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## Rapid diagnosis of “Fatigue” stress fractures using bone scintigraphy: A practical approach

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### Abstract

Stress fractures can broadly be classified into “fatigue” or “insufficiency” fractures depending on baseline bone health and amount of physical activity. Of these fatigue stress fractures present with a classical history of increased physical activity in healthy bones followed by pain typically after a few weeks. Imaging modalities include plain radiographs, MRI, CT Scan, Bone Scintigraphy (Scan) and Ultrasound. We discuss a short case series and explore key points for all these modalities and propose a simple algorithm for rapid diagnosis of fatigue stress fractures involving three phase bone scan.

**Keywords:** Fatigue, Stress fracture, bone scintigraphy

### 1. Introduction

Stress fractures are defined as fractures as a result of abnormal, cyclical loading on normal bone leading to local cortical resorption and fracture and were first described in the foot of Prussian military recruits (March fracture) [1]. These fractures are of broadly two types depending on the etiology and bone strength combined. The “fatigue” or “overloading” fractures which are due to excessive use like in athletes or military trainees. The insufficiency fractures due to routine pressure on the “weak” bones as in after radiotherapy or steroid use causing osteoporosis. Diagnosis of these fractures is mostly achieved by clinical history alone but it is important to differentiate them from rare but other differential diagnoses. So imaging modalities in order to rapidly diagnose these conditions is relevant. With the advent of superior imaging techniques exquisite details of anatomy can be evaluated and assist in early diagnosis of major orthopedic disorders. However anatomical imaging modalities like CT, MRI and ultrasound also need a definitive change or alteration in anatomy due to disease in order to make it detectable. We highlight the use of scintigraphic techniques like bone scan to overcome these limitations for rapid detection of stress fractures.

### 1.1 Case Series

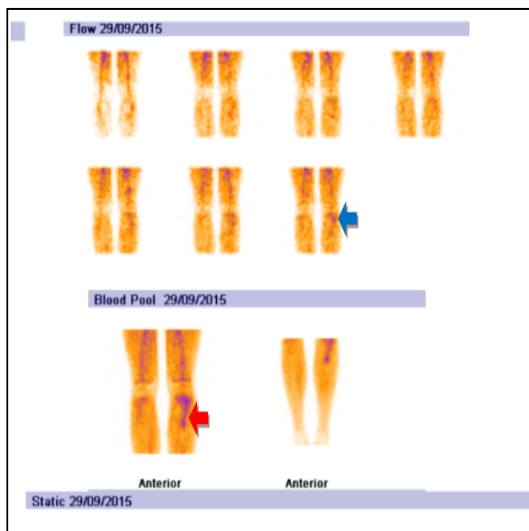
6 patients with history of pain in lower limbs which was bilateral in 2 and unilateral in 4 of the age 25-35 years over a period of two years were included in the study. All of them gave history of excessive/intense physical activity in the last 4-12 weeks. All of them underwent plain radiographs and had normal radiographs of the bilateral lower limb (affected areas). They then underwent a 3-phase bone scan on the same day (Table 1).

**Table 1**

Patient number	Age/Sex	Chief Complaints	History	Bone Scan findings
1.	18/M	Pain in left leg	Army trainee 2 months	Stress fracture left tibia
2.	25/F	Pain in left hip	Army trainee 3 months	Stress fracture trochanteric region of right femur (confirmed with MRI)
3.	23/M	Pain in bilateral legs	Athlete	Shin splints
4.	25/M	Pain in Right lower limb	Army trainee 2 months	Stress fracture right tibia
5.	23/M	Pain in left leg	Athlete	Stress fracture left tibia
6.	22/M	Pain in bilateral legs	Army trainee 1 year	Shin splints

### Correspondence

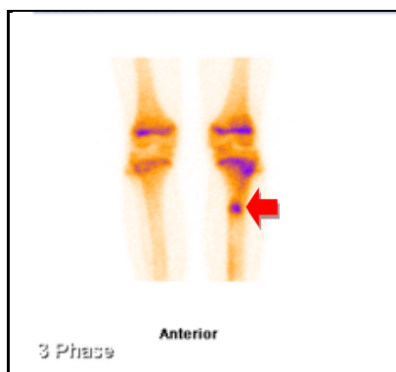
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**Fig 1 [Patient 1]**

