REVIEW

Imaging of stress lesions of bones of the feet

Subbarao Kakarla[1,*]

[1] KIMS Foundation and Research Centre, Minister Road, Secunderabad - 500003, Telangana, India

Abstract

The anatomy and arches of the feet are geared for maintaining the gait and locomotor movements. However, due to modern life styles, occupations such as sports and dances, there is excessive stress on the bones of the lower extremities, mainly on the bones of the feet. These stress lesions are neglected or treated improperly. Stress lesions include not only complete and incomplete fractures but also periostitis and cortical thickening with butterssing of the bone. From this perspective, the imaging findings of the feet are described in early and late stages. CT, scintigraphy and MRI play a role in the early diagnosis and detecting associated findings. These imaging findings are described in detail with appropriate illustrations.

Keywords: stress lesions; bones of the feet; locomotor movements; life style

***Corresponding author:** Prof. Kakarla Subbarao, MS, D.Sc. (HON), FRCR, FACR, FICP, FSASMA, FCCP, FICR, FCGP, Chairman, KIMS Foundation and Research Centre, Minister Road, Secunderabad - 500003, Telangana, India. Email: subbaraokakarla25@gmail.com

Received 10 December 2015; *Revised* 23 February 2016; *Accepted* 1 March 2016; *Published* 9 March 2016

Citation: Kakarla S. Imaging of stress lesions of bones of the feet. J Med Sci Res. 2016; 4(2):94-100. DOI: http://dx.doi.org/10.17727/JMSR.2016/4-023

Introduction

The feet are most important organs for human beings as they help in maintaining the gait and in locomotor movements. The anatomy and arches of the feet help for healthy transfer of movements. They also assist in adapting to different terrains including soft and hard.

A stress fracture is a partial or complete fracture of a bone. Generally it is not associated with a significant traumatic injury. The fracture results from the bone's inability to withstand stress applied in a rhythmic and repeated manner. It is one of the most common and potentially serious overuse injuries. A stress fracture refers to a fracture occurring in a bone due to a mismatch of bone strength and chronic mechanical stress placed upon the bone. It can either be a fatigue fracture with abnormal stresses on normal bone or an insufficiency fracture with normal stresses on abnormal bone. Bone is constantly attempting to remodel and repair itself, especially when extraordinary stress is applied. When excessive stress is placed on the bone, it causes an imbalance between damage and repair. Muscle fatigue can also play a role in the occurrence of stress fractures. The most common sites of stress fractures of the feet include the second and third metatarsals. However, other metatarsals, calcaneum and navicular bones may also be involved. Sometimes it is bilateral and either symmetrical or asymmetrical.

On the other hand, a stress lesion with repeated microtrauma may lead to bone edema, contusion, micro-fracture, vascular compromise followed by osteosclerosis or osteonecrosis. A stress lesion may also manifest as localized cortical thickening with or without periosteal reaction as a response to stress. When the stress is on the articular margin, ischemic necrosis may be seen due to vascular compromise. These lesions of the foot are commonly encountered in people involved in sports, lifestyle exercises, yoga and in professional dancers.

Review of the literature

The first documented report of a stress fracture was in 1855 by a military doctor, who described soldiers presenting with painful and swollen feet [1, 2]. With the discovery of X-rays in the late 19th century, this phenomenon was shown to be the result of a fracture of the metatarsal bone (the 'march fracture' [3]). Since then, stress fractures have been reported increasingly in populations involved in repetitive weight-bearing activities, such as athletes, military personnel and dancers. Although, stress fractures have been described in all most all the bones of the feet, they are most common in weight-bearing parts of the feet [4].

A number of risk factors have been associated with the development of stress fractures, but the exact causation is likely to be multi-factorial [5]. Certainly the type and amount of activity are obvious risks. A number of studies in athletes and military recruits have suggested a variety of other predisposing factors, but the evidence is conflicting. The type, intensity, duration and frequency of activity and other extrinsic factors examined include: the type of shoe worn (e.g., its age and quality) and the type of training surface used [6-8].

An even larger number of factors intrinsic to the athlete may also be implicated. These include age, race, gender, anatomical features such as high foot arches, knock-knees or leg-length discrepancy, characteristics of bone (geometry, density), and health-risk behaviour such as a previous sedentary lifestyle or smoking.

