MRI findings of tibial stress injuries

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Learning objectives

To describe and illustrate the spectrum of MRI findings of tibial stress injuries.

Background

Stress or fatigue injuries result from abnormal repetitive stress on normal bone. They are common in young athletic adults (particularly in runners).

Up to 75% of the exertional leg pain is caused by tibial stress injury (TSI) [1].

Patients with TSI present unilateral or bilateral lower leg pain, relieved by rest. Symptoms may last many weeks or even months.

TSI may be related with training errors, such as increase in training volume, change in training surface or inappropriate shoes [2].

Other common causes of lower leg pain are muscle or tendon injuries, chronic compartment syndrome and nerve entrapment [1, 3]. Non-traumatic causes include neoplasms and infection [4, 5].

In early stages of illness radiographs might be negative, but may rule out other abnormalities.

Ultrasonography is very good diagnostic method to identify soft tissue injuries (muscle or tendon injuries, edema, etc.), sometimes may also visualize superficial changes in cortex.

MRI is the only method to identify early symptoms of stress injuries, even when fracture line is not visible [1, 2, 6, 7, 8, 9, 10].

Sometimes, in non-specific cases with suspicion of neoplasm or infection, contrast administration is required [4, 5].

In patients with doubtful MRI findings CT may be helpful to detect cortical osteopenia - which is the earliest sign of fatigue cortical bone injury [1, 6, 7].

Stress reactions visualized on MRI may also be asymptomatic, especially in long-distant runners [11].
Findings and procedure details

MRI FINDINGS

There are four main MRI findings which may suggest stress injury [1, 2, 6, 7, 8, 9, 10, 11]. They include **soft-tissue changes** (periosteal edema) and **bone changes** (bone marrow edema, cortical abnormalities and fracture line).

First MRI finding of tibial stress injury (TSI) is **periosteal edema**. It may be very subtle and noticeable only on fluid-sensitive sequences (STIR, fat suppressed T2- and PD-weighted images).

Hyperintense changes along tibia are first visible on short tau inversion recovery (STIR) images, then on fat suppressed T2- and PD-weighted images (T2-WI FatSat and PD-WI FatSat). T1- weighted images (T1-WI) may be normal in early stages (fig.1). When edema extends, it is visible both on T1-WI and fluid-sensitive sequences.

Periosteal edema may be unilateral or bilateral. In patients with bilateral TSI the severity of changes visible in MRI may be more intense in less symptomatic leg (fig. 2).

**Osseus stress reactions** begin with bone marrow edema, followed by accelerated remodelling with cortical abnormalities and finally stress fracture.

In early stages bone marrow stays normal on all sequences.

Chronic repetitive stress without appropriate rest causes **bone marrow edema**. It is first seen as focal or ill-defined area of high signal intensity only on fluid-sensitive sequences, then also on T1-WI as low signal intensity areas. Bone marrow edema is usually accompanied by periosteal edema (fig. 3, 4).

Normal cortex has low signal intensity on T1-WI and T2 -WI. Gaeta M. et al. [2] described **cortical abnormalities** visible in CT and MRI:

- **osteopenia** (loss of cortical signal void in MRI)
- **resorption cavity** (round or oval intracortical area of increased signal intensity)
- **striation** (subtle intracortical linear hyperintensity).
Cortical abnormalities (fig. 5, 6, 7 and 8) may be accompanied with periosteal and bone marrow edema.

In many cases bone changes in TSI may not be clearly visible on classical radiographs (fig.9).

In final stage fracture line can be visualised (fig. 10, 11). It is usually accompanied with periosteal, bone marrow and sometimes muscle edema.

Fracture line may be better visible on coronal and sagittal projection (fig. 12, 13) then on axial ones (fig. 14, 15). It is essential to examine carefully all of the images and sequences to make the proper diagnosis.

In cases of bilateral TSI the changes visible in each of the leg are usually seen in different locations and stages (fig. 2, 16, 17).

After rest subtle periosteal new bone formation may be detected (fig. 18), edema and fracture line gradually disappear (fig. 19).

MRI findings of tibial stress injuries may be classified using the grading system based on Fredericson et al. [2] - shown in table 1.

<table>
<thead>
<tr>
<th>Grade</th>
<th>MRI findings</th>
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<td>0</td>
<td>normal examination</td>
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| 1     | PERIOSTEAL EDEMA : mild to moderate on T2-WI  
Marrow: normal on T1- and T2-WI |
| 2     | PERIOSTEAL EDEMA : moderate to severe on T2-WI  
MARROW EDEMA: on T2-WI |
| 3     | PERIOSTEAL EDEMA : moderate to severe on T2-WI  
MARROW EDEMA: on T1- and T2-WI |
| 4     | PERIOSTEAL EDEMA : moderate to severe on T2-WI  
MARROW EDEMA: on T1- and T2-WI |
Table 1.

