CHAPTER **48**

Stress Fractures Of The Foot And Ankle

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INTRODUCTION

Stress fractures are spontaneous breaks of bone which result from the summation of physical stresses, any of which by themselves, would be harmless. Stress fractures are relatively common in occurrence and comprise up to 10% of all sports related injuries. Matheson states that 5-16% of injuries sustained in runners are stress fractures.

CLASSIFICATION

Stress fractures occur in individuals of all ages undergoing varying degrees of physical activity. They are in general classified as fatigue fractures and insufficiency fractures. The former occurs when bone of normal structural integrity is subjected to abnormal stresses; whereas, the latter occurs when bone of deficient structural integrity is subjected to normal physiologic stresses. Fatigue fractures are commonly found in military recruits, athletes, and individuals who abruptly increase the duration or level of intensity of their physical activity. Insufficiency fractures may occur in patients with a variety of conditions including osteoporosis, hyperparathyroidism, Paget's disease, rheumatoid arthritis, osteomalacia, and fibrous dysplasia.

Common bones affected by stress fractures include the tibia, metatarsals, calcaneus, fibula, navicular, femur, and sesamoids. Although stress fractures are much more frequent in bones of the lower extremity, they have occasionally been reported to occur in non-weight bearing bones such as the humerus and ribs. Studies report the most common sites to be the lesser metatarsals and calcaneus.

PATHOPHYSIOLOGY

The most important predisposing factor for developing a stress fracture is a marked increase in the level of physical activity over a short period of time.

Whenever physical stress is applied to the musculoskeletal system, bone and muscle respond by undergoing compensatory change. In fact, bone requires a certain amount of stress for normal remodeling and proper function. Bone is a dynamic and heterogeneous tissue, and undergoes osteonal remodeling after periods of physical stress. Remodeling takes place by the processes of osteoclastic resorption and osteoblastic replacement. However, the former process has been shown to begin earlier and proceed more rapidly than the latter. After a stressful event, microfractures will occur in the area of laminar resorption of the involved bone. Therefore, a period of vulnerability exists during which the bone is somewhat weaker until the slower process of replacement catches up. If a particular bone is stressed repetitively over a period of time without allowing a sufficient amount of time for replacement, a stress fracture can occur due to the summation of non-healed micro-fractures.

An important factor in the development of stress fractures is increased muscular action which increases the load across the affected bone. The primary compensatory change in muscle after increased periods of activity is hypertrophy. However, muscle hypertrophy occurs much more rapidly than osseous remodeling, producing increased loading across the bone. A person may therefore be able to perform more intense physical activity to which the skeletal system is not yet adapted.

Muscle weakness is also thought to play an important role in the development of fatigue fractures in certain instances. Muscle weakness has been shown to reduce the shock absorption capacity of the lower extremities and allows the redistribution of forces to bone, increasing the amount of stress at focal points in the bone.

Biomechanical imbalance has also been implicated as a predisposing factor in the development of fatigue fractures. Structural deformity of the musculoskeletal system resulting in biomechanical imbalance has been shown to produce high stress loads on bones. A high longitudinal arch as seen in the cavus foot-type has been associated with a higher incidence of tibial and femoral stress fractures. In contrast, a low longitudinal arch as seen in pes planus has been associated with a higher incidence of metatarsal stress fractures. A study by Matheson et. al, identified that in military recruits with stress fractures, genu varum was present in 29%, tibial varum in 19%, subtalar varus in 72%, and forefoot varus in 73%.

Insufficiency fractures occur in a similar fashion. Bone of insufficient strength is thought to remain in a state of relative vulnerability for prolonged periods. The balance of resorption versus replacement is tilted heavily toward the former. Normal physical stresses can then eventually lead to fracture in conditions that predispose the musculoskeletal system to insufficient bone stock.

DIAGNOSIS

Accurate diagnosis of stress fractures is often difficult and therefore requires a high index of suspicion. In fact, it has been reported that the appropriate diagnosis is often delayed up to 13 weeks. The key point is recognition of the stress fracture in the early stage of injury, where late sequelae can potentially be avoided. The patient most commonly complains of pain and discomfort, of an aching nature with an insidious onset.

Physical examination usually reveals a limp in gait, and focal tenderness around the area of injury. Swelling in the dorsum of the foot and locally increased skin temperature are common findings in metatarsal stress fractures. A very useful clinical test for a metatarsal stress fracture is intense pain at the distal metatarsal shaft produced during passive dorsiflexion of the digit at the metatarsophalangeal joint. If diagnosis has been delayed, palpation of the metatarsal shaft may reveal the presence of an osseous mass, representing exuberant bone callus formation. This finding indicates that the fracture site has been unstable, resulting in exuberant callus formation as a form of internal splintage. The differential diagnosis when considering a stress fracture may include osteomyelitis, osteoid osteoma, and bone malignancy.