Discussion

Stress fractures and insufficiency fractures occur frequently in the ankle and foot and predominantly involve the second metatarsal, the calcaneus, and, less frequently, the navicular bone and talus. Prior to stress fracture, a condition known as "stress response" occurs. During this period, edema, hyperemia, and osteoclastic activity develop within the stressed area of the bone.

The effect of running or marching causes a build up of micro-damage in bone. The body responds to this through the process of 'bone remodelling', in which damaged/old bone is removed and healthy/new bone is deposited [9]. Prevention is more important than treatment [10, 11]. The navicular fractures are rare and may result in necrosis [12-15].

Clinically, the patients complain of pain either constantly or on strain. There may be no swelling. Pain is aggravated by exercise. On examination, local tenderness is present. Starting from conventional radiology, the following table includes the other imaging methods (Table 1).

Table 1: Imaging methods.

• Conventional/ digital
• MDCT
• MRI
• Scintigraphy
• Pet CT/ MRI

Radiological

Although, conventional radiology is the screening method, MRI and scintigraphy play a major role in the diagnosis and follow up of the cases. CT is superior in defining the fracture lines and observing the healing process.

A spectrum of radiological findings are noted depending upon the age and stage of the fracture. Plain radiographs may not always detect stress fractures. During the first few weeks after the onset of symptoms, radiographs may look normal.

Subsequently in the cortical bone endosteal or periosteal callus formation without fracture line is seen. In some instances, circumferential periosteal reaction with fracture line through one cortex is seen. Occasionally the entire fracture line is noted. Metatarsals of the foot are most commonly involved. The middle and distal portions of the shafts of the 2nd and 3rd metatarsal are most frequently affected. These are notably encountered in military recruits and believed to be due to fatigue of peroneous longus muscle (Figures 1a,b,c,d). When complete healing occurs years later the appearance may suggest enostosis (Figure 1e,f) or ivory type of bone (Figure 1g,h).

Figure 1a: Stress fractures in neck of 2nd and 3rd metatarsal-March fracture. Clinical appearance (right side image).

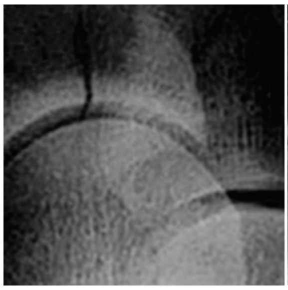

Figure1b: Plain film: Stress fracture navicular.

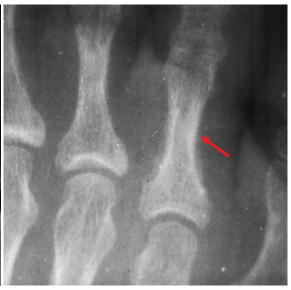

Figure 1c: Healing stress fracture of the phalanx with periosteal reaction.

Figure 1d: 50F - Healing stress fracture of 3rd metatarsal with periosteal reaction (arrow).

Figure 1e: Healing stress fractures of 2nd, 3rd and 4th metatarsals with callus.

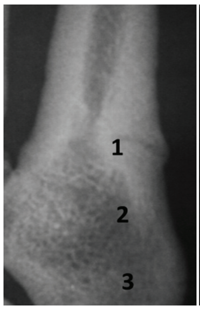

Figure 1f: (i) Stress fracture of 5th metatarsal, (ii) Site of jones fracture, (iii) Site of avulsion fracture.

Figure 1g,h: Enostosis due to healed stress lesion, note the sclerosis.

The sites of stress fractures can be divided into high and low risk stress fractures according to their likelihood of uncomplicated healing with conservative therapy.

High risk fracture sites are talus, tarsal navicular, 5th metatarsal, sesamoid great toe and low risk fracture sites are calcaneus and 2nd + 3rd metatarsal (Figure 1i,j).

