Imaging in Stress-Related Bone Injuries

Poster No.: P-0143
Congress: ESSR 2013
Type: Scientific Exhibit
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Keywords: Osteoporosis, Demineralisation-Bone, Athletic injuries, Diagnostic procedure, MR, Digital radiography, CT, Musculoskeletal bone
DOI: 10.1594/essr2013/P-0143

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Purpose

The purpose of this work is to make a review of the stress-related bone injuries (SRBI) from the radiologist's point of view. We present imaging features of SRBI on Computed Tomography (CT), Radiography and Bone Scintigraphy, with special emphasis on Magnetic Resonance Imaging (MRI).

We also review important definitions of terms as well as the etiopathogenesis, the clinical presentation and the treatment of this injuries.
Methods and Materials

We present a retrospective analysis involving X-ray, bone scintigraphy, CT and MRI studies with the diagnosis of SRBI. Images were acquired in a multidetector CT Siemens Somatom Sensation 20/40 and a MR Signa GE 1.5T. We reviewed the current literature and in this poster we present the most representative cases. 36 patients referred to the Radiological Department of the Infanta Cristina Hospital (Parla, Madrid) in the period from 2008 to 2013 were included in the study.

In this work we show MR images of cases corresponding to ambulatory and hospitalized patients.
DEFINITION OF TERMS

1. **Stress related bone injuries (SRBI):** Spectrum of bone lesions caused by repeated trauma less intense than that which causes an acute fracture. These lesions are part of a dynamic process whose final stage is the stress fracture, but also include bone lesions without frank fracture, as well as muscular or tendinous injuries. The term SRBI is commonly associated with fatigue fractures. We also consider the insufficiency fractures as a type of SRBI as they are by definition one of the two types of stress fractures that must be differentiated from the acute ordinary fractures.

2. **Stress reaction:** Early stage of SRBI, in which the affected bone is weakened, probably suffering microfractures. It represents the previous stage to frank fracture and presents as what we know as bone marrow edema (BME) pattern on MRI, with NO fracture line.

3. **Stress fracture:** Final stage of SRBI. There should be a fracture line on imaging. There are two types of stress fractures: fatigue fractures and insufficiency fractures.

4. **Fatigue fracture:** Result of abnormal or unusual forces applied to normal bone. Typically in active individuals practising new, strenuous and/or very repetitive activities, e.g. athletes making changes in their sport training regimens. It is good to remind that in some texts, the term stress fracture is used as a synonym of fatigue fracture.

5. **Insufficiency fracture:** Result of normal stress applied to abnormal (weakened) bone. Any process that weakens the bone is a potential cause of insufficiency fracture: Osteoporosis, Rheumatoid arthritis, Diabetes Mellitus, Paget's disease, Hyperparathyroidism, Irradiation, Osteomalacia/ Rickets, Pyrophosphate arthropathy, etc.

6. **Pathologic fracture:** This term is frequently used to define an insufficiency fracture that occurs in the site of a neoplasm in the bone. Not uncommonly this term is used just as a synonym of insufficiency fracture (fractures occurring on abnormal bone).

ETIOPATHOGENESIS

In physiological conditions, normal bone is subjected to stress, and responds to it by a constant dynamic process of remodelling in which there is an initial resorption of bone, caused by microscopic fractures, that is replaced by stronger bone. In other words, normal bone needs normal stress to maintain its function.
In SRBI, there is an imbalance between resorption and replacement leading to weakening of the bone, and if stress continues, leading to fracture. According to this, if the weakened bone is left to rest, it may heal.

In case of fatigue fractures, repetitive overload causes the imbalance, while in insufficiency fractures there is also an abnormal bone condition which contributes to the imbalance because of a poor process of remodelling.

In some cases, SRBI are a combination of both fatigue and insufficiency fractures.

CLINICAL PRESENTATION

SRBI in general and fatigue fractures in particular, typically cause pain with activity that is relieved by rest. As the injury progresses, pain may also present at rest.