Kijowski et al.[10] used divided grade 4 - grade 4a with cortical abnormalities and 4b with fracture line visible, for validation of Fredericson MRI classification for TSI in clinical study. According to the results of the study they proposed an abbreviated Fredericson classification system for TSI:

grade 1 - presence of periosteal edema only

grade 2 - periosteal and bone marrow edema

grade 3 - linear intracortical fracture line

LOCATION

TSI may affect proximal, middle or distal tibia, depending on the type of sport activity and acting forces.

MRI signs are usually visible along anterior, medial and posterior border of tibia.

The most common location of stress fracture in runners is posterior medial border of tibia, where the compression forces are cumulated. Different type of forces occurs in jumpers, causing stress fracture of the anterior cortex [2].

Knowledge of those typical locations can be helpful in differential diagnosis (for example neoplasms or infections).

Images for this section:
Fig. 1: Discrete periosteal edema on anterior, medial and posterior side of distal part of left tibia, better visible on ax PD-WI FatSat (arrows) than on ax T1-WI. 46-year-old man with symptoms of lower leg pain and clinical suspicion of stress injury.
**Fig. 2:** Bilateral periosteal edema, more intense on the left (T2 SPAIR cor). No bone marrow edema nor cortical abnormalities are visible. 33-year-old runner with right-sided lower leg pain.

**Fig. 3:** Arrows show periosteal and bone marrow edema on axial T1-WI (on the left) and PD-WI FatSat (on the right).
Fig. 4: Periosteal edema and bone marrow edema (arrows); PD FatSat cor image.
**Fig. 5:** Periosteal edema with discrete bone marrow edema along medial and posterior cortex. Arrows show thickened posterior cortex with linear loss of cortical signal void (ax PD-WI FatSat on the left, middle axT1-WI FatSat, axT1-WI on the right). 25-year-old male runner with 2 months history of lower leg pain.

**Fig. 6:** The same patient - arrows show subtle intracortical linear hyperintensity (striation) in posterior and medial cortex (ax PD-WI FatSat, ax T1-WI FatSat).
**Fig. 7:** Left-sided periosteal and bone marrow edema with cortical abnormalities on medial and posterior side (T1-WI and PD-WI FatSat). In the similar location of right tibia subtle periosteal edema is visible. 29-year-old male runner.
Fig. 8: The same patient. Note that periosteal edema is usually more extensive then changes in cortex (arrows, cor PD-WI FatSat).
**Fig. 9:** Cor PD-WI FatSat reveals cortical abnormalities (arrow), periosteal and bone marrow edema. On the right - very subtle changes on classical radiograph.

**Fig. 10:** Fracture line may not be visible on axial T1-WI and T1-WI FatSat (upper scans), but can be revealed on PD-WI FatSat and CT scans (lower scans). Periosteal edema and subtle bone marrow edema are also present.
**Fig. 11:** The same patient. Contrast medium administration can also help to visualize fracture line (ax T1-WI FatSat without contrast on the left part of the figure and with contrast administration on the right).

**Fig. 12:** Oblique line of stress fracture in distal part of left tibia on coronal PD-WI FatSat and T1-WI.
**Fig. 13:** The same patient, fracture line (arrows) visible on sagittal PD-WI FatSat, T1-WI and T2-WI.

**Fig. 14:** The same patient- axial images are less diagnostic then long projections. Subtle fracture line better visible on T1-WI (arrows) then on PD-WI FatSat (left image).
**Fig. 15:** Fracture line visible on sagittal images (on the left). Bone reactions without clearly visible fracture line on axial images (PD-WI FatSat). Note periosteal edema.
Fig. 16: Bilateral TSI in 38 years old runner. Cor PD FatSat image with proximal injury of the left tibia and distal injury of the right one (arrows).

Fig. 17: The same patient presented on axial images (PD FatSat). Proximal left tibia with fracture line (arrow), and distal right tibia with cortical abnormalities. Note that periosteal and bone marrow edema is more intense in the left tibia.
Fig. 18: Arrows show subtle periosteal new bone formation -healing stress fracture of proximal tibia (cor PD-WI, T1-WI).
**Fig. 19:** Two MR examinations of the same patient before and after treatment. Upper images (cor PD FatSat and T1-WI) show fracture line in proximal tibia, with periosteal and bone marrow edema. Lower images (cor PD FatSat and T1-WI) show healed TSI after 6 months rest. 53-year-old man with lower leg pain after a long distance race.
Conclusion

Tibial stress injuries (TSI) should be suspected in patients with exercise related lower leg pain.

MRI provides early findings of tibial stress injury, preventing stress fracture and leading to early recovery.

MRI findings must be correlated with symptoms and clinical examination, medical history of the patient, laboratory investigation and other exams (ultrasonography, radiological examination, CT, bone scintigraphy).

Abreviations used in text:

TSI - tibial stress injury
MRI - magnetic resonance imaging
CT - computed tomography
(T1-/ T2-/PD-) WI - (T1-/ T2-/PD-) weighted images
FatSat -fat saturation

Personal information

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