RADIOGRAPHIC PRESENTATION

Wilson and Katz in 1969 described a useful radiographic classification of stress fractures:

Type I:	Fracture line with no evidence of endosteal callus or periosteal reaction
Type II:	Focal sclerosis and endosteal callus
Type III:	Periosteal reaction and external callus
Type IV:	Mixed combination of above

Stress fractures vary significantly in their radiographic appearance depending upon the specific bone involved and the type of bone involved. For example, a stress fracture at the base of the first metatarsal appears completely different than one at the distal shaft of the lesser metatarsals. Stress fractures in cancellous bone most commonly present as an area of focal sclerosis in the area of injury. Cancellous bone is found in short bones as well as the epiphyseal and metaphyseal areas of long bones. This would be characteristic of a stress fracture at the base of the first metatarsal. In contrast, fractures of cortical bone, such as in the diaphyseal portion of long bones, present as a periosteal reaction with evidence of new bone formation, and/or an identifiable break in the cortex. Distal lesser metatarsal stress fractures most commonly present in this fashion.

The sooner a patient presents after development of a stress fracture, the greater the likelihood of a negative radiograph. In fact, initial radiographs have been reported to have a false negative rate of 71%, although most will eventually become positive. The radiographic evidence of stress fractures often lags 2-3 weeks behind the onset of symptoms and sometimes serial x-rays for 4-6 weeks are required to establish the radiographic diagnosis. However, emphasis should be placed on high clinical suspicion and the initiation of appropriate treatment before exuberant callus formation has taken place.

There may, however, be instances when one may be attempting to rule-out other potentially serious conditions such as osteomyelitis or osseous malignancies. In these situations certain special studies have been shown to be helpful in establishing the diagnosis.

SPECIAL STUDIES

Special studies are often helpful in the differentiation of primary bone malignancies from healing stress fractures. This is especially true in areas common for the development of osteosarcoma, such as the distal femur. Patients with stress fractures are often young, therefore, falling into the appropriate age category for the development of primary bone tumors. If any doubt exists about the diagnosis, special studies should be obtained. Special studies are often able to demonstrate the presence of a stress fracture when radiographic examination is negative, and may, therefore, aid in early diagnosis.

Bone scintigraphy is the most commonly utilized special study and can sometimes be helpful in establishing the diagnosis of a stress fracture. Bone scans (Tech 99MDP) are very sensitive and become positive long before standard radiographs. In fact, bone scans have been shown to become positive within 6-72 hours of the onset of pain. Prather reports that after the bone scan becomes positive, an additional 11 days will pass before x-rays will show evidence of fracture. However, bone scans are very non-specific and may show abnormalities in conditions other than a stress fracture, including infection and malignancy. Bone scans pose minimal risk for the patient, and can be performed on an out-patient basis. However, the need to obtain full-body scans is encouraged because some patients have been shown to have multiple areas of involvement.

Other special studies which have been used to aid in the diagnosis of stress fractures include computed tomography, conventional tomography, and magnetic resonance imaging. In general, these modalities are infrequently utilized but have shown occasional usefulness in the diagnosis of occult fracture of the calcaneus and tarsal navicular. Although MRI has shown potential usefulness in diagnosing bone tumors, it should be emphasized that bone biopsy is the most definitive measure to establish a diagnosis when malignancy is being ruled out.

PRESENTATION

Metatarsals

The incidence of stress fractures in the forefoot is highest in the second and third metatarsals. The most common anatomic site affected is in the distal diaphysis at the surgical neck. However, stress fractures of the fourth and fifth metatarsals tend to present more proximally in the mid-diaphyseal region. Fractures in the diaphyseal portion of the metatarsals, being composed primarily of cortical bone, appear radiographically as a periosteal reaction or an identifiable break in the cortex. If healing has progressed, evidence of new bone formation may be present (Fig. 1). A stress fracture in the fifth metatarsal will occasionally occur at the proximal diaphyseal-metaphyseal junction (Fig. 2). This presents clinically as a Jones fracture and appears as a radiolucent line with periosteal reaction. Excessive callus on the lateral cortical margins, and intramedullary sclerosis may also be seen. Stress fractures of the lesser metatarsals initially appear as Type I but most often progress to Type III. In contrast, a stress fracture of the first metatarsal most often occurs in the metaphyseal portion around its base and presents as dense sclerosis, representing a Type II stress fracture.

Stress fractures of the lesser metatarsals are commonly seen in military recruits as well as individuals who jog or stand for prolonged periods of time. Less commonly, stress fractures of the lesser metatarsals have been reported to occur in the post-operative period after bunion correction. Most commonly implicated has been the Keller bunionectomy, which produces a sudden weight shift to the middle three metatarsals. Congenital shortening of the first metatarsal has been cited in early literature as representing an important predisposing factor in the development of lesser metatarsal stress fractures. However, more recent literature has failed to substantiate this as a consistent finding.

Calcaneus

A stress fracture of the calcaneus, being composed primarily of cancellous bone, will present radiographically as Type II with a gradual progression from the normal trabecular appearance to small fluffy dots. After 4-6 weeks, radiographs reveal coalescent cloud- like densities eventually forming a band of dense sclerotic bone in the posterior portion of the calcaneal tuberosity (Fig. 3).