Fatigue fractures, traditionally associated with athletes and recruits, are often seen in younger patients. There are multiple ethiologic factors implied in the development of fatigue fractures: intrinsic (e.g. muscular strength), extrinsic (e.g. training surface), hormonal, nutritional, etc. Among them, the details about training regimen conditions are particularly important.

In case of insufficiency fractures, it is common to see them in elderly patients. Clinical presentation is more unpredictable because it varies depending on the factors that weaken the bone and on the clinical situation of the patient.

Physical Examination: When the affected bone is more superficial (e.g. tibia), examination may show localized pain, redness, swelling, and warmth. In deeper locations, examination may show painful range of motion in the affected area.

TREATMENT

The detection of a stress reaction on bone will allow adequate change in clinical management, resulting crucial to avoid progression to fracture.

- In case of fatigue fractures, conservative treatment with rest and nonweight-bearing usually results in good outcome and resolution of the clinical and imaging findings.
• **In case of insufficiency fractures**, healing can take longer periods of rest.

Despite the accuracy of imaging in detecting bone marrow edema, the clinical decisions about treatment or follow up must always be taken in basis of each case individually, because bone marrow edema on MRI may be present even when the injury has healed.

**IMAGING MODALITIES**

1. **RADIOGRAPHY**: It has **low sensitivity to detect SRBI in early stages**. The main value of radiography in early stages is to rule out any other entity, and it must always be included in the initial study of bone. Radiographic findings of SRBI are more conspicuous during follow up, and they are visible from one week until several months from the beginning of symptoms.

Radiographic findings:

- **Cortical bone**: Initial **periosteal reaction or endosteal thickening** that ends with **callus** formation. Radiographs can depict a **radiolucent fracture line** before callus forms. ([Fig. 1 on page 23](#))
- **Cancellous bone**: **Sclerosis** that ranges from patchy (in early stages) to linear.

**Fig. 1**: Fatigue fracture of the distal shaft of the third metatarsal. Initial radiograph shows radiolucent fracture line. Second image (4 weeks later) shows homogeneous periosteal reaction. Third image (4 months after the first radiograph) shows definitive callus.
2. **BONE SCINTIGRAPHY:** Highly sensitive detecting stress reactions on bone because of its ability to detect osteoblastic activity related to remodelling, but on the other hand, it lacks specificity.

**Scintigraphic findings (Fig. 2 on page 23):** SRBI show areas of increased activity that range from poorly defined margins to sharply defined. At final stages the lesions show more intense transcortical localized uptake.

3. **COMPUTED TOMOGRAPHY (CT):** CT is less sensitive than bone scintigraphy or MRI in early stages of SRBI. The value of CT in early stages lies in areas that are difficult to evaluate on radiography or in lesions that are confusing on MRI. CT is even more sensitive than MRI for the detection of cortical fracture lines.

**CT findings** for stress fractures include, like radiography, periossteal reactions/callus, radiolucent fracture lines, sclerosis. Sacrum, pars interarticularis, tarsal navicular, and longitudinal stress fractures of the tibia are suitable locations to evaluate with CT. (Fig. 3 on page 24)
Fig. 3: T1-weighted image (upper image) shows abnormal marrow signal on right sacral ala without visible fracture line. CT image (lower image) clearly depicts insufficiency fracture line.

References: Hospital Infanta Cristina - Madrid/ES

4. MAGNETIC RESONANCE IMAGING (MRI): It is the imaging modality of choice for evaluating SRBI. As sensitive as scintigraphy and more specific. MRI depicts changes in bone and in soft tissues, and it is able to depict pathology weeks before radiography does. (Fig. 4 on page 25)

MRI recommended protocol:
• STIR images, as well as fat-suppressed T2-weighted (T2W) images are excellent tools as they show what we know as **bone marrow edema (BME)**, which presents high signal intensity on fat-suppressed T2-weighted images and STIR, and may show low signal on T1-weighted images.

• **T1-weighted (T1W)** images are a complement to depict fracture line and to complete the study of bone marrow.

