Oblique coronal and oblique sagittal MRI for diagnosis of anterior cruciate ligament tears and evaluation of anterior cruciate ligament remnant tissue

Title page

(a) title:

Oblique coronal and oblique sagittal MRI for diagnosis of anterior cruciate ligament tears and evaluation of anterior cruciate ligament remnant tissue

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Structured Abstract and Levels of Evidence

Background: The purpose of this study was to investigate the efficacy of additional oblique magnetic resonance imaging (MRI) for the diagnosis of anterior cruciate ligament (ACL) tear and evaluation of ACL remnant tissue.

Methods: We retrospectively reviewed the records of 54 knees. Three independent readers evaluated the MR images by the use of three methods: orthogonal sagittal images only (method A); orthogonal sagittal and additional oblique sagittal images (method B); and orthogonal sagittal and oblique coronal images (method C). The sensitivity, specificity, and accuracy for the diagnosis of an ACL tear and the detection of the condition of the ACL remnant tissue by the use of each method were calculated in comparison with arthroscopic findings as the reference standard.

Results: The arthroscopic records revealed 27 knees with intact ACLs and 27 with torn ACLs. Among the 27 knees with torn ACLs, 9 did not have continuous remnant tissue and 18 had certain remnant tissue attached to the femur or the posterior cruciate ligament. The specificities and accuracies of methods B and C for diagnosing an ACL tear were higher than those for method A. The sensitivity, specificity, and accuracy of method C for the detection of ACL remnant tissue were higher than those for method A and B.

Conclusions: Additional use of oblique MRI improved the accuracy of diagnosis of ACL tear and showed a reasonable level of efficacy in detecting ACL remnant tissue.

Level of Evidence: Level Ⅳ (case series)

Text

Introduction

Arthroscopic examination for anterior cruciate ligament (ACL) reconstruction sometimes reveals that there are several types of ACL remnant tissues bridging the femur and the tibia or the posterior cruciate ligament (PCL) and the tibia in the intercondylar notch [1,2]. Recently, ACL remnant tissue has attracted considerable attention in the treatment of ACL tears. When performing ACL reconstruction, preserving the remnant tissue is considered to be beneficial to the recovery of an ACL-deficient patient. Several factors may increase the preservation of ACL remnant tissue including increased revascularization, faster remodeling of the ACL construct, increased mechanical stability, and presence of neural mechanoreceptors and some proprioceptive innervation in the remnant tissues [1-5].

In many cases, the configuration of the ACL remnant tissue and its attachments is assessed during an arthroscopic examination just before ACL reconstruction. At the preoperative preparation, it is difficult to evaluate the state of ACL remnant tissue by conventional magnetic resonance imaging (MRI). Because of its oblique course, visualization of the complete ACL on a single image would not be expected. To achieve full-length visualization of the ligament on one or more sections, the use of oblique MRI, parallel to the long axis of the ACL has been advocated. These oblique images may be valuable for assessment of ACL remnant tissue.

The purpose of this study was to investigate the efficacy of additional oblique coronal and oblique sagittal MRI for the diagnosis of ACL tears and evaluation of ACL remnant tissue.

Materials and methods

We retrospectively reviewed the records of 54 patients (26 male and 28 female, age range: 12–66 years, mean age: 26.9 years) who had no history of previous knee surgery and underwent both MRI of the knee and arthroscopic examination between August 2010 and September 2011.

The MRI protocol included routine orthogonal sequences and two sets of oblique images. All patients were examined using a 1.5 T MRI system (Signa; GE Healthcare, Milwaukee, WI, USA). The parameters for the fast spin-echo T2-weighted orthogonal sagittal images were as follows: TR/TE = 3500/85, 4-mm slice thickness, 1-mm interval. The parameters for the oblique sagittal and oblique coronal T2-weighted images were as follows: TR/TE = 3500/85, 2-mm slice thickness, 0.5-mm interval. The oblique coronal images were obtained in the plane parallel to the course of the femoral intercondylar roof on a sagittal image for section positioning. The oblique sagittal images for visualization of an ACL were obtained in the plane parallel to the medial border of the lateral femoral condyle on an orthogonal coronal image. A single, experienced, orthopedic surgeon performed all of the arthroscopies for patients suspected of having a torn ACL or other internal derangement of the knee. During the diagnostic arthroscopy, damage to the ACL was evaluated by palpation with a probe.

