Meniscal root injury and spontaneous osteonecrosis of the knee

AN OBSERVATION


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We describe injuries to the posterior root of the medial meniscus in patients with spontaneous osteonecrosis of the medial compartment of the knee. We identified 30 consecutive patients with spontaneous osteonecrosis of the medial femoral condyle. The radiographs and MR imaging were reviewed. We found tears of the posterior root of the medial meniscus in 24 patients (80%). Of these, 15 were complete and nine were partial. Complete tears were associated with > 3 mm of meniscal extrusion. Neither the presence of a root tear nor the volume of the osteonecrotic lesion were associated with age, body mass index (BMI), gender, side affected, or knee alignment. The grade of osteoarthritis was associated with BMI.

Although tears of the posterior root of the medial meniscus were frequently present in patients with spontaneous osteonecrosis of the knee, this does not prove cause and effect. Further study is warranted.

Spontaneous osteonecrosis of the knee was first described by Ahlback, Bauer and Bohne1 in 1968 as a distinct clinical entity that primarily affected older women. Patients with the condition typically experience acute medial knee pain and have variable radiographic focal osteonecrosis in the medial femoral condyle.2,3 There are numerous theories describing the cause of spontaneous osteonecrosis of the knee, but the two most widely accepted are a primary vascular insult or trauma, both of which lead to secondary elevations of intraosseous pressure and subsequently osteonecrosis.4-11 As many patients with spontaneous osteonecrosis of the knee are older women, commonly suffering from osteoporosis, insufficiency fracture of the subchondral bone is also considered to be an important factor.2,9,10,12-15

Previous studies reported a high association of meniscal pathology with spontaneous osteonecrosis of the knee,1,3,16,17 but only two described the presence of injury to the posterior meniscal root.5,18 The purpose of this study was to review a retrospective series of patients with injury of the medial meniscal root, co-existing with spontaneous osteonecrosis of the medial compartment of the knee using a validated MRI grading system. The coexistence of root injury and spontaneous osteonecrosis would support, but not prove, the hypothesis that loss of hoop stress resulting from meniscal discontinuity produces increased pressure on the femoral condyle predisposing to subchondral fracture.

Patients and Methods

After obtaining ethical approval all consecutive patients who presented with knee pain and a diagnosis of spontaneous osteonecrosis of the knee within the past four years were identified from the database at our institution (University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania). Patients with secondary osteonecrosis were excluded. The diagnosis was confirmed by MRI, based on published criteria of central condylar hypointense T1 signal intensity, with variable peripheral signal intensity, and central condylar hypointense-to-intermediate T2 signal intensity with hyperintense peripheral signal intensity (Fig. 1).17,19 Bone density measurements were not available for these patients.

There were 30 patients (17 women and 13 men) who met the criteria and were included in the study. Their mean age was 58 years (43 to 81) and their mean body mass index (BMI) was 28 kg/m² (19 to 34). There were 16 lesions in the right knee and 14 in the left. The size of the lesion (anteroposterior, mediolateral, and superoinferior dimensions) and its ellipsoid volume (calculated from anteroposterior, mediolateral, and superoinferior dimensions) was measured by a musculoskeletal radiologist from the MRI studies. The location and type of meniscal body and horn tear, as well as the degree of meniscal extrusion were recorded.20,25 The mean dimensions of the osteonecrotic...
lesions were 15 mm (9 to 25) anteroposteriorly, 12 mm (7 to 19) mediolaterally, and 8 mm (5 to 14) supero-inferiorly. The mean volume of all lesions was 7220 mm$^3$ (1613 to 19,899; Table I). The mean medial meniscal extrusion was 3 mm (1.1 to 6.0) (Table I). The radiologist (DDR) measured knee alignment from standing (weight-bearing) full leg-length anteroposterior radiographs and the Kellgren and Lawrence$^{26}$ arthritis scale to grade osteoarthritis.$^{27}$ The mean knee alignment was 1° varus (8° varus to 4° valgus) and 24 had Kellgren and Lawrence$^{26}$ grade 2 osteoarthritis of the knee. The remaining six patients had grade 3 changes.

A total of 28 MRI studies were performed on a 1.5T MR system (Signa, GE Medical Systems, Milwaukee, Wisconsin) and two on a 0.2T open MR system (Signa, GE Medical Systems). All the MR studies were performed using a volume send/receive knee coil. MR sequences on the 1.5T and 0.2T MR were, respectively:

1) axial fast spin-echo T2-weighted with fat suppression (repetition time (TR) > 3200, echo time (TE) 42); sagittal spin-echo proton density (TR > 2000, min TE <75) and fast spin-echo inversion recovery (TR > 2000, TE 42), coronal spin-echo T1-weighted (TR < 600, TE minimum) and fast spin-echo T2-weighted with fat suppression (TR > 4000, TE 68); 2) axial fast spin-echo proton density (TR 5000, TE 42), sagittal 3-D gradient T1-weighted (TR 72, TE 32), fast spin-echo T2-weighted (TR 5500, TE 100), fast spin-echo inversion recovery (TR 2900, TE 42), and coronal spin echo T1-weighted (TR 650, TE minimum) and fast spin-echo T2-weighted (TR 4300, TE 100).

