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Review

Stress fractures of the foot and ankle

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ABSTRACT

Stress fractures occur as a result of microscopic injuries sustained when bone is subjected to repeated submaximal stresses. Overtime, with repeated cycles of loading, accumulation of such injuries can lead to macro-structural failure and frank fracture.

There are numerous stress fractures about the foot and ankle of which a trauma and orthopaedic surgeon should be aware. These include: metatarsal, tibia, calcaneus, navicular, fibula, talus, medial malleolus, sesamoid, cuneiform and cuboid.

Awareness of these fractures is important as the diagnosis is frequently missed and appropriate treatment delayed. Late identification can be associated with protracted pain and disability, and may predispose to non-union and therefore necessitate operative intervention.

This article outlines the epidemiology and risk factors, aetiology, presentation and management of the range of stress fractures in the foot and ankle.

Contents

Introduction

Stress fractures occur as a result of microscopic injuries sustained when bone is subjected to repeated submaximal stresses. Overtime, with repeated cycles of loading, accumulation of such injuries can lead to macro-structural failure and frank fracture. Most commonly, stress fractures occur in the lower limb

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or spine in those predisposed to repeated episodes of strain, such as military recruits or athletes. Within the foot and ankle, prevalence is greatest at the tibia and metatarsals, although the navicular, calcaneus, fibula, sesamoids and other tarsal bones may be implicated [1]. Risk factors include participation in activities involving repeated submaximal stresses, such as running, jumping or marching, lower bone density, female gender, and a poor pre-participation condition [2]. In particular, a specific risk triad involving repeated stress, low bone mineral density and dietary restraint has been reported in women, with a risk of stress fracture as high as 30–50% in select individuals exhibiting all three traits [3].

Awareness of stress fractures is important as the diagnosis is frequently missed and appropriate treatment delayed. Late identification can be associated with protracted pain and disability and may predispose to non-union, particularly in fractures of hallux sesamoids, the mid-tibial shaft, base of fifth metatarsal, and tarsal navicular [4]. This can necessitate the need for operative intervention as opposed to conservative management, and in the worst case may require the patient to terminate sporting pursuits entirely. This article will outline in prevalence order, the epidemiology, aetiology, presentation and management of the range of stress fractures in the foot and ankle.

Metatarsal

Stress fractures of the metatarsal bones account for 38% of all stress fractures of the lower limb [5]. The 2nd and 3rd metatarsals are most commonly involved, although 4th and 5th metatarsal fractures remain clinically significant given their greater potential for non-union [6].

Fractures of the 2nd metatarsal present with non-specific midfoot pain of insidious onset, often in ballet dancers. The mechanism of injury is repeated extreme plantar flexion at the Lisfranc joint, often adopted during ballet postures. Furthermore, 2nd metatarsal stress fractures may be contributed to by a prominent 2nd metatarsal, naturally pronated foot and poor ankle plantar flexion leading to subsequent compensation via excessive plantar-flexion at the metatarsal-cuneiform joint. Satisfactory treatment is normally achieved via rest or weight bearing cast immobilisation, potentially with adjunctive shock wave therapy [7].

5th metatarsal base fractures present with lateral foot pain, and tenderness at the 5th metatarsal base exacerbated by inversion. Progression to non-union of these fractures is contributed to by the presence of a perfusion watershed at the metaphysis/diaphysis junction between the proximally tracking nutrient artery, which enters the bone at the proximal diaphysis, and the metaphyseal artery [8]. Other predisposing factors include cavovarus foot alignment, as well as an increasing inter-metatarsal angle between the 4th and 5th metatarsals and a protruding 5th metatarsal head [9–11].

Torg described three grades of 5th metatarsal stress fractures. Torg I fractures have sharp margins with no evidence of widening of the fracture line, sclerosis, periosteal reaction, or cortical hypertrophy. Type II fractures exhibit widening of the fracture line, periosteal reaction and/or sclerosis, whilst type III fractures demonstrate a widened fracture line with complete sclerosis. Higher Torg classification and the presence of a plantar gap greater than 1 mm is associated with a longer time to union [12,13]. Though some studies have demonstrated a role for ultrasound in the diagnosis of 5th metatarsal fractures, MRI remains the gold-standard, with X-rays often falsely negative early in the clinical course.

Type I injuries may be suitable for a trial of non-weight bearing cast immobilisation in the first instance, with surgery reserved for cases of failed conservative management and for Type II and III injuries. However, for athletes in whom return to sporting pursuits is a priority, internal fixation with an intramedullary screw may accelerate time to return to sport compared to non-operative management [6]. Some have promulgated a role for extracorporeal shock wave therapy or electromagnetic field therapy in non-operative management, although their exact benefit is unproven [14].