• **Contrast-enhanced MRI**: Less useful in general for evaluating SRBI. Contrast studies demonstrate in general similar findings to STIR images. Enhancing areas in edematous bone or soft tissues are frequent and can lead to erroneous diagnosis of aggressive lesions, furthermore if they are accompanied by a mass (like benign callus) Fig. 5 on page 26 or any atypical appearance.

• **Diffusion weighted imaging**: It has been suggested to be useful for differentiating stress from pathologic vertebral fractures.

**MRI findings and terms:**

• **Stress reaction (Fig. 6 on page 27)**: It is shown as an area of BME without fracture line. It is very important to remember that **BME can be found in asymptomatic physically active individuals**, not necessarily as a pathological finding. We should only use the term "stress reaction" if it is congruent with the clinical setting. Differential diagnosis of BME on MRI includes: acute bone bruise, fracture, osteomyelitis, avascular necrosis, transient osteoporosis, tumor, etc. Correlation with the clinical setting is definitive to achieve the correct diagnosis.
Fig. 6: 26 year old female. Recreational athlete (running and boxing) presented with insidious right groin pain during activity, relieved by rest. Coronal fat-suppressed T2 weighted image shows stress reaction involving inferior aspect of right femoral neck. Control after 6 months with conservative treatment shows resolution of MRI abnormalities.

References: Hospital Infanta Cristina - Madrid/ES

- **Periosteal edema** ([Fig. 7 on page 28](#)): In general we consider periosteal edema as a thin band of high signal intensity adjacent and external to cortex on T2-weighted images. Periostitis is the equivalent clinical term.

- **Endosteal edema** ([Fig. 8 on page 29](#)): It is frequently used as a synonym of bone marrow edema. It is more correct to use it when BME runs beside the inner limit of the cortex.

- **Fracture line**: It generally shows low signal intensity on T1W images and T2W images, although sometimes fluid can be seen within it (high signal on T2WI) ([Fig. 9 on page 30](#)).
- **Musculotendinous injury:** It is common to see muscular and/or tendinous involvement round SRBI. Muscle edema and tendinopathy present as high signal intensity on T2W images, inside or around musculotendinous structures, with or without tendinous or muscular morphologic changes (thickening, flattening, etc). *(Fig. 10 on page 31)*

**Fig. 10:** Sagital fat-supressed T2-weighted image shows stress reaction in the shaft of the metatarsal with extensive surrounding muscle edema, which is common around SRBI in metatarsals.

**References:** Hospital Infanta Cristina - Madrid/ES

**MRI grading system:**

We found that *Fredericson grading system* *(Fig. 11 on page 32)* was the most cited in the reviewed literature. Other authors like *Kiuru et al* suggest muscular edema as a sign that should modify the staging. These classifications allow us to have an idea of how SRBI can progress on MRI, but it is *unclear the relationship between the grading system and the clinical outcome.*

**LOCATIONS OF SRBI** *(Fig. 12 on page 32)*
Stress fractures are more common in the lower extremities, but depending on the activity and risk factors, we can find them in pelvis, spine and even in upper extremities.

Fig. 12: This drawing illustrates the most typical locations of SRBI in each bone of the pelvis and lower limbs, as well as the most typical orientation of the fracture lines.

References: Hospital Infanta Cristina - Madrid/ES

1. FEMORAL NECK: Although stress fractures can occur in any part of the femur, they are more common in the femoral neck. (Fig. 13 on page 33)
• **Compression fracture**: The most common of the femoral neck stress fractures. Inferior aspect. Good prognosis, tend to heal with conservative treatment.

• **Tensile fracture**: Mid to distal superior aspect. Worse prognosis, may require surgical treatment.

• **Atypical tensile fracture**: Proximal superior aspect (near femoral head). Good prognosis.

• **Displaced fracture**: Worse prognosis.