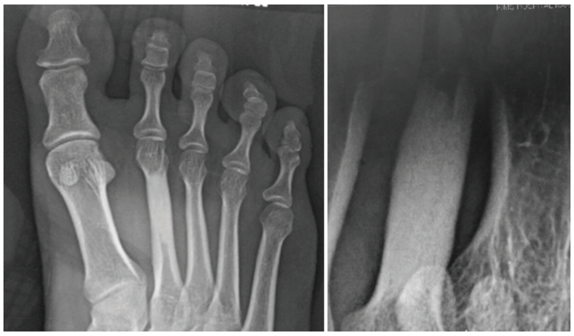

Figure 1i,j: Osteosclerosis due to old healed fractures of 2nd metatarsal

Stress fractures also occur commonly in the calcaneum since it is one of the major weight bearing bones [16]. In the cancelllous bone such as calcaneum cloudlike areas of mineralized bone is noted at various stages (Figure 2a,b,c). MRI may show the fracture line lucidly (Figure 2d).

A stress lesion represents no gross fracture line. Due to repeated microtrauma and simultaneous repairing process a buttress may be noted at the site (Figure 3a,b). Localized periostitis and cortical thickenings are seen. These may appear as bumps or as linear periosteal reaction (Figure 4a,b,c).

On the other hand, when stress occurs constantly at the articular margin, eburnation and even a cartilage

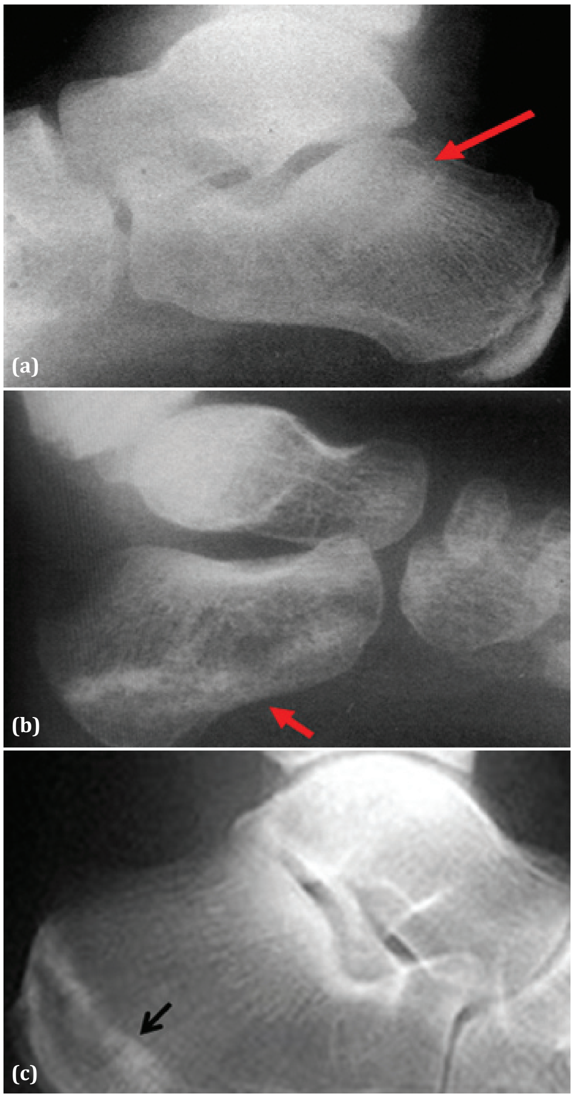

Figure 2a,b,c: Healed stress fracture of the calcaneum.

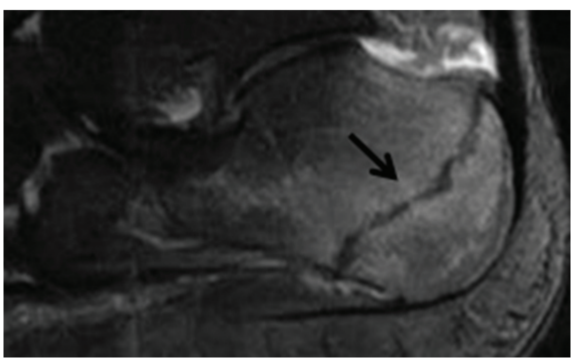

Figure 2d: MRI, Healing stress fracture of calcaneum.

damage may occur. When it is gross, it results in osteochondritis dissecans (Figure 5).