**Phase 1:** Perfusion Phase: showed increased blood flow- perfusion in the upper left leg (Blue Arrow)

**Phase 2:** Blood Pool Phase: showed increased blood pooling in the upper left leg (Red Arrow)



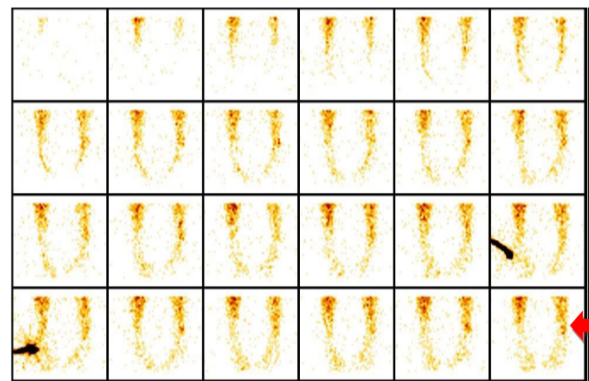
**Fig 2 [Patient 1]**

**Phase 3:** Uptake Phase: Showed a focal area of intense tracer uptake in the upper 1/3<sup>rd</sup> of the left tibia (Arrow)



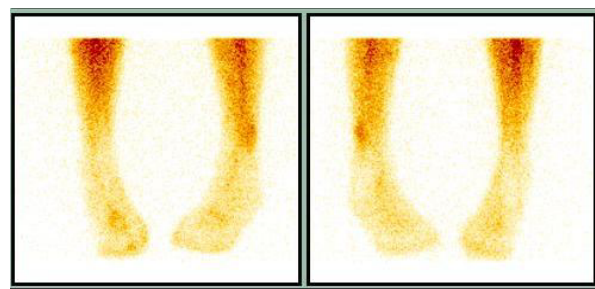
**Fig 3 [Patient 1]**

**Phase 3:** Whole Body View: Showed no other abnormality and increased tracer uptake in the ends of the long bones bilaterally-physiological ossification centres at this age (Arrow)



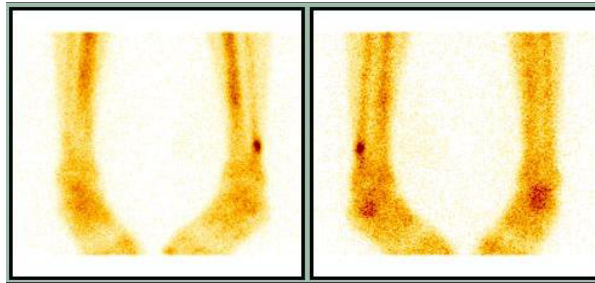
**Fig 4 [Patient 3]**

**Mildly increased blood flow in the lower end of left leg**



**Fig 5.a. [Patient 3]**

First two panes reveal anterior and posterior blood pool image with mild linearly increased tracer pooling in the both legs



**Fig 5.b [Patient 3]**

Last two panes show delayed image in anterior and posterior views with tracer uptake in the bilateral tibiae and lower end of fibula

## 2. Discussion & Review

### 2.1 History and presentation:

When a typical history of painful focal areas in an extremity is supported by a history of intense physical activity associated with that region and corresponds to the time of its start a fatigue fracture can be suspected. Like metatarsal stress fractures in military trainees, tibial stress fractures seen in runners.

### 2.2 Pathophysiology of fatigue fractures:

Lamellar bone predominates in the adult and is composed of cortical (80%) and cancellous bone (20%). Cortical bone is found mainly in the diaphyses of the long bones and also comprises the Bshell^ of the cuboidlike bones such as vertebral bodies. The majority of stress fractures in runners occur in cortical bone. Cancellous bone is found in the

metaphyses of long bones and the center of cuboid-like bones. It is less dense, undergoes more rapid turnover, and more stress remodeling than cortical bone [2].

## 2.3 Imaging Modalities

### 2.3.1 Plain Radiographs

Commonest investigations in an orthopedic outpatient department are always a radiograph. The plain radiograph is first line for imaging of any musculoskeletal injuries, pain, and suspicion of a stress fracture. Microfractures due to stress or overt physical activity do not show any abnormality or may show inconclusive changes on plain radiographs and are especially difficult to diagnosis in the setting of osteopenia. Though poorly sensitive, a stress fracture may reveal subtle linear sclerosis, focal endosteal or periosteal reaction, and fracture through one cortex with superimposed periosteal reaction on plain radiographs [3].

### 2.3.2 Magnetic Resonance Imaging (MRI)

MR Imaging is extremely sensitive (sensitivity 100%, specificity 85%), although typically a second-line modality, obtained when radiographs are normal, pain is of unknown etiology, or in athletes requiring a definitive diagnosis. A linear hypointense fracture line on T1-weighted and T2-weighted images with adjacent bone marrow and soft tissue hyperintensity on T2-fat saturated or short tau inversion recovery (STIR) sequences (edema) are typical findings. Tibial stress fractures are classified into various grades from I through IV(a,b) on MRI as per Fredericson MRI classification for medial tibial stress syndrome [4].