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**Fig. 14**: Location of the different types of fractures in the femoral neck, with their respective prognosis. The area in red (bad prognosis) represents fractures more likely to develop delayed consolidation, non-union, fragment dislocation or avascular necrosis of femoral head.

**References**: Hospital Infanta Cristina - Madrid/ES

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2. **OTHER FEMORAL LOCATIONS:**

• **Femoral lesser trochanter** ([Fig. 15 on page 35](#)): Overuse injury, combination of SRBI and enthesopathy, in the distal insertion of iliopsoas tendon. It can cause bony stress reaction, and although less commonly, can cause stress fracture. Findings on MRI are:
a) Signs of iliopsoas tendinopathy at its insertion.
b) Periostitis around lesser trochanter.
c) BME in the lesser trochanter that can extend into the inferior aspect of the femoral neck.
d) (We should recognize the normal calcar femorale, which is a physiologic spur seen as a hypointense line in this area and must not be misdiagnosed as a fracture line). (Fig. 16 on page 36)

**Fig. 16**: Coronal fat-suppressed T2-weighted image (left) shows bone marrow edema extending into the femoral neck. Axial fat-suppressed T2-weighted image (right) shows BME in the lesser trochanter consistent with stress reaction. There is fluid around iliopsoas tendon (blue arrow) suggesting insertional tendinopathy. Calcar femorale (white arrow) must not be misinterpreted as a fracture line.

**References**: Hospital Infanta Cristina - Madrid/ES

- **Diaphyseal fractures, subchondral fractures of femoral head**: Less common.

"Thigh splints" term used to describe SRBI caused by stress at the muscular insertions into the bone like "shin splints" (see below). It is a periosteal injury at the posteromedial aspect of the proximal-mid femoral dyaphisis.

3. **TIBIA**: The most commonly affected bone in the skeleton. Fracture line typically horizontal or oblique orientation. 10% are longitudinal (CT useful for longitudinal fractures). SRBI can be found in different locations:
• **Posterior/posteromedial cortex**: Most common. Tend to heal with rest. Form part of the term "shin splints" (see below).

• **Anterior cortex**: Less common but fractures in this location tend to become displaced and are more likely to develop delayed union or non-union. Its presence in radiography is known as "the dreaded black line". (Fig. 17 on page 37)

Two even less common sites of tibial SRBI:

• **Tibial plateau**. Older patients. Near the epiphyseal scar. Medial most frequent. (Fig. 18 on page 38)

• **Medial malleolus**. Located next to the tibial plafond.

"Shin Splints" (Medial tibial stress syndrome, Soleus syndrome) (Fig. 19): Term used to describe the clinical presentation of a common type of SRBI typically seen in athletes and soldiers consisting of diffuse tenderness along the posteromedial aspect of tibia.

The main diagnostic features include medial or posteromedial tibial periosteal edema with or without BME, even with fracture line in advanced cases.

MRI is preferred for acute shin splints, whereas in chronic cases scintigraphy seems more suitable.

![Fig. 19: "Shin splints". 31 year old male. Athlete with tenderness along the medial aspect of the leg while running. Axial and sagital STIR images show endosteal edema (short arrow) along the posterior aspect of the tibia with subtle periosteal edema on axial image (long arrow).](image)

**References**: Hospital Infanta Cristina - Madrid/ES

4. **FIBULA**: Distal third more common. Tend to heal with rest.
5. **TALUS** *(Fig. 20 on page 40)*: Uncommon fracture. The location and orientation of talar fractures seems to be **variable**. Talar head, neck and body may be affected. Associated with tarsal navicular stress fractures in 60%.

6. **CALCANEUM** *(Fig. 21 on page 40)*: Most commonly: **Dorsal posterior aspect** and **vertical** orientation. Frequently bilateral. Good prognosis.

7. **NAVICULAR**: Stress fractures more common oriented in the **sagittal plane**, located in the **middle third** of the navicular, where vascular supply is poorer. This makes navicular fractures more likely to complications in addition to the difficulty in their early diagnosis.

