Osseous lesions associated with anterior cruciate ligament injuries
Assessment by magnetic resonance imaging at various periods after injuries

K. Nawata • R. Teshima • T. Suzuki

Abstract In 56 patients with anterior cruciate ligament (ACL) rupture, we retrospectively examined osseous lesions secondary to the rupture using magnetic resonance imaging (MRI). Depending on the time from their ligamentous injury to the performance of MRI, the patients were divided into three groups: the acute group (less than 1 month, n = 20), the subacute group (between 1 and 12 months, n = 16), and the chronic group (12 months or more, n = 20). Occult osseous lesions which were not detected by roentgenography were revealed by MRI in 14 patients in the acute group (70.0%), 5 in the subacute group (31.3%), and 1 in the chronic group (5%). The detection rate of osseous lesions by MRI was significantly higher in the acute group than in the other groups (P < 0.001). Osseous lesions were always detected in the same locations of the lateral compartment of the knee joint. When examined by arthroscopy, these lesions were often found to be accompanied by articular cartilage injuries. In the acute group, osseous lesions were visible in the high signal intensity area of T2-weighted images and in the low signal intensity area of proton density images. They were interpreted as representing hemorrhage and edema within the bone marrow. In the subacute and chronic groups, the osseous lesions were smaller, and their signal intensity on T2-weighted images was lower than that in the acute group, probably reflecting the ongoing resorption of the hemorrhage and healing of the lesions. These results suggest that osseous lesions develop following injury to the ACL.

Introduction

Injury to the anterior cruciate ligament (ACL) of the knee is sometimes accompanied by secondary injuries to other components of the knee joint such as the articular cartilage and the meniscus. On the other hand, osseous lesions secondary to rupture of the ACL are difficult to assess with conventional imaging modalities. For this reason, there are many questions about these lesions, including whether or not they actually exist. Using magnetic resonance imaging (MRI), we examined the incidence of osseous lesions associated with injury to the ACL and analyzed their location and qualitative aspects. Based on these analyses, we discuss the pathophysiology and the onset mechanism of these lesions.

Patients and methods

The subjects were 56 randomly selected patients diagnosed as having ACL rupture and who underwent MRI between August 1989 and January 1993. There were 26 men and 30 women, with ages ranging from 13 to 59 years (mean 27.8 years). Patients with severe multiple ligamentous injuries were excluded from this study. Depending on the time from their ligamentous injury to the performance of MRI, the patients were divided into three groups: the acute group (less than 1 month; 20 patients), the subacute group (between 1 and 12 months; 16 patients) and the chronic group (12 months or more; 20 patients). In these patients, we examined the incidence of osseous lesions and their location and signal intensity. In 28 patients who underwent arthroscopy and reconstruction of their ACL disruption (11 in the acute group, 9 in the subacute group, and 8 in the chronic group), the osseous lesions were compared with the features of the articular cartilage surface.

All knees underwent MRI using a standard protocol for internal derangement of the knee. We used two MRI devices, a Siemens Magnetom H15 (1.5 T) and a Shimadzu SMT-100 (1.0 T), each fitted with a dedicated transmit-receive extremity coil. In all patients, coronal and sagittal imaging of contiguous sections 5 mm thick was performed. We took T2-weighted images (TR 1800–2000 ms and TE 90 ms) and proton density images (TR 1800–2000 ms and TE 20–22 ms) by the spin-echo technique.

Results

Roentgenography revealed no osseous lesions in any subject. MRI, however, disclosed osseous lesions in 20 patients, i.e., 14 of the 20 patients (70.0%) in the acute group, 5 of the 16 patients (31.3%) in the subacute group,
and 1 of the 20 patients (5%) in the chronic group. The incidence of osseous lesions was higher in the acute group than in any of the other groups, and it differed significantly between any two of the three groups ($P < 0.001$, chi-square test; Fig. 1). All osseous lesions were located in the lateral compartment of the knee joint (Table 1). In the acute group, the osseous lesions in the lateral femoral condyle had a band-shaped or spotted appearance, extending from the subchondral bone plate (slightly posterior to the terminal sulcus) to the cancellous bone region. In the same group, the lesions in the lateral tibial plateau were linear, extending horizontally from the posterior region. The lesions were visible in the high signal intensity area of T2-weighted images and in the low signal intensity area of proton density images (Fig. 2). Although the osseous lesions were localized at the same sites in all three groups, the lesions in the subacute and chronic groups had lower signal intensities and narrower areas on T2-weighted images (Fig. 3).

In 28 patients who underwent arthroscopy, the arthroscopic features of the articular cartilage were compared with the MRI findings of the osseous lesions. Injuries to the articular cartilage of the lateral femoral condyle, such as deep fissures and cracks, were noted in 5 patients in the acute group, 5 in the subacute group, and 3 in the chronic group. Of these 13 patients, 4 in the acute group, 2 in the subacute group, and none from the chronic group had osseous lesions. Thus, the incidence of complication by osseous lesions was highest in the acute group. The site of altered articular cartilage detected by arthroscopy was identical with the site of osseous lesions revealed by MRI (Fig. 4).

**Discussion**

In 1989, Mink and Deutsch [2] reported that occult osseous lesions were disclosed by MRI in the bone marrow of patients with knee joint contusion or ligamentous injury, and that these lesions represent trabecular fractures, accompanied by edema and hemorrhage. It was recently reported that these occult osseous lesions were frequently detected in the lateral compartment of patients with acute ACL tears [4, 6]. In the present study, patients with ACL rupture were divided into three groups depending on the time from ligamentous injury to the performance of MRI. Osseous lesions were compared among these three groups of patients for the purpose of analyzing their time course and pathophysiology.

The incidence of osseous lesions was highest in the acute group, and it became markedly less frequent in the subacute and chronic groups. Considering the signal intensities and the size of the osseous lesions, the lesions in the acute group seemed to represent hemorrhage and edema in the bone marrow, while the smaller lesions in the subacute and chronic groups appeared to represent ongoing resorption of the hemorrhage and healing of the lesions. Osseous lesions were always detected in the same region. They were frequently accompanied by injury to the cartilage surface. Although the present study is not a

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**Fig. 1** Percentage of osseous lesions occurring in the acute, subacute, and chronic groups. *Statistically significant, $P < 0.01$

**Table 1** Location of osseous lesions

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lateral femoral condyle</td>
<td>19</td>
</tr>
<tr>
<td>2. Lateral tibial plateau</td>
<td>17</td>
</tr>
<tr>
<td>3. Medial femoral condyle</td>
<td>1</td>
</tr>
<tr>
<td>1 + 2.</td>
<td>15</td>
</tr>
<tr>
<td>1 + 2+ 3</td>
<td>1</td>
</tr>
</tbody>
</table>

*a Number of patients, 20; number of lesions, 37*