MRI of Stress Reaction of the Distal Humerus in Elite Tennis Players

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OBJECTIVE. The purpose of this study was to describe the MRI appearance of stress reaction in the distal humerus in 12 elite tennis players. In addition, we aimed to determine whether any MRI findings were associated with changes in recovery times.

CONCLUSION. Stress injury to the distal humerus is a cause of chronic arm pain among elite tennis players and may be exacerbated during full competition. The degree of marrow edema on STIR MRI may be predictive of time to return to competition.

Upper-limb stress injuries to bone are relatively rare, accounting for 2.8–8.2% of stress fractures among athletes [1, 2]. These injuries are caused by an imbalance between bone tissue breakdown and repair in response to physical activity. At normal levels of activity, the two processes are in balance. In cases of physical overuse, however, tissue breakdown exceeds repair, and a stress response occurs in the bone. Female athletes may be at slightly higher risk of stress injury than men owing to impairment of repair mechanisms caused by associated menstrual irregularity and eating disorders (female athlete triad) [3].

Clinical symptoms of stress injury are nonspecific and include insidious onset of pain and tenderness. The diagnosis is often overlooked initially because the symptoms are nonspecific and are more commonly caused by soft-tissue overuse injury. Radiographs acquired early in the condition are likely to have normal findings [4]. Both MRI and bone scintigraphy are sensitive techniques for detecting stress injuries to bone [5]. It has been suggested that MRI is the preferred initial imaging technique because it is more specific and provides more information to the referring clinician than do other techniques [6].

We describe the MRI findings in the humerus in a group of elite tennis players who presented with symptoms at the 2002 and 2003 Australian Open tennis championships, at which a distinctive pattern of middle to distal humeral stress reaction was seen.

Subjects and Methods

Twelve professional tennis players presented consecutively to the medical team covering the Australian Open tennis championships in 2002 and 2003. The eight men and four women had a mean age of 24 years (range, 16–29 years). All the patients described pain in the middle and distal parts of the humerus of the dominant limb when serving, the pain continuing after the match. Duration of symptoms varied between 2 and 16 weeks (mean, 7 weeks). Examination revealed diffuse tenderness along the medial supracondylar ridge, the lateral supracondylar ridge, or both, of the distal part of the humerus. Results of clinical tests for common flexor or extensor tendinopathy were negative.

Institutional review board approval for scanning control subjects and retrospective consent from the athletes were obtained. The control group consisted of 20 healthy volunteers and 10 elite tennis players without symptoms.

Each subject underwent MRI of the affected limb performed with a 1.5-T superconducting MRI system (Signa Horizon, GE Healthcare). MRI was performed on the dominant upper limb of the control subjects with the same sequences as for the patient group. An axial proton density sequence (TR/TE, 4,000/30–45; matrix size, 256 × 224; section thickness, 4 mm; no intersection gap) and coronal, sagittal, and axial STIR (5,000/45–60/120; matrix size, 256 × 256; section thickness, 3 mm; no intersection gap) sequences were used. The scans were evaluated for morphologic features and signal intensity of the humeral cortex, periosteum, and bone marrow. The extent of marrow edema was classified as mild (0–24%), moderate (25–74%), or severe (75–100%) according to the maximal cross-sectional area of abnormal marrow signal intensity on axial scans, as measured on the MRI workstation.

Keywords: bone, elbow, elite athletes, MRI, musculoskeletal imaging, sports medicine, stress fracture, stress reaction, stress response, tennis, upper limb

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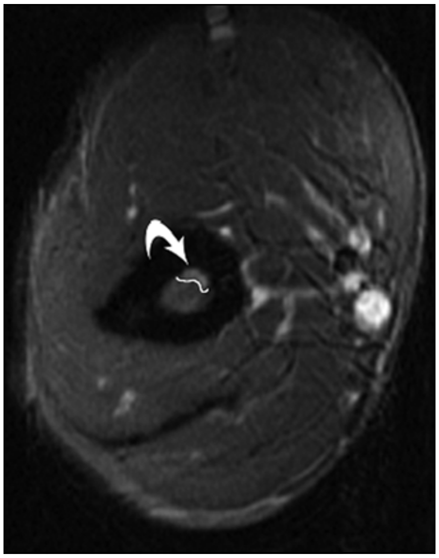

Fig. 1—26-year-old male professional tennis player with mild distal humeral stress reaction. Axial STIR MR image of distal humerus shows mildly increased signal intensity (*arrow*) occupying less than 25% of cross-sectional area (*outlined*) of marrow cavity.