**Statistical analysis.** One-way analysis of variance (ANOVA) was used to test for differences and associations between patients with and without root tears, with respect to age, BMI, volume of osteonecrotic lesion and degree of meniscal extrusion. The chi-squared test of independence was used to test for differences between patients with and without posterior root tears, with respect to gender and the knee studied. Statistical testing was performed with SPSS version 12.01.1 (SPSS Inc., Chicago, Illinois) with a level of significance set at $p < 0.05$.

**MRI classification.** There are no published MR imaging criteria for meniscal root tears. We defined tears as either partial or complete. Both types required the presence of abnormal MRI signal intensity and abnormal morphology. Partial tears were defined by an abnormal intermediate signal intensity on short TE root images, probably representing disorganised collagen, and an abrupt decrease in cross-sectional area on coronal and sagittal images. Complete tears were defined by areas of hyperintense T2 signal intensity replacing the normal meniscal root, together with a discontinuity anywhere between the horn-root junction and its tibial insertion (Fig 2).

In order to measure the reliability and accuracy of the MRI classification for posterior medial roots, five control patients without osteonecrosis or root tear were randomly mixed with 16 of those with spontaneous osteonecrosis. The five controls were patients with arthroscopically-proven intact posterior meniscal roots, but with medial meniscal body tears. The control group consisted of three men and two women, whose mean age
was 48 years (44 to 56) and mean BMI was 28 kg/m² (24 to 33). There were three right knees and two left. All five imaging studies were performed on a 1.5T MR system (Signa, GE Medical Systems) using the pulse sequences described above. Standing (weight-bearing) anteroposterior radiographs of the knee for the control group were reviewed by the same musculoskeletal radiologist (DDR), who had graded the knees with spontaneous osteonecrosis. All the five controls had Kellgren and Lawrence grade 2 osteoarthritis of the knee.

The accuracy of the MRI root-injury classification was determined by comparing the classification with the surgical findings. Confirmation of root status from arthroscopy or arthrotomy reports was available for the five controls, for three patients with spontaneous osteonecrosis of the knee and with partially torn roots, and for four patients with spontaneous osteonecrosis and completely torn roots. All studies in this validation of the root-tear classification were prospectively and blindly reviewed by two musculoskeletal radiologists (EA, HK) who had not seen the cases before nor knew the clinical or surgical findings. They were asked to review only the posterior medial meniscal root and classify it as intact, partially torn, or completely torn using the criteria described above. Both radiologists performed this procedure twice, with at least four weeks separating the sessions. Only sagittal and coronal MR images, demonstrating the region of the medial meniscal root, were available to them. Before review of the MR images all the medial femoral condyles were digitally obscured, so that the presence or absence of osteonecrosis could not be determined from the images. The same procedure was used for the blinded readings of the MRI studies for the remaining 14 patients with osteonecrosis, who were not included in the validation of the MRI root-tear classification.

Intraobserver re-test for reliability was determined by comparing the repeat MRI classifications made by each observer. In order to determine interobserver re-test reliability, we compared the MRI classifications between observers. In order to estimate accuracy and reliability, we used the kappa coefficient, which represents agreement.
beyond chance. By convention a kappa of 0.81 to 1.00 is almost perfect, 0.61 to 0.8 substantial, 0.41 to 0.6 moderate, 0.21 to 0.4 fair, and 0.01 to 0.21 slight.28

The intraobserver reliability kappa coefficients for the two root-tear classification sessions were 0.57 and 0.73 while the interobserver reliability kappa coefficients were 0.62 and 0.67, respectively. The observers’ agreement with the surgical findings ranged from 0.63 to 0.75. Interobserver reliability and accuracy of classification improved with the second set of measurements.

**Results**

Of 30 patients with spontaneous osteonecrosis of the medial femoral condyle 24 (80%) had a posterior medial meniscal root injury, 15 complete and nine partial tears. The anterior medial meniscal root was intact in 18 patients and torn in six. No patient had an injury to the ipsilateral posterior lateral meniscal root. Medial meniscal tears of the posterior horn, 15 horizontal and five oblique longitudinal, were identified in 20 of the 24 patients with root injury. There were six patients with spontaneous osteonecrosis who had neither a root injury nor a meniscal tear (Fig. 3).