In cases where it is necessary to pursue operative management, open reduction via a lateral incision to the 5th metatarsal and fixation with 3.5 or 4.0 mm lag screw is usually effective. The screw enters the styloid process and is angled obliquely medially and distally. It gains purchase in the medial cortex distal to the fracture [15]. An alternative technique is intramedullary screw fixation. The screw size varies with the canal size, however must be of sufficient diameter to obtain purchase and to generate compression. In most cases, a 4.5 mm cortical screw is chosen, but, in larger individuals, a 6.5 mm cancellous screw may be necessary.

Tibia

Tibial stress fractures are often cited as the most common site of stress fracture in military recruits and runners [1]. Whilst sharing the common risk factors associated with other lower limb stress fractures, gait plays a particular role in the evolution of tibial injuries. Increasing hip adduction, rear-foot eversion and subsequent rotational torque along the longitudinal axis of the tibia whilst running has been demonstrated to be associated with a tibial stress fracture [16]. This supports the conclusion that stress magnitude, as opposed to frequency, plays a greater role in the development of tibial stress fractures [17].

Stress fractures of the tibia present with exertional lower limb pain. They are also common in children who undertake rigorous sporting pursuits where they represent a mimic of Ewing sarcoma and osteoid osteoma due to similarities in the early clinical and radiological course [18]. CT, MRI and bone scans can help differentiate, and as for most stress fractures, have a role in establishing the diagnosis. 57% of tibial stress fractures occur in the distal third, 30% in the middle third, and the remaining 13% in the proximal third and medial condyle [19].

Treatment is initially through cessation of activity, often for as long as 4–6 months. Conservative management may be aided by the use of ESWT [20]. In at risk individuals with an intractable pattern of strain such as athletes, chronic and recurrent tibial stress fractures may require operative intervention. Intramedullary nailing demonstrates good results and accelerates time to return to sport compared to conservative treatment [21].

Calcaneus

Calcaneal stress fractures present with exercise induced heel pain, and may be misdiagnosed as either a heel spur or plantar fasciitis. MRI is helpful in making the diagnosis as plain radiographs are often negative [22]. They have been reported after elective hip and knee arthroplasty, as well as in association with a long anterior process of the calcaneus, or calcaneonavicular coalition [23,24]. Miki et al. [23] reported on 5 patients with ipsilateral calcaneal insufficiency fractures that occurred at a mean of 10 weeks post hip or knee arthroplasty. This represented an incidence of less than 1 percent. All patients had evidence of osteoporosis on bone density scan. They stipulated that this may be due to altered mechanical stress, or increased load associated with reduced pain in the replaced joint and post operative analgesics.

Stress fractures of the calcaneus represent a relatively common injury, with one study of American military recruits reporting them

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as the 2nd most commonly seen stress fracture of the foot in men (after metatarsal) and the most frequently observed in women [25]. The posterior calcaneus is injured most frequently, ahead of the anterior and middle parts [22]. Treatment is usually successful in the first instance with exercise modification only.

Navicular

Stress fractures of the navicular typically present with a poorly localising midfoot pain aggravated by physical stress and relieved by rest [26]. Associated with push off compression forces such as sprinting or jumping exercises, they are rarely reported but potentially commonly overlooked. Other risk factors include pes cavus, metatarsus adductus, limited subtalar or ankle motion, medial narrowing of the talo-navicular joint, a short first metatarsal and potentially, an os supranaviculare [27]. A mean delay of four months between the onset of symptoms and diagnosis demonstrates the difficulty of making the diagnosis, likely contributed to by a 66% false negative rate on plain X-rays and the need for CT or MRI [28]. Physiologically the navicular may be predisposed to stress fractures through the presence of a relatively avascular watershed in the central third of the bone, although cadaveric examinations have questioned the significance of this finding [29].

Treatment is with non-weight bearing cast immobilisation for at least 6 weeks, this being the gold standard reported in Torg et al's meta-analysis [30]. This demonstrated a 96% healing rate at 5 weeks with non-weight bearing immobilisation. Partial weight bearing treatment and displacement were associated with non-union. Delayed union, should it occur, may be treated with either further immobilisation, particularly in the context of a failure of treatment by partial weight bearing, or by open reduction and internal fixation [31,32]. Time to return to sport does not appear to be accelerated by surgery [33]. Failure of conservative management requires open reduction and internal fixation.