On occasion, depending upon the number and quantity of stresses, compromise of vascular supply

Figure 3a: Periostitis of 3rd and 4th metatarsals with cortical thickening.

Figure 3b: Stress Periostitis 5th Metatarsal in a dancer.

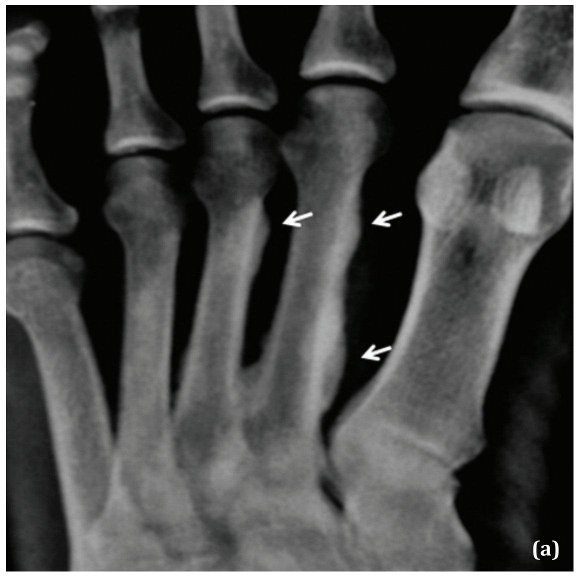

Figure 4a: Healed stress lesions of 2nd and 3rd metatarsal with bumps in a farmer.

Figure 4b: Talipes equinovarus with stress periosteal reaction of 4th and 5th metatarsal.

Figure 4c: Stress Lesion 5th Metatarsal in 10-year-old boy with mild varus deformity.

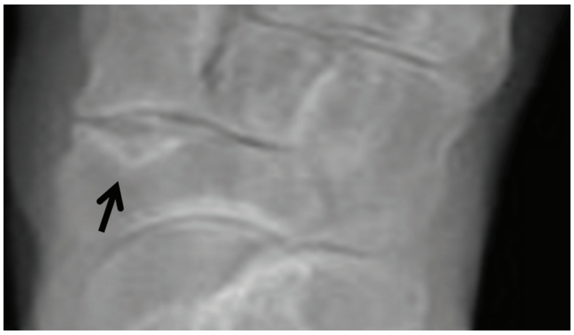

Figure 5: Osteochondritis dessicans of navicular following stress.

occurs and the ischemic necrosis of the concerned bone follows. Controversies exist regarding the etiopathology of osteochondrities. Freiberg lesion is considered as osteochondritis (Figure 6ab). Freiberg disease, also known as Freiberg infraction, is osteochondrosis of metatarsal heads. As per the literature, several authors' names have been attributed to these stress lesions. The following table includes all the eponyms (Table 2) [17].

Table 2: Eponyms.

Dias disease – Trochlear of the talus
Freiberg infraction – Head of second metatarsal
Iseline disease – Base of 5th metatarsal
Kohler disease – Tarsal navicular
Mueller – Weiss disease – Navicular
Sever disease – Calcaneal apophysis

In fact, the spontaneous osteonecrosis or idiopathic osteonecrosis of bones are due to chronic stress

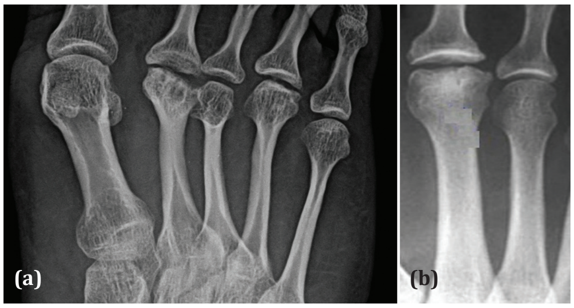

Figure 6a,b: Freiberg disease 2nd metatarsal head with flattening and sclerosis.

and microtrauma of the small vessels. Avascular necrosis or osteonecrosis refers to ischaemic death of the constituents of bone. It can be thought of as traumatic (secondary to neck of femur fractures) or non-traumatic. The metatarsal heads and talus are the common sites (Figure 7a,b,c). It typically affects the 2nd metatarsal head (the third and fourth may also be affected). It can be bilateral in up to 10% of cases.