8. **METATARSAL** *(Fig. 22 on page 41) (Fig. 23 on page 42)*: Most common in the **middle and distal portions of the second and third metatarsal** shafts. Tend to heal with rest.

*Fig. 22*: Extensive bone marrow edema in the shaft of the third metatarsal visible on fat-suppressed T2-weighted (middle image) and T1-weighted (left) images, with periosteal edema and abnormal intracortical signal on all images consistent with callus formation (arrow). Axial T1-weighted image (right) shows marked changes around the shaft of the metatarsal which correspond to callus formation and soft tissue swelling.

*References*: Hospital Infanta Cristina - Madrid/ES
Fig. 23: 32 year old male suffering typical metatarsal fatigue fracture. Radiograph shows subtle callus formation around the neck of the third metatarsal. CT image taken 7 weeks later demonstrates fracture line with surrounding callus formation. 

References: Hospital Infanta Cristina - Madrid/ES

Jones fracture: (can be ordinary fractures or stress fractures) Transverse fractures of the base of the fifth metatarsal more than 1.5 cm distal to the tuberosity. Poor prognosis for healing.

9. SACRUM: Typical in sacral alae. MRI shows unilateral or bilateral BME and may show the fracture line. CT will help to find the fracture line and bone scintigraphy may show the typical "H" or "Honda" sign in bilateral fractures.

- Insufficiency fractures (Fig. 24 on page 43): Fracture line usually shows vertical orientation. Postmenopausal osteoporosis is the most common associated risk factor. It is not uncommon the presence of SRBI in pelvic bones in patients with pelvic tumors who have undergone radiotherapy. In these patients we can even find multifocal SRBI that can lead us to the false diagnosis of metastases. (see INSUFFICIENCY FRACTURES IN ONCOLOGIC PATIENTS).
- Fatigue fractures: More oblique orientation (from superolateral to inferomedial).
Fig. 24: 56 year old female with rectal cancer treated with radiotherapy. Axial T2-weighted (left), axial fat-suppressed T1-weighted after contrast administration (middle) and CT image (right) show bilateral insufficiency sacral fractures (arrows) surrounded by extensive BME which enhances after contrast administration. White arrow shows fluid within left fracture.

References: Hospital Infanta Cristina - Madrid/ES

10. PUBIS: Inferior pubic ramus (Fig. 25 on page 43) is among the most common pelvic SRBI along with sacral fracture.

In case of SRBI in athletes, it is common to find them around symphysis pubis (osteoitis pubis and parasymphseal SRBI).

Pubic rami and parasymphseal insufficiency fractures usually require longer periods of time to heal.

11. ACETABULUM (Fig. 26 on page 44): Supra-acetabular insufficiency fractures occur in the same patient population than sacrum and pubic bones fractures. In most cases, the fracture line on MRI runs curvilinear and parallel to the acetabular roof.
Fig. 26: Typical supra-acetabular insufficiency fracture running parallel to the acetabular roof on T1-weighted image.

References: Hospital Infanta Cristina - Madrid/ES

12. SPINE:

- Fatigue fractures are most common in pars interarticularis of L4 and L5 levels of lumbar spine in adolescent and young athletes. MRI has demonstrated high accuracy diagnosing lumbar fatigue fractures but CT is more suitable for incomplete fractures at the upper lumbar spine and for incomplete fractures of pars interarticularis when there are intense sclerotic changes. Radiography may be useful in complete fractures.
• **Insufficiency fractures** are frequently found in elderly osteoporotic patients, as compression fractures of **vertebral body**.

13. **HALUCIAL SESAMOID BONES:** Medial sesamoid most commonly affected. Diagnosis may be difficult to differentiate from other entities on sesamoids: osteochondritis, chondromalacia or avascular necrosis. The detection of a fracture line will be definitive besides radiotracer uptake and BME on scintigraphy and MRI respectively.

In case of bipartite medial sesamoid as normal variant, medial sesamoid tend to be much larger than lateral sesamoid.