Medial meniscal extrusion was associated with a complete tear of the posterior medial meniscal root (ANOVA, \( p = 0.001 \)). All complete posterior medial root tears had > 3 mm of meniscal extrusion (Table I). There was no significant difference between patients with and without root tears in respect of age, BMI, volume of osteonecrotic lesion, and knee alignment (ANOVA, \( p > 0.1 \)). Additionally, there was no significant difference between patients with and

<table>
<thead>
<tr>
<th>Posterior medial root</th>
<th>Volume of osteonecrotic lesion (mm³)</th>
<th>Meniscal extrusion (mm)</th>
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<tbody>
<tr>
<td>Intact</td>
<td>6360 (1770 to 7941)</td>
<td>1.5 (1.1 to 2.0)</td>
</tr>
<tr>
<td>Partial tear</td>
<td>7617 (1613 to 17 696)</td>
<td>1.9 (1.6 to 2.3)</td>
</tr>
<tr>
<td>Complete tear</td>
<td>7683 (1584 to 19 899)</td>
<td>3.8 (3.3 to 6.0)</td>
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MRI showing an intact posterior medial meniscal root in a patient with spontaneous osteonecrosis. The root has an abnormal T1 signal, although there was no morphological abnormality. a) Coronal spin-echo T1-weighted MR image (500, 11) showing abnormal grey T1 signal in the posterior medial meniscal root (arrow). b) Sagittal spin-echo proton density MR image (2117, 14) showing abnormal grey signal in the posterior medial meniscal root at its tibial insertion (arrow). c) Coronal spin-echo T2-weighted image (2200, 69) illustrates normal signal and morphology of the posterior medial meniscal root (arrow). d) Sagittal fast spin-echo T2-weighted MR image (2117, 75) illustrates normal morphology of the posterior medial meniscal root at the tibial insertion site (arrow).
without posterior root tears, in respect of gender and knee studied (chi-squared test, \( p = 0.6 \)). The Kellgren and Lawrence grading was associated with the BMI (\( r = 0.75, p = 0.001 \)) but not with age, gender, side of the knee, or volume of osteonecrotic lesion. Neither the presence of a root tear nor the volume of the lesion were associated with age, BMI, gender, side of the knee, or knee alignment.

**Discussion**

Previously, meniscal pathology has been associated with spontaneous osteonecrosis of the knee but not with root injury. In Ahlback et al.’s original description of spontaneous osteonecrosis of the knee, meniscal tears were present in six of 14 patients. Norman and Baker,16 and other authors, have found medial meniscal tears in 50% to 78% of patients with spontaneous osteonecrosis.3,9,17 In our study, posterior medial meniscal root injury was present in 80% of patients with spontaneous osteonecrosis and medial meniscal tears in 67%. Meniscal root injuries have not been previously described in association with spontaneous osteonecrosis of the knee because root injuries have only recently been recognised. In our practice, medial meniscal root injury is uncommon; among 1500 consecutive knees undergoing MRI for knee pain we found root injuries in only 42 (2.8%).

The MRI root-tear classification used in this study defines partial and complete tears based on abnormal morphology and MR signal intensity. It is the first to be validated and, to our knowledge, this is the first report of an association between spontaneous osteonecrosis of the knee and meniscal root injury. Limitations of the study included the retrospective analysis, lack of bone density data, the frequency of surgical confirmation and the exclusion of the lateral compartment. However, even with these limitations, the fact that spontaneous osteonecrosis of the knee is commonly associated with meniscal root injury is interesting and warrants dissemination, if only to stimulate further studies. Future investigators should consider inclusion of bone densitometry and also meniscal motion analysis as described by Vedi et al.29

In order to explain the coexistence of spontaneous osteonecrosis and root injuries, we support the hypothesis that root injury alters meniscal function, increases loading of the femoral condyle and ultimately results in subchondral fatigue fracture. In older patients, spontaneous osteonecrosis has been reported as a complication of meniscectomy, supporting the theory that increased focal condylar loading has a role in the generation of osteonecrosis.10-34 The effects of mechanical environmental changes, such as increased focal loading, depend on the local bone structure and integrity;35 similar mechanical conditions can result in a variety of chondral-subchondral disorders.36 Spontaneous osteonecrosis of the knee occurs primarily in older women, often suffering from osteoporosis. Consequently, osteonecrosis may be a response to focal increased loading. Coexistent degenerative change should also be considered as a possible prerequisite for spontaneous osteonecrosis, as each patient in our study had at least grade 2 radiological osteoarthritis.

If meniscal root injury does lead to femoral overload, then the importance of this study may extend beyond spontaneous osteonecrosis of the knee. In younger patients with stronger bone, meniscal discontinuity and its increased focal loading may lead to chondrolysis and accelerated osteoarthritis. Thus, the early diagnosis of root injuries may be critical for preventing osteoarthritis of the knee in all age groups.

While the aetiology of spontaneous osteonecrosis of the knee remains elusive and is probably multifactorial, it is possible that posterior medial meniscal root injury plays a role in its development.

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**References**