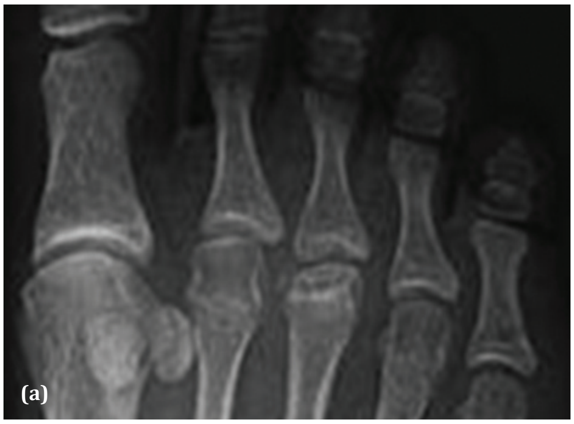

Figure 7a: Osteonecrosis of 3rd metatarsal head due to stress with flattening and irregularity of articular margins.

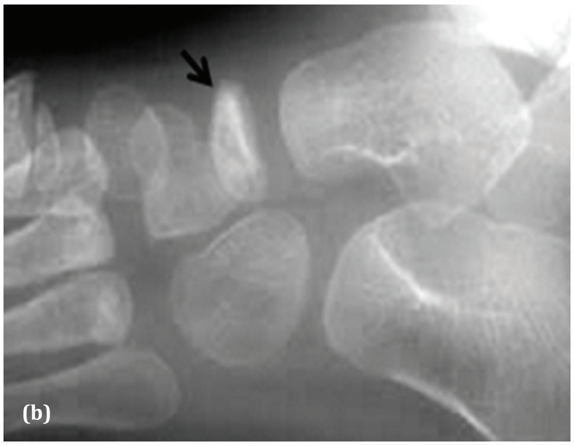

Figure 7b: Osteonecrosis of navicular due to stress (Kohler's lesion) flattening compression of navicular.

Figure 7c: Ischemic necrosis of the talus following a stress fracture, flattening and sclerosis of dome of talus.

Scintigraphy

Radiopharmaceutical uptake in bones scan is due to chemisorptions, blood flow, bone turnover, immature collagen and enzymatic activity.

Bone scans can show evidence of stress fracture within a few days upon onset of symptoms. It is represented as a focus of increased radioisotope activity ('hot spot') due to increased bone turnover at the site of new bone formation. Scintigraphy is more sensitive but non-specific [18]. The uptake is diffuse due to metabolic process surrounding the fracture. This increased uptake can also be due to osteomyelitis, bone tumour or avascular necrosis, and as such the specificity is low (Figure 8a,b).

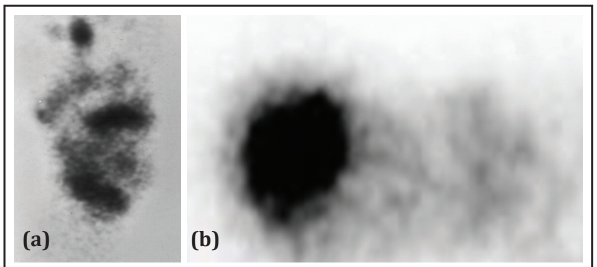

Figure 8a: Scintigraphy - stress fractures of the tarsal navicular and 2nd metatarsal. Apart from navicular, the other areas of foot are also hot, due to Sudeck's atrophy.

Figure 8b: Scintigraphy – stress fracture of navicular. Note hot area.

MD CT

The appearances are similar to those on plain radiograph with sclerosis, new bone formation, periosteal reaction and fracture lines in long bones. It is also useful in differentiating stress fractures from bone tumour or osteomyelitis if the plain radiographs are negative and bone scans are positive (Figure 9a,b,c). 26-year-old male - pain in the mid foot since one month.