MR images were reviewed retrospectively by 3 orthopedic surgeons who had at least 10 years' experience but were unaware of the clinical history, physical findings or arthroscopic findings. Each reviewer independently evaluated the MRI images using three methods: orthogonal sagittal images only (method A); orthogonal sagittal and additional oblique sagittal images (method B); and orthogonal sagittal and oblique coronal images (method C). An image that most clearly demonstrated the ACL or ACL remnant tissue was selected from each of the 3 imaging series by an experienced, orthopedic surgeon. To avoid any recall bias, MRI images were evaluated using the 3 methods separately and in a different order. The status of the ACL was graded from direct signs on MR images as intact ACL, tear with continuous ACL remnant tissue, or complete tear (i.e., tear without continuous remnant tissue).

The sensitivity, specificity, and accuracy of the diagnosis of an ACL tear and detection of the condition of the ACL remnant tissue by the use of each method were calculated in comparison with arthroscopic findings as the reference standard. The interobserver agreement was assessed by kappa (κ) statistics, and agreements in percentages were calculated for all patients. The data were analyzed using the Statistical Package for the Social Sciences (SPSS) for Windows version 19.0 (SPSS Inc., Chicago, IL, USA).

All patients were informed that data from their cases would be submitted for publication, and provided informed consent. This study was approved by the ethics committee of our university.

Results

The arthroscopic records revealed 27 patients with intact ACLs and 27 with torn ACLs. Among the 27 patients with torn ACLs, 9 did not have continuous remnant tissue (complete tear) and 18 had certain remnant tissue attached to the femur or the posterior cruciate ligament. Sensitivity, specificity, and accuracy values aiding the diagnosis of an ACL tear are summarized in Table 1, and those aiding the detection of ACL remnant tissue are summarized in Table 2. The specificities and accuracies of methods B and C for diagnosing an ACL tear were higher than those for method A. The sensitivities, specificities, and accuracies for methods B and C for the detection of ACL remnant tissue were higher than those for method A. The sensitivity, specificity, and accuracy of method C for the detection of ACL remnant tissue were higher than those for method B.

The interobserver variability for the diagnosis of an ACL tear is shown in Table 3, and interobserver variability for the detection of ACL remnant tissue is shown in Table 4. The present study showed that the highest match among readers is for method C using orthogonal sagittal and oblique coronal images.

Discussion

The diagnostic accuracy of MRI for detecting an ACL tear is over 90% in patients with positive abnormal direct signs such as discontinuity, disappearance, and changes in signal intensity on shadows of ligament (primary signs) on MR images [6,7]. Indirect signs (secondary signs) such as bone bruising, buckling of the PCL, and anterior tibial translocation further improve the accuracy [8-10]. Standard orthogonal MRI cannot visualize the complete ACL on a single image because the ACL originates from the posteromedial aspect of the lateral femoral condyle and courses through the lateral intercondylar notch. Because of artifacts from the popliteal artery and partial volume effects, a complete diagnosis of ACL injuries would not be expected (Fig. 1). Thus, poor visualization is reported in 5%–10% of normal ACL using acquired standard sagittal MRI [11].

To improve the diagnostic efficacy for ACL remnant tissue, it is necessary to achieve full-length visualization of the ACL by slicing along the plane parallel to the long axis of the ACL (Fig. 2). The ACL arises from a semicircular attachment approximately one centimeter in radius on the posteromedial corner of the medial aspect of the lateral femoral condyle, which extends backward along the anteromedial aspect of the intercondylar notch to the attachment on the intercondylar eminence of the tibia. The tibial attachment is approximately three centimeters in anteroposterior diameter [12,13]. Therefore, if the ACL remains, we are able to obtain an oblique view of it by slicing along the ACL. In case the ACL image is unclear, a bony landmark would be helpful for slicing. Diagnostic efficacy of the oblique MRI obtained in this manner has been reported in previous studies [14,15] and is consistent with our findings for the diagnosis of ACL injury.

In acute cases of injury, bleeding or edema of the fibers of an untorn ACL often cause a signal change in MRI, which makes the evaluation of ACL tears more difficult. Furthermore, patients with a fibrous scar around their ACL and those with osteoarthritis are also particularly prone to misdiagnosis using standard orthogonal MRI [14]. Even in these cases, accurate diagnosis can be achieved by full-length visualization of the ligament on one section.

Our findings showed a higher diagnostic performance and higher match rate among readers for method C compared with method B. The reasons for this are that oblique coronal images provide sections substantially perpendicular to the femoral attachment of the ACL, the medial aspect of lateral femoral condyle. These sections more clearly show the course of the ACL and its femoral attachment. In patients with an ACL tear from its femoral attachment with a continuous remnant, we observed hypotonicity of ACL fibers and their attachment to the lateral femoral condyle in a lower position than normal (Fig. 3). According to Staeubli et al., oblique coronal images oriented parallel to the intercondylar roof are an excellent method for MRI and is the imaging modality of choice to visualize clearly the diagonal anatomical course of the ACL and its relationship to the intercondylar notch and PCL [16]. Hong et al. also reported that oblique coronal images improved diagnostic accuracy of ACL injury and were effective for its grading [15]. The oblique coronal images clearly visualize the continuity, tension, and changes in width and signal intensity. Thus, oblique coronal imaging is considered to be the most useful MRI method for evaluating the condition of remnant tissue because it enables us to evaluate directly its relationship to the medial aspect of lateral femoral condyle.

