [10].

Humeral stress fractures have been described in the setting of overuse, usually related to sport. Humeral stress fractures have been described in tennis players [21], baseball pitchers [2, 6], badminton players [5], volleyball players, weight lifters [13, 18], and arm wrestlers [15]. Humeral stress fractures also have been reported in military

Fig. 6A–B The diagrams illustrate the two subtypes of longitudinal stress fracture by morphologic features: (A) transcortical, in which the fracture line runs perpendicular to the cortex of the bone; and (B) intracortical, in which the fracture line runs parallel to the cortex of the bone.

personnel active in grenade throwing [14]. When present, humeral stress fractures are usually complete spiral fractures of the middle to distal shaft [2, 6, 14, 15, 18]. Stress reaction without fracture also has been reported involving the humerus [21]. In these cases, radiographs were normal and MRI showed periosteal reaction and marrow edema pattern but no fracture line.

Initial radiographs are often negative in the setting of longitudinal stress fractures. It can take several weeks for a periosteal reaction to become radiographically visible [10]. Early findings, as in this case, can be so subtle as to be overlooked. The fracture line often is not observed radiographically [11]. Even when visible, the fracture line may be apparent only on oblique radiographs [10]. The MRI appearance of longitudinal stress fractures can be nonspecific. MRI of longitudinal stress fracture usually shows prominent bone marrow edema and may show periosteal reaction [11]. Unfortunately, these findings may be misinterpreted as evidence of infection or neoplasia. MRI may show linear focal irregular low signal (on T1, T2, or STIR sequences) along the surface of the cortex consistent with periosteal or endosteal new bone formation, cortical thickening, and/or a discrete fracture line through the cortex. A distinct fracture line is not always visible with MRI, however [11]. CT scans in individuals with longitudinal stress fractures show subtle increased density adjacent to the cortex attributable to periosteal or endosteal reaction and, as in this case, also may show a distinct longitudinal fracture line. In one reported series of longitudinal stress fractures, CT showed a fracture line in 82% of cases whereas MRI confirmed a fracture defect in 73% [11]. The combination of MRI and CT allowed depiction of a fracture line in 93% of cases. By depicting the fracture, CT is likely to be a more specific technique to use in this setting. The fracture line, depicted on cross-sectional imaging, can have two possible patterns: intracortical [23], where the fracture parallels the cortex, or transcortical, where the fracture is perpendicular to the cortex [4, 8, 11]

(Fig. 6). The fracture line in the current case was transcortical.

The clinical setting should prompt a high index of suspicion for stress fracture. Patients with longitudinal stress fractures commonly present with indolent pain with a duration of symptoms of several weeks [1, 4, 10, 11, 22], sometimes presenting as late as 6 months after onset of symptoms [11]. Longitudinal stress fractures generally affect two groups of patients: athletes and patients with osteoporosis (most commonly postmenopausal women) [4, 10, 11]. Fractures of the humerus (often spiral humeral shaft fractures) are not uncommon in patients with osteoporosis [3, 16, 17], but they usually occur in the setting of trauma, although the trauma may be minor. As is the case for patients presenting with femoral neck fractures or vertebral insufficiency fractures, clinical presentation with upper limb stress fractures represents an important opportunity for osteoporosis screening to attempt to reduce future morbidity in patients with hitherto undiagnosed osteoporosis [9].

We describe a case of a longitudinal stress fracture occurring in the humeral shaft. The combined radiographic, MRI, and CT appearances are characteristic of this pattern of injury, heretofore described only in the lower limb. The diagnosis of stress fracture, including longitudinal stress fractures, should be considered in a patient complaining of upper limb pain in the setting of increased use of that limb, particularly in patients with osteoporosis. Activity modification, even without immobilization, can lead to resolution of symptoms. Radiographs can appear normal or near-normal soon after the onset of symptoms and the MRI finding of bone marrow edema pattern can be misleading. Followup radiographs and CT are useful for establishing the diagnosis.

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