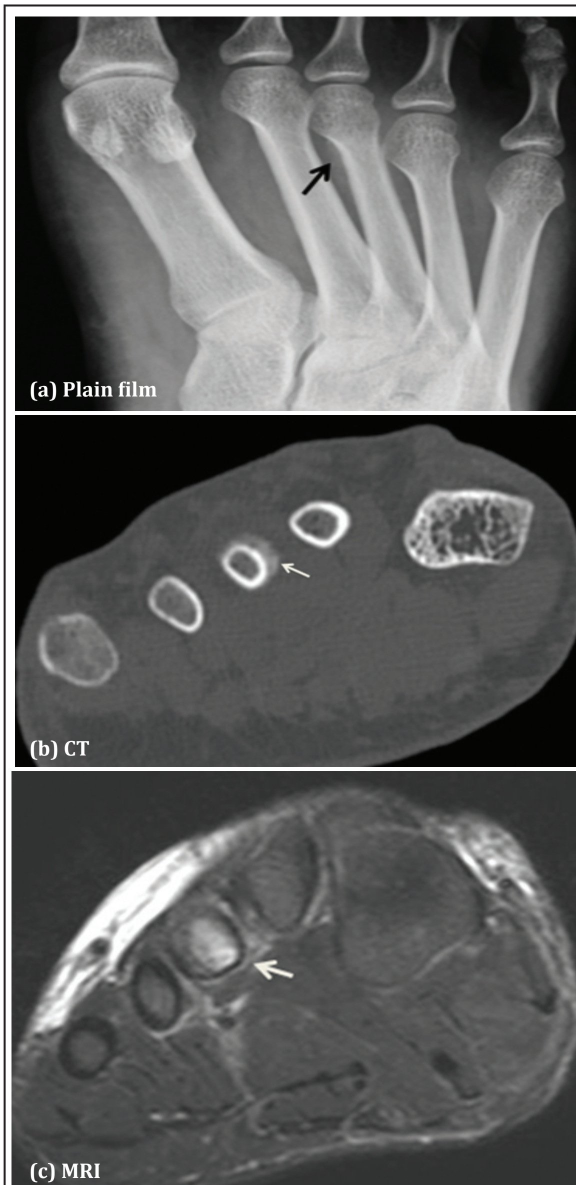

Figure 9: a, b. Healing stress fracture 3rd metatarsal with periosteal reaction, c. MRI shows edema also.

MRI

On MRI the fracture line usually extends through the cortex and into the medullary canal and is elucidated with bone oedema in the surrounding marrow. MRI is also useful to differentiate ligamentous/ cartilagenous injury from bone injury.

Manifesting at MR imaging as poorly defined, abnormal signal intensity of the bone marrow similar to that of a bone contusion with an ill-defined area of hypointensity on T1-weighted images and hyperintensity on T2-weighted images and fat-suppressed images (Figure 10).

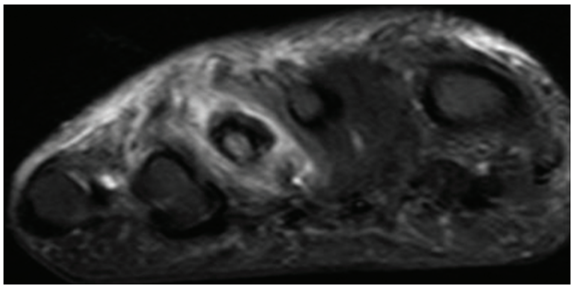

Figure 10: MRI – healing stress fracture 3rd metatarsal surrounded by edema.

MR imaging has been found to be more sensitive than conventional radiography and more specific than bone scintigraphy in the detection of occult fractures, particularly in the elderly and in osteoporotic patients. Acute posttraumatic fractures will appear similar to stress-related fractures at MR imaging, with hypointense lines representing the fracture surrounded by ill-defined areas of edema and haemorrhage [19].

MRI has surpassed bone scintigraphy as the imaging tool for stress fractures, showing equal sensitivity (100%) but a higher specificity (85%), probably by giving better anatomical detail and more precisely depicting the tissues involved (Figure 11a,b,c).

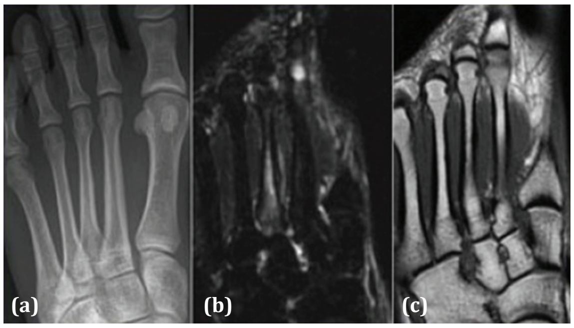

Figure 11: a. Plain film is normal; b & c. T1, T2 presenting edematous changes due to stress.