### 2.3.3 CT Scan

Though they provide a 3-Dimensional image of concerned bones and may show linear fracture lines with higher sensitivity than plain radiographs, CT scans would not be able to and in fact may underestimate the extent of involvement. CT may provide false reassurance regarding the activity of a stress injury. Chronic lesions may have the appearance of bone turnover on CT, while their true activity and edema cannot be assessed [5].

### 2.3.4 Ultrasound

Like for many more areas of diagnosis Ultrasound is increasingly becoming a readily available and efficient tool for evaluation of stress fractures too. Its utility is limited to the evaluation of more superficial bones like tibia. Ultrasound can evaluate the hyperechoic superficial margins of cortical bone, revealing cortical buckling and surrounding hypoechoic callus. Power Doppler technology is also emerging as a tool to estimate bone injury with evaluation of vascularity [5].

### 2.3.5 Bone Scintigraphy

Functional techniques like bone scintigraphy (bone scan) which use internally administered radioisotopes to detect bone lesions/disorders have an advantage of early or more sensitive detection of disease due to their functional evaluation property. Before anatomical damage tissue always undergoes functional changes in the form of altered perfusion, tissue destruction (osteolytic activity) or regeneration (osteoblastic activity) which can be picked up earlier before anatomical changes occur.

Many initial studies have reviewed the use of bone scintigraphy in the evaluation of stress injuries and three-phase Technetium-99m-methylene diphosphonate (Tc-99m-MDP) bone scans are often considered the gold standard. The

scintigraphic techniques have excellent sensitivity in detecting abnormal metabolic bone activity; however, it has poor specificity, with up to 40% of increased tracer uptake occurring at asymptomatic sites [6].

Bone scintigraphy involves internal administration (intravenous) of a bone seeking isotope (Tc99m-biphosphonates) like Tc99m MDP. About 25-30mCi of the tracer is injected and patient is imaged during perfusion immediate, blood pooling at 5-10 minutes and delayed at 3 hours (bone uptake) phases. Any osteoblastic activity is accompanied by increased blood flow and blood pooling which is seen as excessive tracer accumulation at the point of fracture. With medial tibial stress syndrome, sometimes increased uptake may only be seen on the delayed phase [7].

Although fatigue and insufficiency fractures can be self-limited and go onto healing even without diagnosis, there is usually value in initiating prompt therapeutic measures as incomplete stress fractures have the potential of progressing to completion and requiring more invasive treatment or delay in return to activity. Accuracy in the identification of these injuries is also relevant because the differential diagnosis includes entities that would otherwise be treated significantly differently like osteoid osteoma, osteomyelitis or metastasis. These conditions usually present with pain like in stress fractures.

## 3. Concept of rapid diagnosis with Scintigraphy

With this background and considering bone scan as the gold standard for diagnosing or even ruling out stress fractures and though bone scintigraphy is known to be poorly specific for diagnosis in case of increased uptake we hereby propose the following protocol for rapid diagnosis of stress related bone damage or fatigue fractures.

### 3.1 Step I: Detailed clinical history

**a. Time:** A detail of the onset of pain which would always be associated "after" a particular duration of initiation of the strenuous activity typically few weeks later.

**b. Location:** The pain would be typically located at the areas/bone/region "involved" in the physical activity e.g shin in athletes or feet (metatarsal region) in army recruits

### 3.2 Step II: Normal "Plain Radiographs"

A plain radiograph would be the most useful immediate modality of imaging for suspected stress fractures as they are rapid, inexpensive and help in ruling out many obvious conditions which would be visible on plain radiographs

### 3.3 Step III Bone scan

A three phase bone scan would be the next choice of imaging agent for the following reasons:

- "Faster"- Does not require a lot of expertise and minimal subjective variation as against MR/Ultrasound imaging
- Includes whole body imaging "always" which helps exclude involvement of any other site and thus further confirm diagnosis by exclusion of other causes

#### 3.3.1 Limitations of using Bone Scan

**3.3.1.1 Cost:** Though expensive, this modality is usually equivalent to cost of a contrast enhanced CT or an MRI.

**3.3.1.2 Availability of Bone Scan:** This is one of the major hurdles especially in remote areas or small cities.

#### 4. Conclusion

In our series of patients with history suggestive of stress fracture and normal radiographs our approach with a 3 phase bone scan as the modality of choice we were able to diagnose stress fractures in all. With these case examples and understanding of basic pathophysiology of fatigue stress fractures the methodology rapidly diagnosing stress fracture using 3 –phase bone scan in a patient with a typical history with a near normal radiograph can be very useful.

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