The differential diagnosis of a painful heel should include stress fracture, heel spur syndrome/ plantar fasciitis, neuritis, bursitis, and periostitis. Pain elicited upon side-to-side compression of the calcaneus is more frequent in patients with stress fracture than other causes of heel pain.

Calcaneal stress fractures are thought to be caused by the antagonistic pull of the Achilles tendon

Figure 1. Note fracture line through medial and lateral cortex of 2nd metatarsal with periosteal reaction and exuberant callus formation. A moderate amount of endosteal sclerosis is also present. Also, note the fracture line through the medial cortex of the 3rd metatarsal.

Figure 2. Stress fracture of the 5th metatarsal at the proximal metaphyseal/diaphyseal junction.

Figure 3. Stress fracture of the calcaneus. Note the sclerotic band coursing posterior/superior to anterior/inferior.

opposite that of the plantar tendons. The eccentric and concentric contraction of the gastrocnemius muscle during activities such as jumping, parachuting and prolonged standing is also thought to be a causative factor.

Navicular

Stress fractures of the navicular, although infrequent in occurrence, have received a great deal of attention in the literature. However, it is important to note that they are commonly misdiagnosed as tibialis anterior tendinitis, and therefore careful examination is emphasized. Early diagnosis is essential due to the high incidence of non-union, delayed union, and refracture in unrecognized navicular stress fractures. Physical examination reveals dorso-medial mid-tarsal pain upon direct palpation. Radiographic presentation usually begins as an incomplete fracture confined to the dorsal 5 mm of bone. The injury normally involves the central 1/3 of the bone and is linear in the sagittal plane. If the patient's history and clinical findings suggest a stress fracture but x-rays are negative, special studies such as a bone scan, conventional or computed tomography may be indicated. Computed tomography of the area in question has been shown to accurately define the amount of fracture, displacement, and healing.

Fibula

A stress fracture of the fibula is commonly known as a "runner's fracture". The fibula has been reported to represent the earliest bone affected by stress fracture. The most common area of involvement is in the diaphyseal shaft, approximately 3-5 cm above the level of the ankle joint (Fig. 4).

Routine radiographs may be negative for several weeks, and therefore, serial x-rays may be necessary to establish the diagnosis.

Figure 4. Stress fracture of the fibula in the distal diaphyseal shaft. The fracture is bi-cortical with exuberant callus formation.

TREATMENT

Conservative treatment for the management of stress fractures has been shown to be very effective in most instances. However, the prognosis during treatment with conservative measures is much better when an early diagnosis is made.

Stress fractures of the metatarsals are frequently associated with significant pain and swelling in the forefoot. Therefore, rest, ice, elevation, and compression are the mainstay of initial treatment for these injuries. Compression can be effectively achieved with use of a soft gel cast such as an Unna's boot dressing. This normally is quite successful for reducing the swelling in the forefoot. Oral nonsteroidal anti-inflammatory medications are also extremely useful in decreasing local inflammation and the associated discomfort. Restriction of activity is emphasized for these injuries. For stress fractures of the first, second, third, and fourth metatarsal, three weeks in a below-knee, weight bearing cast is effective in most instances. This treatment regimen works well if the fracture is non-displaced or minimally angulated medially or laterally in the transverse plane. However, in instances where displacement of the distal fracture fragment has occurred and there is significant dorsal or plantar angulation of the metatarsal head, open reduction with Kirschner wire fixation is the treatment of choice. Postoperatively the patient is placed in a below knee weight-bearing cast for a period of three weeks. At the end of the casting period the K-wire is removed and the patient is allowed full weight bearing in a surgical shoe for another one or two weeks.

Proximal stress fractures of the fifth metatarsal at the metaphyseal-diaphyseal junction deserve special consideration. These injuries are notorious for delayed or non-union and may require the patient to remain non-weight bearing in a below knee cast for six to eight weeks. In cases of chronic fracture with marked intramedullary sclerosis, open reduction with in-lay bone grafting should be used in addition to internal fixation, followed by protective weight bearing for up to three months.

Calcaneal stress fractures are normally treated very conservatively. Casting is rarely required, and the patient is allowed weight bearing in an Unna boot with a surgical shoe until symptoms resolve.

Uncomplicated partial fractures and non-displaced complete fractures of the navicular are treated in a non-weight bearing below-knee cast for six weeks. Complete stress fractures which have become displaced may be managed in a non-weight bearing below- knee cast for six weeks, or treated with open reduction and internal fixation followed again with a non-weight bearing below-knee cast for six weeks. The most common means of achieving rigid internal compression fixation is with two 3.5 mm cortical screws implanted using the lag technique. In cases of delayed or non-union, the treatment of choice is medullary curettage and inlay bone grafting with or without internal fixation, followed by a non- weight bearing below-knee cast for six weeks.

For stress fractures of the fibula, it is recommended that the patient decrease activity and undergo the previously mentioned conservative measures including ice, elevation, and a short course of oral anti-inflammatory medications. Other measures include placement of a lateral heel wedge in combination with a rigid heel counter to decrease eversion. Occasionally, adhesive strapping or a below-knee cast may be utilized.

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