Radiograph, STIR and T1WI of grade 3 stress fracture of 3rd metatarsal. STIR (short tau inversion recovery), T1-weighted (T1WI) and T2-weighted images (T2WI) are used for characterization and grading.

Conclusions

Stress lesions include gross fractures, stress response and stress reaction. Radiologically, fracture, periostitis and cortical thickening are noted. Conventional radiology is the screening method. Early detection is done by scintigraphy and MRI. MD CT are useful in detecting early periostitis. The common bones involved in the feet include metatarsals, calcaneum, navicular and talus. The imaging findings are described in detail.

Acknowledgement

The Departments of Radiology, NIMS, & KREST Museum, Hyderabad.

Conflicts of interest

Author declares no conflicts of interest.

References

1. Freiberg AH. Infraction of the second metatarsal - a typical injury. Surg Gyn Ob. 1914; 19:191.
2. Cerrato RA. Freiberg's disease. Foot Ankle Clin. 2011; 16(4):647–658.
3. Hulkko A, Orava S. Stress fractures in athletes. Int J Sports Med. 1987; 8(3): 221–226.
4. Daffner RH, Pavlov H, Stress fractures: current concepts. A J R Am J Roentgenol. 1992; 159(2):245–252.
5. Bennell K, Matheson G, Meeuwisse W, Brukner P. Risk factors for stress fractures. Sports Med. 1999; 28(2):91–122.
6. Milgram C, Chisin R, Giladi M, Stein M, Kashtan H, et al. Multiple stress fractures. A longitudinal study of a soldier with 13 lesions. Clin Orthop Relat Res. 1985; (192):174–179.
7. Jones RI. Fracture of the base of the fifth metatarsal bone by indirect violence. Ann Surg. 1902; 35(6):697–700.
8. Watson HI, O'Donnell B, Hopper GP, Chang W. Proximal base stress fracture of the second metatarsal in a highland dancer. BMJ Case Rep. 2013; 2013.
9. Berger FH, de Jonge MC, Maas M. Stress fractures in the lower extremity. The importance of increasing awareness amongst radiologists. Eur J of Radiol. 2007; 62(1):16–26.
10. Jones BH, Thacker SB, Gilchrist J, Kimsey CD Jr, Sosin DM. Prevention of lower extremity stress fractures in athletes and soldiers: a systematic review. Epidemiol Rev. 2002; 24(2):228–247.
11. Muscolo L, Migues A, Slullitel G, Costa – Paz M. Stress fracture nonunion at the base of the second metatarsal in a ballet dancer: a case report. AM J Sports Med. 2004; 32(6):1535–1537.
12. Fowler JR, Gaughan JP, Boden BP, Torg JS. What you should know about navicular stress fractures. Podiatry Today. 2010; 23(11).
13. Kurda D, Gaillard FA et al. Stress fractures refer to fractures occurring in bone due to a mismatch of bone, Radiopaedia. Org.
14. Jaimes C, Jimenez M, Shabshin N, Laor T, Jaramillo D. Taking the Stress out of Evaluating Stress Injuries in Children. Radiographics. 2012; 32(2):537–555.
15. Lee S, Anderson RB. Stress fractures of the tarsal navicular. Foot Ankle Clin. 2004; 9(1):85–104.
16. Leabhart JW. Stress fractures of the calcaneus. J Bone Joint Surg Am. 1959; 41 (7):1285–1290.
17. McGraw-Hill Concise Dictionary of Modern Medicine. © 2002 by The McGraw-Hill Companies, Inc.
18. Leffers D, Collins L. An overview of the use of bone scintigraphy in sports medicine. Sports Med Arthrosc. 2009; 17(1):21–24.
19. Arendt EA, Griffiths HJ. The use of MR imaging in the assessment and clinical management of stress reactions of bone in high-performance athletes. Clin Sports Med. 1997; 16(2):291–306.