14. **OTHER LOCATIONS:** SRBI can be found in almost any bone, depending on patient population. E.g. shoulder or elbow can be affected in baseball and tennis players, wrist in gymnasts as well as ribs in golfers.

**INSUFFICIENCY FRACTURES IN ONCOLOGIC PATIENTS**

As we mentioned above, the diagnosis of bone lesions in oncologic patients can be a difficult challenge. On the one hand, the possibility of any bone lesion in this patients to be a metastasis is obviously higher. And on the other hand, the appearance of SRBI in oncologic patients is often atypical.

Insufficiency pelvic fractures in patients treated with radiotherapy are a good example of it. These patients frequently show multiple pelvic nonspecific bone lesions on scintigraphy that appear atypical on MRI.

The patients who have undergone RT and suffer insufficiency fractures are often patients suffering osteoporosis too. The combination of both factors seems to be definitive to cause an extreme weakness of the bones. In our experience, this weakness of the bones is usually present in the imaging studies by the moment the insufficiency fracture appears. If we are able to demonstrate it, it can be helpful to begin to orientate the diagnosis (although not definitive). A good way to do it in our own experience is to check not only the injured bone, but all the bones on images in some steps:

1. **Look for chronic changes after RT in bone marrow** (**Fig. 27** on page 44): Typical **intense fatty replacement** in the bones of the treated area and sometimes also in the adjacent bones.
2. **Look for changes related to osteoporosis in bone marrow**: Increased fatty marrow component that gives the bones a more heterogeneous aspect with rounded areas of focal fatty marrow that may coalesce.

3. **Look for chronic stress fractures in other bones** (*Fig. 28 on page 45. C, B*): The presence of vertebral fractures or the presence of callus in typical locations for SRBI like pubic rami in pelvis suggests weakened bones.

4. **Look for acute stress fractures in other bones** (*Fig. 28 on page 45. D*) that may show more typical features than the lesion we are evaluating. The presence of multiple lesions is not so uncommon after RT.

5. Be careful. This is only a way to confirm the presence of weakened bones that are more likely to suffer insufficiency fractures, but these steps should never replace a complete study of any bone lesion to rule out neoplasm or any other ethiology (e.g. other lesions caused by RT like avascular necrosis).
**Fig. 28**: 70 year old patient who suffered rectal cancer treated with RT. A. Coronal fat-suppressed T2-weighted shows a non-specific lesion in an atypical location for SRBI (lower aspect of the acetabulum) B. Same patient. Coronal T1-weighted shows extensive fatty marrow replacement related to RT in all the bones included in the study. C. Same patient. Sagital T1-weighted shows a chronic osteoporotic (insufficiency) vertebral fracture. D. Same patient. Coronal T1-weighted shows typical bilateral sacral SRBI (stress reaction in the right sacral ala and insufficiency fracture in the left) Lesions B, C and D suggest weakened bone, so we should consider the possibility that maybe the first non-specific lesion could be a SRBI.

**References**: Hospital Infanta Cristina - Madrid/ES
Fig. 1: Fatigue fracture of the distal shaft of the third metatarsal. Initial radiograph shows radiolucent fracture line. Second image (4 weeks later) shows homogeneous periosteal reaction. Third image (4 months after the first radiograph) shows definitive callus.

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**Fig. 2:** 56 year old male with rheumatoid arthritis and pain in both ankles. Bone scintigraphy revealed diffuse increased uptake in the right talus and less intense uptake around left talonavicular and posterior subtalar joints. Definitive diagnosis was given by MRI (Fig 4) as the scintigraphic findings were not specific enough.

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Fig. 3: T1-weighted image (upper image) shows abnormal marrow signal on right sacral ala without visible fracture line. CT image (lower image) clearly depicts insufficiency fracture line.

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**Fig. 4:** 56 year old male with rheumatoid arthritis and pain in both ankles. Bone scintigraphy (Fig. 2) revealed diffuse increased uptake in the right talus and less intense uptake around left talonavicular and posterior subtalar joints. MRI shows insufficiency fracture (arrow) in right talus and changes of arthritis in left talonavicular and posterior subtalar joints. Definitive diagnosis was given based on MRI findings as the scintigraphic findings were not specific enough.

