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Can MRI Distinguish between Acute Partial and Complete Anterior Cruciate Ligament Tear?

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INTRODUCTION

Partial anterior cruciate ligament (ACL) tear has been recognized for many years1,2). It is generally treated conservatively because prognosis is considered better than complete tear3), whereas complete ACL tear is usually treated operatively especially for those who are young and physically active. Although magnetic resonance (MR) imaging has been shown to be an accurate means for diagnosing complete ACL tear4,5), it is not proven whether partial ACL tear can be reliably diagnosed on the basis of MR findings.

This study was undertaken to determine whether sagittal spin echo images can distinguish between acute partial and complete anterior cruciate ligament tear.

MATERIALS AND METHODS

Among the patients who underwent arthroscopy for suspected anterior cruciate ligament tear for the past four years, there were eight patients (two males and six females aged 17 to 46 years) with partial anterior cruciate ligament (ACL) tear, who underwent both MRI and arthroscopy within six weeks following trauma (partial tear group). Six of these patients had a torn anteromedial band and the others had a torn posterolateral band.

There were three arthroscopists who performed examinations. The criteria of partial ACL tear used by these surgeons include:

1) An end of partially torn band of ligament is directly visualized and good tension is proved in the intact band of ligament by palpation with a probe on arthroscopy.
2) Lachman test is scored zero or 1+, and pivot shift test is negative. The clinical information was obtained from medical records and it was included in the criteria to exclude cases with only few fibers of ligament remaining intact. These who underwent arthroscopy over six weeks following trauma and those with concurrent posterior cruciate ligament (PCL) tear were excluded. There were fourteen MR examinations in fourteen patients with

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Partial vs. Complete ACL Tear

complete ACL tear confirmed at arthroscopy within six weeks following trauma (complete tear group). Ten examinations in ten patients with arthroscopically intact ACL were selected at random to serve as control for this study (control group).

Proton density-weighted and T2-weighted sagittal spin-echo or turbo spin echo images of the three groups were retrospectively reviewed by the authors (M.Y. and T.Y.) with attention to the primary and secondary signs of ACL tear. Coronal images were not included in this study, because several different protocols were employed. The results of the arthroscopies were known at the time of image review. The primary signs of ACL tear include discontinuity of low signal band, abnormal axis of the ligament (any deviation of the ligament from expected course) and focal or diffuse increased signal intensity. The secondary signs of ACL tear include bone bruise, anterior translocation of the tibia with regard to the femur and PCL curvature value. The degree of anterior translocation of the tibia with regard to the femur was measured according to Vahey (6) with regard to a plane parallel to the long cephalocaudal axis of the image at the mid-sagittal plane of the lateral condyle. The most posterior aspect of the posterior edge of the convex black line of cortical bone was used to measure the degree of subluxation. The PCL curvature value was defined according to Tung (7) as $x/y$, where $x$ represents the distance between the deepest tibial and femoral insertion points of the ligament and $y$ represents the maximal distance of a perpendicular line drawn between $x$ and $y$ and the under surface of the PCL, measured on proton-density-weighted sagittal images.

The data were analyzed by one factor ANOVA and Scheffe's F-test for statistical significance.

MR imaging examinations of the knee were performed with one of two 1.5 T magnets (Siemens Magnetom H15, Shimadzu SMT150GUX) by using a dedicated knee coil. The imaging parameters include 2000/20, 80/2 (TR/TE/excitations) (spin echo), 3300/19, 33 (turbo spin echo), slice thickness 4 to 5 mm, gap 0-1 mm, 14-16 cm: field of view and matrix 92 or 256 x 256. The sagittal images were obtained in the plane parallel to the medial aspect of the lateral femoral condyle.

RESULTS

Primary signs (Table 1):

Discontinuity, abnormal axis and increased signal intensity on proton-density-weighted images were noted in almost all knees with partial and complete tears. All knees with complete ACL tear had discontinuity and increased signal intensity on T2-weighted images, whereas half of the knees with partial tear had continuous band of low signal and three of eight knees with partial tear lacked increased signal intensity on T2-weighted images (Fig 1).