Operative management of navicular stress fractures should aim to restore both navicular concavity and the length of the medial column. Fixation is achieved by distraction of the medial column, followed by reduction, trial fixation with k-wires and their subsequent replacement with lag screws to achieve definitive fixation [34].

Saxena proposed dividing navicular stress fractures into three categories [35]. Type I injuries were those with an isolated dorsal cortical break. Type II injuries demonstrated fracture propagation into the navicular body, and Type III fracture propagation into another cortex. This classification was supplemented by one of three modifiers namely type "A" (avascular necrosis of a portion of the navicular), "C" (cystic changes of the fracture), or "S" (sclerosis of the margins of the fracture) [35]. Saxena reported on twenty-two navicular stress fractures sustained during athletic activity. Type I and II injuries had an average return to activity of 3.0 and 3.6 months, respectively. Type III injuries had an average return to activity of 6.8 months. ORIF was recommended for type III injuries and some type II in the presence of modifiers based on delayed healing in this group. In his series, nine patients underwent open reduction internal fixation (some with bone grafting); this group's average return to activity was 3.1 ± 1.2 months (range, 1.5–5 months). Thirteen patients treated conservatively had an average return to activity of 4.3 ± 2.8 months (range, 2–13 months). The difference between the two groups' return to activity was significant ($p = .02$) [35,36].

Fibula

Stress fractures of the fibula account for 6.6% of lower limb stress fractures [1]. This may be explained by the limited weight bearing role of the Fibula. Stress fractures of the fibula share many characteristics to those of the tibia. MRI is helpful in diagnosis as they can mimic bone tumours or osteomyelitis in the early clinical course, particularly as they are not infrequently seen in children who undertake sports or ballet [37]. In adults, a similar association with running and jumping exists as for tibial stress fractures. Other risk factors include tibio-fibular synotosis or repeated heavy lifting [38,39].

A study of 635 South Korean military recruits identified only 12 fibular stress fractures over a 12 month period, the majority located in the proximal 1/3rd of the fibula. Treatment is almost always with cessation of sports, rest, immobilisation and analgesia as required [40].

Talus

Stress fractures of the talus represent a relatively rare injury, with only 4.4 cases reported per 10,000 person years even in military recruits [41]. Consequently, little literature exists, with the first documented cases only reported in the 1990s [42]. Presentation is with exercise induced ankle or heel pain. The talar head is most commonly affected, followed by the body, and least commonly the posterior talus [41].

The cycles of repeated strain required to precipitate a stress fracture of the talus regularly result in concomitant stress fractures in more predisposed tarsal bones. 78% of upper body of the talus fractures are associated with calcaneal fracture, whilst 60% of talar head fractures are associated with navicular fractures [41]. No consensus exists on management, with non-operative treatment of six weeks non-weight bearing immobilisation successfully employed.

Medial maleollus

This is a rare injury with a high risk for non-union. Presentation is with medial ankle pain and tenderness. Treatment can initially be via cast immobilisation and non-weight bearing, however internal screw fixation may be required and is associated with more rapid healing and return to sporting pursuits [43]. General risk factors are similar as per other stress fractures of the lower limb, as is the need for MRI or CT to establish the diagnosis. Some consider that anteromedial ankle impingement may be involved in the pathophysiology of the condition and advocate surgical decompression at the time of fixation [44].

Sesamoids

Sesamoid bones have a role in reducing weight bearing pressure on the metatarsal heads, and in protecting the tendons of the hallux by reducing friction. Fractures of the hallux sesamoids present with activity induced forefoot pain which is characteristically worst during forced dorsiflexion of the metatarsophalangeal joint and relieved by rest. Diagnosis is via MRI or bone scan.

Initial conservative management can take the form of immobilisation, however failure of non-operative treatment leading to symptomatic non-union is common and can mandate internal fixation or sesamoidectomy. Sesamoidectomy is associated with a more rapid return to sports than surgical fixation, however concerns exist that sesamoid excision can result in progressive hallux valgus or varus, depending on which one is excised [45].

Cuneiform

On rare occasions heel and midfoot pain may be symptomatic of a stress fracture of a cuneiform. These are rare, with only seven

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reported cases at the time of this article. Risk factors are typical to other stress fractures, namely changes in gait, large body habitus, and new or excessive exercise patterns. In addition, there is an association with plantar fasciitis [46]. Sprinters are at particular risk, as the middle cuneiform may be subject to increased stress in the runner during the propulsive phase, as it transmits weight proximally in the medial column. Successful treatment has been reported with weight bearing immobilisation in a fracture boot followed by a gradual reintroduction to sports [47].