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Fig. 5: Hypertrophied callus after stress fracture. Patient with history of breast cancer and osteoporosis presented spontaneous fracture in left superior pubic ramus. Upper image (T1 weighted) shows a well defined mass in the site of fracture that enhances on gadolinium-enhanced T1-weighted MR imaging (down) consistent with hypertrophied callus.

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Fig. 6: 26 year old female. Recreational athlete (running and boxing) presented with insidious right groin pain during activity, relieved by rest. Coronal fat-suppressed T2 weighted image shows stress reaction involving inferior aspect of right femoral neck. Control after 6 months with conservative treatment shows resolution of MRI abnormalities.

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Fig. 7: Axial and sagital fat-suppressed T2-weighted images show a thin band of high signal intensity adjacent and external to the anteromedial tibial cortex consistent with periosteal edema. The finding correlated well with the clinical suspicion of periostitis.

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Fig. 8: 38 year old female recreational athlete (runner) with right groin pain irradiated to the thigh since three months. Coronal STIR shows endosteal edema along the inferior aspect of the right femoral neck, consistent with stress reaction.

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**Fig. 9:** Coronal T2-weighted image. Right insufficiency fracture shows fluid within fracture line (arrow).

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Fig. 10: Sagital fat-suppressed T2-weighted image shows stress reaction in the shaft of the metatarsal with extensive surrounding muscle edema, which is common around SRBI in metatarsals.

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Fig. 11: Fredericson MRI classification system for stress injuries.

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Fig. 12: This drawing illustrates the most typical locations of SRBI in each bone of the pelvis and lower limbs, as well as the most typical orientation of the fracture lines.

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Fig. 13: 78 year old female with osteoporosis and rheumatoid arthritis. She complained of severe bilateral inguinal pain. Coronal STIR sequence in all images. (A) Initial MRI study shows stress reaction in the right femoral neck and hypointense fracture line (arrow) surrounding by BME in the left one. (B) The patient went on with her physical activity. MRI study five weeks later shows another fracture (arrow) in the right femoral neck and progression of the left fracture. (C) Four months later, the patient had undergone surgical treatment for the left fracture. MRI image shows postsurgical artifact in the left femur and decreased BME in the right femur.

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Fig. 14: Location of the different types of fractures in the femoral neck, with their respective prognosis. The area in red (bad prognosis) represents fractures more likely to develop delayed consolidation, non-union, fragment dislocation or avascular necrosis of femoral head.

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**Fig. 15:** 39 year old female. Bone scintigraphy shows bilateral radiotracer uptake in lesser trochanters, more intense in the left, consistent with bone stress reaction in the insertion of iliopsoas tendon.

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**Fig. 16:** Coronal fat-suppressed T2-weighted image (left) shows bone marrow edema extending into the femoral neck. Axial fat-suppressed T2-weighted image (right) shows BME in the lesser trochanter consistent with stress reaction. There is fluid around iliopsoas tendon (blue arrow) suggesting insertional tendinopathy. Calcar femorale (white arrow) must not be misinterpreted as a fracture line.

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Fig. 17: 34 year old male. Recreational athlete. Pain along anterior aspect of the leg while running and palpable mass (on the point of maximum pain). Radiograph shows fatigue fracture line in the anterior tibial cortex surrounded by benign periosteal reaction. These fractures are prone to delayed consolidation and non-union, so this fracture line is called the "dreaded black line".

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Fig. 18: 48 year old male who began running almost 7 km a day during the last two months. He had been suffering insidious pain in both knees while running that had become more severe. Coronal fat-suppressed T2-weighted images of both knees show bilateral stress reaction in the medial tibial plateau (asterisks).

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Fig. 19: "Shin splints". 31 year old male. Athlete with tenderness along the medial aspect of the leg while running. Axial and sagittal STIR images show endosteal edema (short
arrow) along the posterior aspect of the tibia with subtle periosteal edema on axial image (long arrow).