Secondary signs (Table 2):

Bone bruise was noted in five (62.5%) of eight knees with partial tear (Fig. 2) and in six (43%) of fourteen knees with complete tear. Bone bruise was noted in the middle third of the lateral femoral condyle or in the posterior aspect of the lateral tibial plateau or in both regions. In the anterior translocation of the tibia with regard to the femur, there was statistical difference only between control group and complete tear group ($P < 0.05$). In PCL curvature value, no statistical difference was noted among the three groups.

DISCUSSION

'Partial tear of the ACL' is defined differently among various researchers and no universal definition is available at the moment. Neaves et al (1) defined partial ACL tear as those with less than 75% tearing, good tension in the remaining intact portion and negative pivot shift test. Barrack et al (1) used criteria; 1) a significant portion of a least one bundle was in continuity and was potentially functional as judged by palpation with a probe and arthroscopic anterior drawer testing; 2) the Lachman test scored zero or 1+ (less than 5 mm); 3) the pivot shift was negative or only trace-positive. Lehnert et al (4) defined as partial tears those injuries in which one-quarter to three quarters of the ligament was torn. It seems, however, that the majority of the authors think that a significant portion of the ligament should be intact to be eligible for partial tear and when only few fibers of the ligament remain intact but are not functioning, they are considered analogous to complete tear. Our definition of partial ACL tear includes arthroscopic features and clinical information to minimize bias among arthroscopists. We focused on acute cases and excluded chronic cases, because chronic complete ACL tear with bridging fibrous scars may mimic partial ACL tear or intact ACL. Although partial tears are thought to have better prognosis (5), long-term follow-up results are controversial in terms of frequency of ACL deficient knee, ranging from 14 to 56% (6-10). These differences may account for difference in patient population, amount of ligament tearing (6), presence or absence of other ligament injuries, and difference in rehabilitation program.

Acute partial tears of the ACL are distinguishable from normality, but are not distinguishable from complete tears on the basis of proton-density-weighted images, because both have discontinuity and abnormal axis of the ligament and increased signal intensity. There is, however, a couple of findings suggesting partial tear. Preserved continuity of the low signal band on T2-weighted images is one of them and was seen in four of eight knees with partial ACL tear, even though proton-density-weighted images show discontinuity of the ligament...
Table 1  Primary signs of ACL tear

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<th>T2-weighted image</th>
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<tr>
<td></td>
<td>discontinuity</td>
<td>abnormal axis</td>
</tr>
<tr>
<td>partial tear</td>
<td>8/8</td>
<td>8/8</td>
</tr>
<tr>
<td>complete tear</td>
<td>14/14 (N=6)²</td>
<td>14/14</td>
</tr>
<tr>
<td>control</td>
<td>0/10</td>
<td>0/10</td>
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* Numbers in parentheses indicate cases with non-visualized low signal band of the ligament

Fig. 1  MR images of the knee of 43 year old female with torn anteromedial band of ACL proved at arthroscopy.
(A) Proton-density-weighted sagittal image (2000/20) shows the ACL to be convex posteriorly with increased signal intensity in the tibial side of the ligament (arrow).
(B) T2-weighted sagittal image (2000/80) shows contiguous low signal band of the ligament, again convex posteriorly.

Another interesting observation is the fact that non-visualization of the ligament on proton-density-weighted images was seen in only complete ACL tears, and at least a part of low signal band was visible in partial tears.