Cuboid

Stress fractures of the cuboid are also rare, with only seven reported cases at the time of this article [48]. This may represent an element of under diagnosis as X-rays are often negative. CT has a helpful role in diagnosis [49]. Treatment has been successful with non-operative immobilisation.

Key papers

1) *Mallee WH, Weel H, van Dijk CN, van Tulder MW, Kerkhoffs GM, Lin CW*. Surgical versus conservative treatment for high-risk stress fractures of the lower leg (anterior tibial cortex, navicular and fifth metatarsal base): a systematic review. Br J Sports Med. 2014 Aug 19. pii: bjsports-2013-093246. doi: 10.1136/bjsports-2013-093246. [Epub ahead of print].An up to date systematic review looking into the treatment of the most clinically important stress fractures based on prevalence and propensity to delayed or non union.
2) *Torg JS, Balduini FC, Zelko RR, Pavlov H, Peff TC, Das M*. Fractures of the base of the fifth metatarsal distal to the tuberosity. Classification and guidelines for nonsurgical and surgical management. J Bone Joint Surg Am. 1984;66 (20): 209-214.Torg's original classification of 5th metatarsal fractures and recommendations for treatment
3) *Varner KE, Younas SA, Lintner DM, Marymont JV*. Chronic anterior midtibial stress fractures in athletes treated with reamed intramedullary nailing. Am J Sports Med. 2005 Jul;33(7):1071-6.A cases series of 11 colliagate-level athletes undergoing tibial nailing for anterior cortex stress fractures.

MCQS

1) Classifications of Stress fractures. True or False.
   a) Navicular stress fractures are divided into 3 different types each modified by 2 further criteria.
   b) A Torg II fracture of the 5th metatarsal demonstrats a widened fracture line with complete sclerosis.
   c) Torg I fractures of the 5th metatarsal demonstrate sharp margins with evidence of widening of the fracture line, but no sclerosis, periosteal reaction, or cortical hypertrophy.
   d) A Saxena III navicular fracture shows propagation into more than one cortex.
   a) false b) false c) false d) true
2) The following may be considered risk factors for the named stress fracture. True or false.
   a) Long 2nd metatarsal and 2nd metatarsal stress fracture.
   b) A talar head stress fracture for stress fractures of the calcaneus.
   c) Anteromedial ankle impingement and medial malleolar fractures.
   d) Long 1st metatarsal and navicular fracture.
   e) Increasing 4th–5th metatarsal angle in fractures of the 5th metatarsal.
   a) true b) false c) true d) false e) true
3) Anatomy. The following statements are True or False.
   a) The 5th metatarsal base has a vascular watershed between the distally tracking nutrient artery and metaphyseal artery which may predispose to fracture.
   b) The most common site of tibial stress fracture is the middle third.
   c) The navicular may be predisposed to stress fractures through the presence of an avascular watershed in the distal third of the bone.
   d) The majority of fibular stress fractures occur in the distal third.
   e) The middle cuneiform transmits weight proximally in the medial column.
   a) false b) false c) false d) false e) true
4) True or False. In Navicular fractures...
   a) Avascular necrosis of a portion of the navicular, cystic changes to the fracture and the presence of callus constitute modifiers to Saxena's classification.
   b) Type II injuries always require operative fixation.
   c) Surgery accelerates time to return to sport.
   d) Weight bearing immobilisation may be employed in the initial management.
   e) Failure of conservative management mandates fixation with k-wires.
   a) false b) false c) false d) false e) false
5) Treatments. The following statements are true or false.
   a) Type II navicular injuries have propagation of the fracture across two cortices and should be treated with 6 weeks of non-weight bearing immobilisation.
   b) Type III fractures of the 5th metatarsal should be treated with weight-bearing immobilisation in an air-cast boot.
   c) Stress fractures of the proximal third of the fibula can be treated with rest and analgesia only.
   d) Stress fractures of the hallux sesamoids should be treated with sesamoidectomy in the first instance due to their propensity to non-union.
   e) Surgical fixation accelerates time to return to sport in navicular fractures and may thus be considered in elite athletes.
   f) Surgical fixation accelerated time to return to sport in medial malleolar fractures and thus may be considered in elite athletes.
   a) false b) false c) true d) false e) false f) true

Conflict of interest statement

I can confirm that none of the authors have any financial and personal relationships with other people or organisations that could inappropriately influence (bias) their work.

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