Magnetic resonance imaging of proximal tibial fractures in short-distance runners

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Aims and objectives

To describe magnetic resonance (MR) imaging findings of the tibia in novice symptomatic short-distance runners.

Methods and materials

Patient selection

The study was approved by the Local Ethics Committee and written informed consent was obtained. Between June 2012 and September 2014, we prospectively included novice runners with written request for MR imaging evaluation of the knee. We considered novice runners who began to run the previous two months and followed a short-distance program (below 4 miles per session and/or below 12 miles per week). All patients had previous negative standard radiographic examinations of the knee performed in the previous months from the MR imaging. Exclusion criteria were: age under 18 years; contraindications to MR imaging; injury of the lower extremity in the last 3 months before MR imaging; pregnancy; and history of a cardiovascular, pulmonary, endocrine, metabolic, neurological, neuromuscular, oncological or musculoskeletal disorder, previous head and spinal surgery.

MR imaging was performed within two months the end of the short-distance program.

Baseline characteristic, including age, body mass index, running experience, sport activities, previous injury at the lower extremities, were recorded. Running experience was considered a previous participation on running on a regular basis as described in literature [11]. Associated sport activities practiced beyond running were subdivided into axial loading (eg. tennis) and without axial loading (eg. swimming).

MR imaging

The MR imaging examination was performed using both a GE Signa HDxt 3.0 T scanner (General Electric Medical Systems, Milwaukee, WI, USA) with a 2-channels phased-array extremity coil and with a 1.5 T Siemens with an 8 channels knee coils depending on scanner availability. The subject was positioned supine with the knee extended and...
fixed with a fitting pad to avoid motion. **Table 1** shows MR imaging protocol for knee examination. The MR imaging protocol included T1-turbo spin-echo (T1-TSE) sequence and an axial T2-turbo spin-echo (T2-TSE) sequence with fat saturation in all three planes. For the clinical suspect, we considered not necessary to perform diffusion-weighted sequences and contrast enhance weighted sequences.

The total acquisition time of the entire MR imaging protocol was 30 min approximately.

The MR images were fully anonimized and stored in a dedicated study hard disk different from that of the Hospital. A unique code was assigned to each image set. We added 40 data sets with negative MR imaging of the knee randomly selected from our radiological research database. The image sets were randomised in reading sequence for the purpose of interpretation using a randomisation table made in Excel (Microsoft, version 14.3.9 for Mac), to keep authors blind to clinical data, as previously describe in literature [16].

Two authors (A.T. and B.B.), with 7 and 3 years of experience in musculoskeletal imaging and MR imaging research respectively, evaluated all MR images independently and in different sessions. The two authors were not involved in the previous sections of this study and were blinded to clinical symptoms. The same authors, blinded to the initial results, repeated the image analysis 4 weeks after the initial session, to assess intra-observer variability.

The grading system of Fredericson [10] were used for MR images evaluation:

- grade 0: normal MR imaging findings;
- grade 1: periosteal edema or reaction;
- grade 2: bone marrow edema on T2-weighted fat-suppressed images;
- grade 3: high signal intensity in the marrow on T2-weighted fat-suppressed images and low signal intensity in the marrow on gradient-echo T1-weighted images;
- grade 4: fracture line.
Bone marrow edema (BME) was classified as presence of cloud-like and amorphous with indistinct margins of increased T2-weighed images. This patchy pattern of BME was not measured due to their discontinued margins, as suggested by previous report [2].

Medial, central or lateral location of the findings within the tibia was given.

In addition, presence and grade (mild, moderate, severe) of effusion and the presence of knee bursitis were recorded.

**Statistical Analysis**

Statistical analysis was performed by one author, with 8 years of experience in statistical analysis, using statistical software (SPSS, version 12.0.1, SPSS, Excel 2007, Microsoft and MedCalc, Version 11.4-MedCalc Software, Broekstraat 52, 9030 Mariakerke, Belgium).

Descriptive statistics were used for MR imaging findings.

Intra- and inter-reader agreement for tibial stress reaction was determined by using generalised weighted K statistics and was classified as excellent (k values > 0.80), good (k = 0.61-0.80), moderate (k = 0.41-0.60), fair (k = 0.21-0.40), or poor (k #0.20) [17].

The Pearson test and linear regression analysis were used to correlate tibial stress reactions with patient’s age, body mass index, previous injury at the lower extremities, previous running experience and previous sport activities. P<0.05 was considered statistically significant for all statistical testing.

**Results**

Forty knees MR imaging evaluations of thirty-eight adult patients were performed. The mean body mass index was calculated as weight in kilograms/height in meters: males 23 ± 3; females 22 ± 4; the patient age was: males: 42 ± 11; females 39± 10. Patients' characteristics are shown in Table 2.
Concerning previous running experience, it was the first running experience in 21 patients. Associated sport activities practiced beyond running were determined in 16 novice runners.

N=11 novice runners declared to had had a previous injury at the lower extremities, but in all the cases injuries occurred at least twelve months before begin to run. In all cases previous injuries were at the level of the tibia.

N=26 MR imaging exams were done using the 1.5-T equipment and total of 14 exams using the 3.0-T equipment.