In partial ACL tear, a significant portion of the ligament is, by definition, intact. At least a part of ligament should, therefore, be expected as a continuous band of low signal intensity separately from torn ligament on MRI, when slice thickness is thin enough. This was not possible in our imaging protocol with section thickness of either 4 or 5 mm, where partial
Table 2: Secondary signs

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<th>Bone bruise</th>
<th>Anterior translocation of the tibia</th>
<th>PCL curvature value</th>
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<tr>
<td>Partial tear</td>
<td>5/8</td>
<td>&lt;3 (3.8) mm</td>
<td>0.18 (0.07)</td>
</tr>
<tr>
<td>Complete tear</td>
<td>6/12</td>
<td>6.1 (4.4) mm</td>
<td>0.21 (0.05)</td>
</tr>
<tr>
<td>Control</td>
<td>0/10</td>
<td>0.76 (3.3) mm</td>
<td>0.18 (0.5)</td>
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Numbers in parentheses indicate one standard deviation.

Fig. 2: MR images of the knee of a 17-year-old female with torn posterolateral band of ACL with bone bruise proved at arthroscopy. Proton-density (A) and T2-weighted (B) sagittal images (200/20, 80) show discontinuity of the ACL (arrow head). Bone bruise is seen in the middle third of the lateral femoral condyle and the posterior aspect of the lateral tibial plateau (arrow) on T2-weighted sagittal image (C).

Volume averaging is inevitable. Perhaps thinner section slices or three dimensional technique may enable us to see torn and intact components.

Both anterior translocation of the tibia and PCL curvature value are related to anterolateral instability. These secondary signs of ACL tear may increase the conspicuity of tears and the confidence in the diagnosis of the tears, however, it was not known whether these signs can truly indicate the completeness of the tear. Because partial tears are associated with less degree of anterolateral instability, a significant difference...
in PCL orientation and tibial subluxation between the complete and partial tear groups appears likely, contrary to our results. It should be noted, however, that in acute stage of ACL tear, physical examinations utilizing arthroscopy instability may be difficult to perform due to muscular spasm, which may be responsible for statistically insignificant difference in PCL orientation and tibial subluxation between the complete and partial tear groups.

Bone bruise associated with ACL tear is believed to result from impaction of the lateral femoral condyle into the posterior tibia, either during the initial rotary subluxation or as the lateral femoral condyle recoils to return to anatomic alignment. Murphy et al. emphasized that bone bruise suggests complete ACL tear, because only one of six partial ACL tears had a bone bruise in their series. We think, however, that bone bruise does not necessarily indicate complete ACL tear on the basis of our result where five of eight knees with partial ACL tear are associated with bone bruise. Similar results were reported recently by McCauley et al., where the frequency of bone bruising was similar in partial tear and complete tear groups. The difference in the results may simply represent difference in population of the patients, that is, difference in the degree of tear, because no arthroscopic criteria of partial ACL tear was given in their study. Although we did not attempt to quantify the degree of tear, the quantity of the T1 scans may account for presence or absence of bone bruise.

Further study is necessary to determine whether bone bruising has an implication in terms of clinical outcome in patients of partial ACL tear.

Our goal of this study was to determine whether partial and complete ACL tears are distinguishable on MRI, and hopefully to find a specific sign of partial ACL tear. Several potential problems with regard to this study must be considered, however. First, the results of arthroscopy were not blinded to the observers of MRI, where objective evaluation of MR imaging may not be achieved. Second, false negative studies were not considered, because only those cases with arthroscopic confirmation were included in this study. Patients with negative MR studies are unlikely to become candidates for arthroscopy unless there is significant instability on physical examination. Third, only sagittal images were included for evaluation, because several different pulse sequences were employed for coronal images unlike sagittal images where proton density- and T2-weighted spin echo (turbo spin echo) sequences were invariably obtained. We admit that the attachment of ACL to the femur may not be fully evaluated on sagittal images alone.

In conclusion, partial ACL tears can easily be distinguished from normality on proton density-weighted images. Complete and partial tears of the ACL are not distinguishable on the basis of sagittal proton density-weighted images. Preserved continuity of the low signal band on T2-weighted images is one of the findings, suggestive of partial ACL tear.

REFERENCES