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**Fig. 20:** Sagital T1-weighted and STIR images show insufficiency fracture of the head of the talus in a patient with osteoporosis. Low signal fracture line visible on both images (arrows), surrounded by abnormal signal intensity consistent with bone marrow edema (low signal on T1-weighted image and high signal on STIR).

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**Fig. 21**: 47 year old obese male who used to run 10 Km a day during the last months. He presents with pain even at rest. SAG T1-weighted image shows typical calcaneal stress fracture: vertical and parallel to the posterior cortex. There is benign periosteal reaction on the dorsal aspect of the cortex (arrow). Lower image: SAG T1-weighted 13 months after the first image following conservative treatment shows almost complete resolution of the lesion.

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Fig. 22: Extensive bone marrow edema in the shaft of the third metatarsal visible on fat-suppressed T2-weighted (middle image) and T1-weighted (left) images, with periosteal edema and abnormal intracortical signal on all images consistent with callus formation (arrow). Axial T1-weighted image (right) shows marked changes around the shaft of the metatarsal which correspond to callus formation and soft tissue swelling.

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**Fig. 23:** 32 year old male suffering typical metatarsal fatigue fracture. Radiograph shows subtle callus formation around the neck of the third metatarsal. CT image taken 7 weeks later demonstrates fracture line with surrounding callus formation.

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**Fig. 24:** 56 year old female with rectal cancer treated with radiotherapy. Axial T2-weighted(left), axial fat-suppressed T1-weighted after contrast administration (middle) and CT image (right) show bilateral insufficiency sacral fractures (arrows) surrounded by extensive BME which enhances after contrast administration. White arrow shows fluid within left fracture.

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**Fig. 25:** Axial T1-weighted image shows callus formation in a stress fracture of the right inferior pubic ramus.
**Fig. 26:** Typical supra-acetabular insufficiency fracture running parallel to the acetabular roof on T1-weighted image.

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**Fig. 27:** 53 year old woman with history of cervical cancer treated with radiation therapy (RT). Axial T1-weighted images. Left image shows abnormal low signal intensity on both sacral alae, more pronounced on the right, related to bilateral SRBI. Right image shows the sacrum of the same patient prior to RT. Note the presence of intermediate signal intensity red marrow on pre-RT study, compared to the extensive fatty replacement after RT.

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Fig. 28: 70 year old patient who suffered rectal cancer treated with RT. A. Coronal fat-suppressed T2-weighted shows a non-specific lesion in an atypical location for SRBI (lower aspect of the acetabulum) B. Same patient. Coronal T1-weighted shows extensive fatty marrow replacement related to RT in all the bones included in the study. C. Same patient. Sagital T1-weighted shows a chronic osteoporotic (insufficiency) vertebral fracture. D. Same patient. Coronal T1-weighted shows typical bilateral sacral SRBI (stress reaction in the right sacral ala and insufficiency fracture in the left) Lesions B, C and D suggest weakened bone, so we should consider the possibility that maybe the first non-specific lesion could be a SRBI.

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Conclusion

SRBI are a group of injuries with particular imaging features and particular locations in each bone of the skeleton. **MRI is the imaging modality of choice** to evaluate them, although CT, Radiography and Bone scintigraphy also play an important role.

The radiologist should be familiar with the initial injury of SRBI (**stress reaction**) because an appropriate conservative treatment in this stage may prevent the development of a fracture.

The radiologist should remember that an area of BME on MRI must be considered a stress reaction **only if the clinical context is congruent** with it.

**Insufficiency fractures in oncologic patients** represent a considerable challenge for the radiologist. Looking for any sign that suggests weakened bones (post-RT fatty marrow replacement, osteoporotic bone marrow, previous osteoporotic fractures, concomitant typical acute SRBI) may help to orientate the diagnosis, although it shouldn't replace an adequate complete study of any bone lesion in these patients.
References