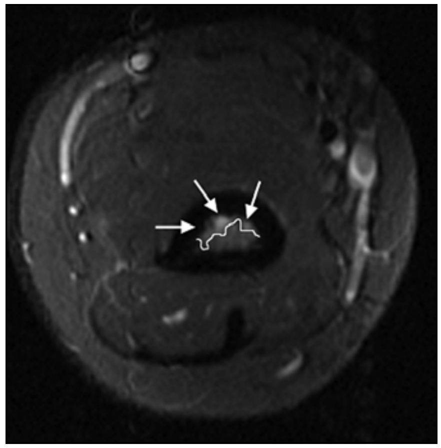

Fig. 2—23-year-old male professional tennis player with distal humeral stress reaction. Axial STIR MR image shows patchy increased signal intensity (*arrows*) within anterior aspect of marrow cavity occupying 38% (*outlined*) of total cross-sectional area.

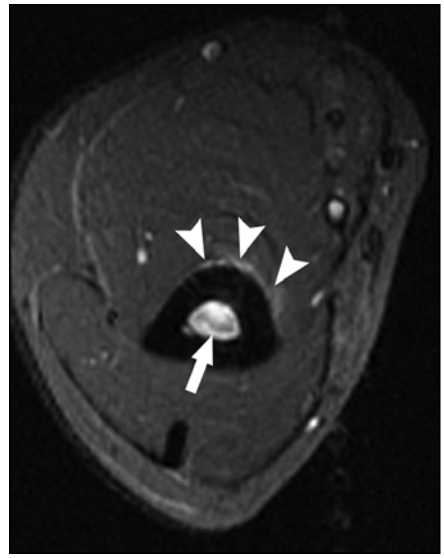

Fig. 3—24-year-old male professional tennis player with distal humeral stress reaction. Axial STIR MR image shows entire marrow cavity is of high signal intensity (*arrow*). Anteromedial periostitis (*arrowheads*) is evident.

The clinical history interview and examination of each subject were performed by either a sports physician or an orthopedic surgeon. Clinical follow-up was performed 1 year after presentation. A musculoskeletal radiologist with 10 years of musculoskeletal experience and a radiology clinical fellow interpreted the images with findings reached by consensus.

Results

All 12 players with symptoms had bone marrow edema within the middle to distal parts of the humerus on STIR MR images. The mean length of marrow edema was 10.1 cm (range, 6–15 cm). Among the men, marrow edema was classified as mild (Fig. 1) in two cases, moderate (Fig. 2) in three cases, and severe (Fig. 3) in the other three cases. One of the cases of moderate bone marrow edema was associated with moderate posteromedial periostitis. Among the women, marrow edema was classified as severe in all cases and was associated with mild anteromedial periostitis in two cases (Fig. 4).

The degree of marrow edema was related to the duration of symptoms: mild, 2.5 weeks (range, 2–3 weeks); moderate, 11.3 weeks (range, 5–16 weeks); and severe, 12 weeks (range, 8–16 weeks). No cortical abnormality, fracture, or soft-tissue mass was seen in any of the players.

One of the control elite tennis players had subclinical mild patchy increased STIR signal intensity in the distal part of the humerus. The STIR signal was normal in the other nine control tennis players and in all 20 control subjects who were not tennis players.

