Comparison of Conventional Spin-Echo and Fast Spin-Echo Magnetic Resonance Imaging with Fat Suppression in Cruciate Ligament Injury

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Aim. To compare the quality and diagnostic reliability of conventional spin-echo and fast spin-echo with fat suppression magnetic resonance (MR) imaging in the evaluation of cruciate ligament injury.

Methods. Thirty-five patients with internal knee injury and positive clinical signs of cruciate ligament injury were examined by using an Elscint Prestige 2T MR scanner. Findings of conventional and fast spin-echo with fat suppression MR sequences were evaluated and compared with each other and with arthroscopic findings. In all patients, arthroscopy was performed within 2 months after the MR examination.

Results. Analysis of anterior cruciate ligament injury with conventional spin-echo sequence showed 81.8% sensitivity. The sensitivity of fast spin-echo sequences with fat suppression was 96.9%. According to the type of the anterior cruciate ligament injury, the sensitivity of fast spin-echo sequences with fat suppression was higher than that of conventional spin-echo sequence (85.7% and 66.7%, respectively) for partial rupture, but the sensitivity of both sequences for complete rupture was the same (100% both).

Conclusion. Fast spin-echo with fat suppression sequence can be used routinely in clinical practice for the assessment of acutely injured knees as the substitute for conventional spin-echo sequence without decreased diagnostic reliability.

Key words: anterior cruciate ligament; arthroscopy; magnetic resonance imaging; knee injuries; posterior cruciate ligament

Cruciate ligament injuries have reached epidemic proportions in modern life. The reason is increasing sports and recreation activities, as well as increasing rates of traffic trauma. The incidence of acute anterior cruciate ligament tears is estimated at 1:3,000 in the general population of the USA, and is even higher in specific population, such as competitive football, skiing, and soccer athletes (1-3). Because of the prevalence of this injury and treatment requirements, early, reliable, and non-invasive diagnosis is very important.

Since Reicher et al (4) first introduced magnetic resonance (MR) imaging for the examination of the knee in 1985, it has been the diagnostic technique of choice, replacing arthrography and diagnostic arthroscopy. The advantages of MR imaging are its non-invasiveness and high accuracy especially in evaluation of internal knee injury, including the clinically challenging acute cruciate ligaments rupture (5-8). Imaging time and poor distinction between the signal intensity of acute edema, hemorrhage, and injured ligament tissue are the major disadvantages of conventional spin-echo) sequences. Use of fast spin-echo sequences with fat suppression decreases imaging time and makes better contrast resolution between pathomorphological changes and different tissues (6-10). The value of MR imaging in the assessment of knee injury, especially cruciate ligaments injury, is well known. Since MR imaging is a routine diagnostic procedure in the evaluation of the injured knee, there are many studies comparing MR imaging reliability with arthroscopy as a gold standard. All studies agree that MR, as a noninvasive diagnostic tool, is the method of choice in diagnostic evaluation of knee injury (8-17). The choice of optimal sequence depends on the pathomorphological points we want to show.

The aim of this study was to compare the quality and diagnostic reliability of conventional spin-echo and fast spin-echo sequences with fat suppression. Our hypothesis was that a fast spin-echo sequence with fat suppression was more reliable in the assessment of the cruciate ligament injury, especially in acute knee trauma, and that it could be used instead of a conventional spin-echo sequence when a quick and reliable diagnosis is needed.
Material and Methods
Between January 2000 and January 2002, 35 patients with obvious internal knee injury were examined by MR and subsequent arthroscopy.

All patients were highly suspicious of having anterior cruciate ligament injury on clinical tests, and were examined by one of three orthopedic surgeons, subspecialists in knee surgery. Positive clinical tests for anterior cruciate ligament injury were an indication for MR examination, which was always performed before arthroscopy.

Median age of the patients was 30 years (range, 16-57); 22 were men and 13 women. All patients underwent MR imaging on a 2.0 T Elscint Prestige unit (Elscint, Haifa, Israel) with a dedicated knee coil and a 14- to 16-cm field of view. The knee was positioned in 5-10° flexion and 15-20° external rotation. Each patient was scanned with both conventional spin-echo and fast spin-echo sequences with fat suppression in the coronal and sagittal plane. Fast spin-echo imaging was performed with an echo train of 14. Time to repeat/time to echo was 5,200/126, and scanning lasted 4.41 min. For spin-echo sequence, time to repeat/time to echo was 550/12 and scanning lasted 4.20 min. A 256x256 matrix with two image-excitations was used to generate both the conventional and fast spin-echo sequences with fat suppression, with a 3-mm section thickness and a 0.5-mm gap. A routine examination also included axial fat-suppressed fast spin-echo T2, sagittal gradient echo T2*, and coronal oblique fast spin-echo T2 sequences, taking approximately 35 minutes.