MR imaging revealed tibial stress reactions in four knee MR examinations. Among stress reactions, two patients presented a grade 4 tibial stress reaction, one patient presented MR imaging findings classified as grade 3 tibial stress reaction bilaterally. No tibial stress reactions were found in the others 36 knees. MR imaging showed bursitis (one prepatellar, five semimetendinosus and gastrocnemius bursitis) and effusion in six knees, including three patients with tibial stress reactions and two patients with no tibial stress reaction.

Table 3 shows MR imaging findings and the corresponding grade. All of the tibial stress reactions were observed at the level of the medial tibial plate.

Figures 1 to 3 show tibial stress reactions found in three novice runners.

Overall intra- and inter-observer agreement with 95% confidence intervals (95%CI) among the two readers were 0.73% (95%CI: 0.68%-0.88%) and 0.71% (95%CI: 0.66%-0.85%). K values are reported as weighted with linear weights and are considered good.

No significant correlation of patient's age and body mass index and previous injury at the lower extremities and stress reaction was observed (p values not significant).

A negative correlation between previous running experience and additional sport activities and tibial stress reaction (r²=0.15; 95% confidence interval for r²: 0.08 to 0.20; P=0.05; and r²=0.13; 95% confidence interval for r²: 0.07 to 0.18; P=0.05, respectively) was found.

Table 1: MR imaging protocol
<table>
<thead>
<tr>
<th></th>
<th>T1-w TSE sequences</th>
<th>T2-w TSE fat-suppressed sequence</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>3-T MR imaging</td>
<td>1,5-T MR imaging</td>
</tr>
<tr>
<td>Repetition time (ms)</td>
<td>550</td>
<td>500</td>
</tr>
<tr>
<td>Echo time (ms)</td>
<td>7.9</td>
<td>14</td>
</tr>
<tr>
<td>Flip angle</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>FOV</td>
<td>20-22</td>
<td>20-22</td>
</tr>
<tr>
<td>Voxel size (mm)</td>
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<td>0.2x0.2x2</td>
</tr>
<tr>
<td>Matrix</td>
<td>320x320</td>
<td>320x320</td>
</tr>
<tr>
<td>Slice thickness (mm)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Phase resolution</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Echo train length per slide</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Bandwidth Hz/px</td>
<td>122</td>
<td>124</td>
</tr>
<tr>
<td>SAR (W/kg body weight)</td>
<td>1.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Acquisition time</td>
<td>5 min. 14 s</td>
<td>5 min. 45 s</td>
</tr>
<tr>
<td></td>
<td>5 min. 10 s</td>
<td>6 min. 36 s</td>
</tr>
</tbody>
</table>

**Table 2:** Patients' characteristics.

**Novice runner (=38)**

- Age, mean ± SD years: 40 ± 12
- Female (%): 15 (39.4%)
- Male (%): 23 (60.6%)
- Body mass index: 23 ± 5
mean ± SD years
Running experience (%)
Yes 17 (44.7%)
No 21 (55.3%)
Sport activities
No 22 (57.9%)
With axial load 10 (26.3%)
Without axial load 6 (15.8%)
Previous injury at the lower extremities
No 27 (71%)
>12 months 11 (29%)

**Table 3: MR imaging findings**

<table>
<thead>
<tr>
<th>Total knee evaluated (=40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tibial stress reaction</td>
</tr>
<tr>
<td>Grade 0</td>
</tr>
<tr>
<td>Grade 1</td>
</tr>
<tr>
<td>Grade 2</td>
</tr>
<tr>
<td>Grade 3</td>
</tr>
<tr>
<td>Grade 4</td>
</tr>
<tr>
<td>Location of tibial stress reaction</td>
</tr>
<tr>
<td>Medial</td>
</tr>
<tr>
<td>Lateral</td>
</tr>
<tr>
<td>Bursitis or effusion</td>
</tr>
<tr>
<td>mild</td>
</tr>
<tr>
<td>moderate</td>
</tr>
<tr>
<td>severe</td>
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</table>
Fig. 1: A 41 years old woman with bilateral knee pain. MR imaging coronal T1-weighted (a,c) and T2-weighted fat-suppressed images show a tibial stress reaction of grade 3, according to Fredericson's grade, at the level of medial tibial plate, bilaterally. (a,b) Right knee; (c,d) Left knee.
**Fig. 2:** Figure 2: A 45 years old man with left knee pain. MR imaging sagittal T1-weighted (a) and T2-weighted fat-suppressed (b) and coronal T1-weighted images (c) show a distinct fracture line at the level of the medial tibial plate (grade 4 of tibial stress reaction).

**Fig. 3:** Figure 3: A 40 years old man with left knee pain. MR imaging coronal T1-weighted (a) and T2-weighted fat-suppressed (b) images show a distinct fracture line at the level of the medial tibial plate (grade 4 of tibial stress reaction).
Conclusion

- Tibial stress injuries may occur in novice short-distance runners.
- MRI can efficiently demonstrate tibial stress reactions in novice symptomatic short-distance runners.
- Tibial fracture in novice short-distance runners occurred in the medial tibial plate.

Personal information

References


6. Ooms L, Veenhof C, de Bakker DH. (2013) Effectiveness of Start to Run, a 6-week training program for novice runners, on increasing health-enhancing physical activity: a controlled study. BMC Public Health13:697