All 12 elite athletes with symptoms entered a rehabilitation program to prevent further stress injury. Clinical follow-up information was available for eight patients 1 year after presentation. One of the men had retired from the sport because of continued pain despite extended periods of rest. He had moderate bone marrow edema and posteromedial periostitis on STIR MR images. The other seven patients returned to the professional circuit within 6 months of presentation. The players with mild cases of edema returned to competitive tennis within 10 weeks, the two with moderate edema within 14 weeks, and the players with severe edema within 26 weeks of initial MRI diagnosis. None of the injuries progressed to frank humeral stress fracture.

Discussion

Upper-limb-dominant sports, such as tennis and swimming, are associated with stress injuries to the bones of the upper extremity [7–10]. Although soft-tissue overuse injuries are more common, stress injuries to the bones of the upper limb are an important cause of unrecognized limb pain in athletes [11]. In elite tennis players, the powerful swinging action transmits considerable force across the bones of the upper limb, shoulder girdle, and rib cage. Stress fractures of the humerus, ulna, wrist, and metacarpals have been found in adolescent tennis players [12–15]. “Little Leaguer’s shoulder,” that is, epiphysiolysis of the proximal humeral physis, can occur in adolescent tennis players [16]. “Humeral shin splints” have been found on bone scintigraphy of adult tennis players [17]. Ulnar stress fracture of the nondominant arm in a tennis player using a two-handed backhand stroke has been reported [18, 19]. Rapid movement and change of direction and frequent changes in playing surface predispose players to lower limb stress injury, the tibia being the most commonly affected bone overall [8].

A stress fracture can be considered the end point of a continuum of bone response to overuse injury. The first step along this continuum may involve activation of the acute repair process in the periosteum, that is, periostitis. With persistent repetitive microtrauma, inflammatory change occurs within the cortical bone and marrow cavity, eventually leading to end-stage stress fracture [20]. These early inflammatory changes can be recognized on MRI as areas of increased STIR signal intensity.

The marrow changes seen in our patient group represent a debilitating stress reaction occurring in the middle to distal part of the humerus. The location within the bone is unusual and may relate to the action of the brachialis or