We assessed the anterior cruciate ligaments integrity using the following scale: 1. normal, 2. partially torn, or 3. completely torn on spin-echo and fast spin-echo with fat suppression images, separately.

Primary and secondary signs of the ligament injury helped us in the assessment of ligament integrity. Primary (direct) signs were the discontinuity of the anterior cruciate ligament in the sagittal and coronal oblique planes and failure of fascicles of the ligament to parallel the line representing the intercondylar roof on midline sagittal images. Secondary (indirect) signs of rupture included anterior translation of the tibia; specific distribution of bone bruise (in lateral compartment), increased curvature of the posterior cruciate ligament, decreased angle between lateral tibial plateau and anterior cruciate ligament (less than 45°), and position of the posterior cruciate ligament line (5,17,18).

Complete rupture of the anterior cruciate ligament was diagnosed if the primary sign or at least 3 secondary signs were present. Our criteria for partial anterior cruciate ligament rupture included the absence of secondary signs of complete anterior cruciate ligament rupture and one or more following signs: abnormal intrasubstance signal intensity with definable intact ligamentous fibers in continuity between femoral and tibial attachments and bowing or undulating contour of intact ligament (5,17,18).

The corresponding arthroscopic reports by 3 orthopedic surgeons, subspecialists in knee surgery, were reviewed for all 35 patients; each cruciate ligament was categorized as normal, partially torn, or completely torn on spin-echo and fast spin-echo with fat suppression images, separately.

Results
All 35 patients were examined by MR and arthroscopy. We found 33 anterior cruciate ligament injuries. In 35 examined knees, complete tears were arthroscopically confirmed in 27 (Figs. 1-5), partial tears in 9 (Figs. 6 and 7), and normal anterior cruciate ligament was found in one (Table 1).

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Table 1. Magnetic resonance (MR) spin-echo (SE) sequence, fast spin-echo sequence with fat suppression (FSE FS), and arthroscopic findings of cruciate ligaments

<table>
<thead>
<tr>
<th>MR findings (No. of patients)</th>
<th>Arthroscopic findings of cruciate ligaments (n = 33)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>normal</td>
</tr>
<tr>
<td>SE sequence: normal (n = 5)</td>
<td>1</td>
</tr>
<tr>
<td>partial tear (n = 6)</td>
<td>0</td>
</tr>
<tr>
<td>complete tear (n = 22)</td>
<td>0</td>
</tr>
<tr>
<td>FSE FS sequence: normal (n = 1)</td>
<td>1</td>
</tr>
<tr>
<td>partial tear (n = 7)</td>
<td>0</td>
</tr>
<tr>
<td>complete tear (n = 25)</td>
<td>0</td>
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</table>
In most patients, complete rupture of the anterior or posterior cruciate ligament was found in the middle third of the ligament. The most reliable sign of complete rupture was non-visualization of the ligament fascicles parallel to the intercondylar roof line on midline sagittal images and discontinuity of ligamentous fibers in the sagittal and coronal oblique planes found in 22 of 27 complete ruptured ligaments. Bowing or undulating contour of the ligament, abnormal intrasubstance signal intensity with definable intact ligamentous fibers in continuity between femoral and tibial attachments were findings of partial rupture of the ligament.

According to the type of the anterior cruciate ligament injury, the sensitivity of fast spin-echo sequences with fat suppression was higher than the sen-

**Figure 2.** A. Sagittal spin-echo image: thick anterior cruciate ligament with inhomogeneous signal intensity without fibre continuity in the middle third of the ligament – complete acute rupture. B. Sagittal fast spin-echo image with fat suppression: clearly visible discontinuity of the ligamentous fibres in the middle third of the ligament as a sign of complete acute rupture (arrow).

**Figure 3.** A. Sagittal spin-echo image: without possibility to see anterior cruciate ligament except for some ligament fibres in distal attachment (arrow). B. Sagittal spin-echo image with fat suppression: complete acute rupture in the middle third of the ligament with ligament edema (arrow). C. Coronal oblique image shows complete discontinuity of anterior cruciate ligament in the middle third (arrow).
sensitivity of the spin-echo sequence for determining partial rupture (85.7% vs 66.7%), but the sensitivity of both sequences for complete rupture was the same (100.0%). For anterior cruciate ligament injury (for both partial and complete rupture), the sensitivity of spin-echo sequence was 81.8%, and sensitivity of fast spin-echo sequences with fat suppression was 96.9%.