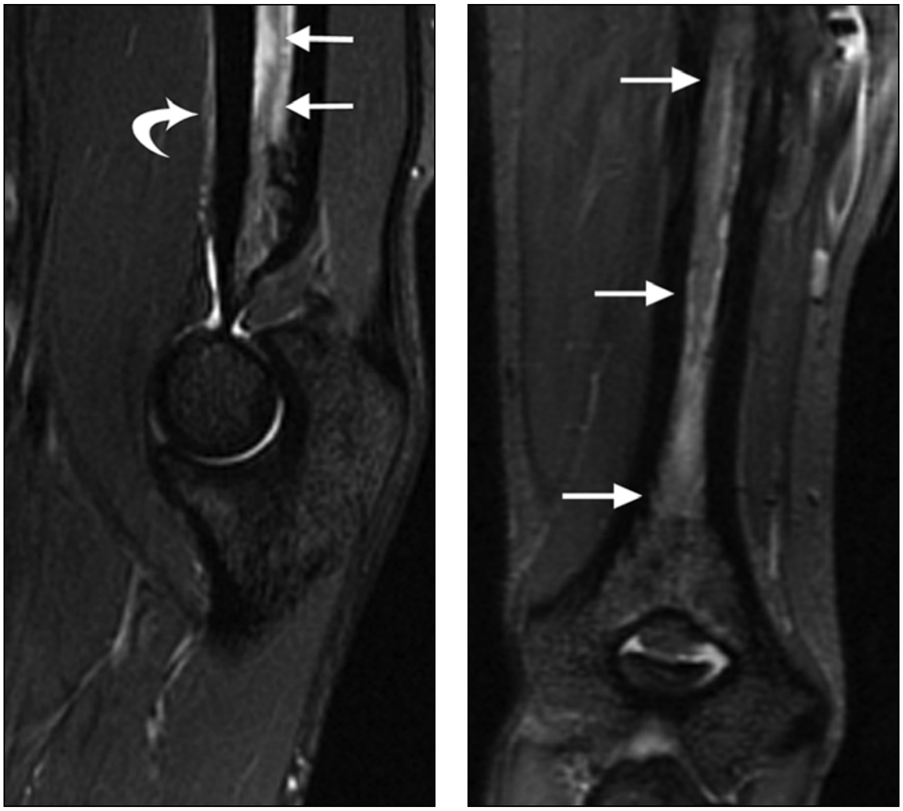

Fig. 4—22-year-old female professional tennis player with distal humeral stress reaction.
A, Sagittal STIR MR image shows marked marrow edema within distal humeral diaphysis (*straight arrows*). Linear anterior periostitis (*curved arrow*) is evident.
B, Coronal STIR MR image shows extent of marrow edema within distal humeral diaphysis (*arrows*).

pectoralis muscle or both on the humeral diaphysis. The repetitive excess muscle activity during active play, especially during the swing phase of the serve, results in marked torsion of the humeral shaft and subsequent stress reaction within the distal part of the humerus. It is possible that changes in racquet head size and weight and new ball types may have contributed to the cause of this condition.

All four women patients in the study had severe changes in the marrow, and two had associated periostitis. It may be that women are at higher risk of developing stress reactions as part of the female athlete triad. However, in a 15-year retrospective study [21] of stress injuries in collegiate athletes, including tennis players, there was no significant difference in injury patterns between the two sexes.

The differential diagnosis of lower humeral and elbow pain in the serving arm of an elite tennis player includes lateral humeral epicondylitis, brachialis or biceps brachii muscle and tendon abnormality, and osteochondral injury. The role of imaging in the management of stress injury is to establish the correct diagnosis and to identify early stress changes within bone. The principal aim in the management of stress reactions is to prevent progression toward full stress fracture. This goal should be attainable if conservative measures are instituted early in the rehabilitation period.

MR grading systems based on T1-weighted, T2-weighted, and STIR images have been described and used to predict patient outcome and to help plan treatment [22, 23]. In the system devised by Fredericson et al. [23], chronic stress injuries to the tibia in runners were graded 0 (completely normal) to 4 (fracture line) according to T1-weighted and STIR signal characteristics. Grade 1 was defined by periosteal reaction but normal marrow on T1-weighted and STIR images. Grade 2 was bone marrow edema on STIR but not T1-weighted images. Grade 3 was defined by abnormal T1-weighted and STIR marrow signal. Although we found periostitis in our cases, we used STIR marrow signal changes alone in our grading system. In this sense, the grading system we describe is an alternative classification of the Fredericson grade 2–3 stress response.

The absence of periostitis in the mild cases of edema in our study contradicts the grading system described by Fredericson et al. [23], in which periostitis is associated with lower-grade stress reactions. In our series, there appeared to be a trend in duration of symptoms, degree of marrow edema, and presence of periostitis. This difference may be explained by the different patient groups in the two studies. It may be that the anatomic features and stresses placed on the humerus in tennis players are not comparable with the stresses placed on the tibia in runners. We postulate that the stress injuries seen in our patient group were likely to be related to excess torsional and rotational forces applied to the humeral diaphysis from wielding the racquet rather than the distractional forces from muscle action applied to the tibia in runners. In addition, unlike the tibia, the humerus is not weight-bearing, and hence the biomechanical properties are different.

The main limitation of this study was the small population size. We describe an uncommon condition in a select patient group, and inevitably the numbers were small. We did not include T1-weighted imaging in our protocol and accept that some reviewers may see this as a limitation. However, we believe that our sequences were sufficient to exclude the presence of stress fracture. For the same reason, we did not perform CT on these patients. We also accept that there was potential for reporting bias because the radiologists were not blinded to the clinical information before each study, and reports were reached by consensus.

We conclude that the severity of marrow edema on STIR MRI as described with our criteria may be predictive of recovery time after distal humeral stress reaction in elite tennis players.

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