**Discussion**

Many studies compared one of the MR sequences with arthroscopy (8-12), but none compared two MR sequences and each MR sequence separately with arthroscopy. To the best of our knowledge, there are no reports on the individual sensitivity and specificity for each sequence. Few studies comparing the two sequences had a small patient sample (14). Smith et al (15) studied 28 patients using fast spin-echo sequences with fat suppression and compared them with conventional spin-echo images, but only three of these patients underwent subsequent arthroscopic evaluation. In our study, all 35 patients had arthroscopy performed after MR imaging. To our knowledge, our series is the largest reported so far, assessing the accuracy of fast spin-echo sequences with fat suppression and conventional spin-echo sequences in the evaluation of cruciate ligament status.

In the assessment of the cruciate ligaments, MR images were usually interpreted by using primary and secondary signs of ligament injury (16-18). In our study, the interpretation was based on spin-echo and fast spin-echo sequences with fat suppression images, analyzed together and separately.

We found that the most accurate and reliable signs for the complete anterior cruciate ligament tear were primary (direct) signs, i.e., discontinuity of the anterior cruciate ligament in the sagittal and coronal

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**Figure 4.** A. Sagittal spin-echo image: anterior cruciate ligament is absent – complete chronic rupture. B. Sagittal spin-echo image with fat suppression: empty-notch sign. Chronic anterior cruciate ligament tear with horizontally orientated ligament (arrow).

**Figure 5.** A. Sagittal spin-echo image: loss of continuity of the posterior cruciate ligament (arrow). B. Sagittal spin-echo image with fat suppression: complete rupture of the posterior cruciate ligament with irregular posterior margin (arrow).
oblique planes and failure of fascicles of the ligament to parallel the Blumensaat line on midline sagittal images. Since many institutions do not routinely obtain images in coronal oblique plane, it has been rarely described (10,19). Secondary or indirect signs included a buckled posterior cruciate ligament, ventral translocation of the tibia, specific distribution of bone bruise (in lateral compartment), increased curvature of the posterior cruciate ligament, decreased angle between lateral tibial plateau and anterior cruciate ligament (less than 45°), and position of the posterior cruciate ligament line (5,16-20).

Some signs were more sensitive for the detection of acute tears (a posterolateral tibial or lateral femoral bone bruise and an edematous soft-tissue mass), whereas others were more sensitive for the detection of chronic tears (sagittal non-visualization of fascicles, the abnormal posterior femoral line sign, and anterior

Ruptures of the anterior cruciate ligaments were found mostly in the middle part of the ligament (76.9% of the anterior cruciate ligament ruptures), corresponding with those reported in other studies (8,12,13).

As opposed to findings of other authors (22,24), we found that soft tissue edema in the intercondylar fossa (edema of the ligament fibers) without joint effusion was characteristic for acute ligament rupture. Vahey et al (22) and Turner et al (24) described the pathomorphological substrate in the intercondylar fossa as homogenous signal of low intensity on T1 and slightly higher intensity on T2-weighted images (the same signal intensity as fatty tissue on T2-weighted image). Compared with this signal intensity, joint effusion has a very high signal. This is the reason why using fast spin-echo sequences with fat suppression gives better contrast resolution and can distin-
guish tissue edema from joint effusion in ligament injury.

Comparison of the findings on spin-echo with fast spin-echo sequences with fast suppression revealed a difference in the sensitivity of sequences in evaluation of cruciate ligament injury. For anterior cruciate ligament rupture either partial or complete, the sensitivity of spin-echo sequence was 81.8%. According to the literature, spin-echo sensitivity ranges between 83 and 94% and specificity between 84 and 99% (8,11,12,17,22,25,26). The sensitivity of fast spin-echo sequence with fat suppression for anterior cruciate ligament injury in our study was 85.7%, whereas the range of sensitivity and specificity reported in the literature was 84-100%. In some studies, indicators of study availability of fast spin-echo sequence with fat suppression for posterior cruciate ligament injury were also high: sensitivity was 90-100%, and specificity 84-100% (8,11,12,17,22,25,26).

We did not have any false-positive diagnoses. According to the literature, the false-positive diagnosis of ligamentous tear may be explained by the presence of intraligamentous eosi

References


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