The present study has some limitations that may affect the interpretation of our findings. The interval between injury or onset of symptoms and the MRI examination and between the MRI examination and arthroscopic evaluation were inconsistent. Therefore, the chronicity of an ACL tear, which may affect MRI findings, was disregarded. Another limitation is the difference in slice thickness being used in the orthogonal sagittal images (4 mm slice thickness) and in the oblique sagittal and oblique coronal images (2 mm slice thickness). In this study, we evaluated the performance of oblique MRI images only for detecting the presence of remnant tissue. Further research is necessary for the detailed evaluation of remnant tissue visualization patterns. More detailed information regarding ACL remnant tissue obtained from oblique MRI images may be helpful in making appropriate decisions for treatment of ACL injuries.

Conclusions

In conclusion, the additional use of oblique coronal and oblique sagittal MRI of the knee improved the accuracy of diagnosis of an ACL tear and showed a reasonable level of efficacy in detecting ACL remnant tissue. Oblique coronal images parallel to the femoral intercondylar roof, which clearly depict the ACL, especially in the femoral origin area, may provide further improvement in the diagnostic efficacy for ACL remnant tissue.

Conflict of interest

No conflicts of interests are declared.

Acknowledgments

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Tables with captions

Table 1

Results for the diagnosis of an ACL tear

	Sensitivity (%)	Specificity (%)	Accuracy (%)
Method A	83.9	76.5	80.2
Method B	83.9	88.9	86.4
Method C	87.7	93.8	90.7

Method A indicates orthogonal sagittal images only; Method B, orthogonal sagittal and additional oblique sagittal images; and Method C, orthogonal sagittal and oblique coronal images.

Table 2

Results for the detection of an ACL remnant

	Sensitivity (%)	Specificity (%)	Accuracy (%)
Method A	46.3	69.4	61.7
Method B	61.1	83.3	75.9
Method C	68.5	87.0	80.9

Method A indicates orthogonal sagittal images only; Method B, orthogonal sagittal and additional oblique sagittal images; and Method C, orthogonal sagittal and oblique coronal images.

Table 3

Interobserver agreement for the diagnosis of an ACL tear

		% Agreement	κ	Interpretation
Method A	Reviewer 1 vs. Reviewer 2	74	0.481	Moderate
	Reviewer 1 vs. Reviewer 3	76	0.519	Moderate
	Reviewer 2 vs. Reviewer 3	80	0.586	Moderate
Method B	Reviewer 1 vs. Reviewer 2	78	0.550	Moderate
	Reviewer 1 vs. Reviewer 3	76	0.519	Moderate
	Reviewer 2 vs. Reviewer 3	87	0.741	Good
Method C	Reviewer 1 vs. Reviewer 2	91	0.812	Almost perfect
	Reviewer 1 vs. Reviewer 3	83	0.669	Good
	Reviewer 2 vs. Reviewer 3	85	0.707	Good

Table 4

Interobserver agreement for the detection of an ACL remnant

		% Agreement	κ	Interpretation
Method A	Reviewer 1 vs. Reviewer 2	59	0.343	Poor
	Reviewer 1 vs. Reviewer 3	57	0.337	Poor
	Reviewer 2 vs. Reviewer 3	63	0.436	Moderate
Method B	Reviewer 1 vs. Reviewer 2	69	0.451	Moderate
	Reviewer 1 vs. Reviewer 3	69	0.486	Moderate
	Reviewer 2 vs. Reviewer 3	70	0.517	Moderate
Method C	Reviewer 1 vs. Reviewer 2	83	0.705	Good
	Reviewer 1 vs. Reviewer 3	69	0.494	Moderate
	Reviewer 2 vs. Reviewer 3	70	0.520	Moderate

Captions to illustrations

Fig. 1.

On standard orthogonal sagittal MRI, it is usually difficult to visualize the complete ACL on a single image. The ACL cannot be visualized throughout its entire length.

Fig. 2.

Oblique MRI parallel to the long axis of the ACL may be useful for achieving full-length visualization of the ligament on one section and valuable for its assessment. The relationship between the ACL and the lateral femoral condyle at the femoral insertion site can be viewed directly on oblique coronal images.

(A) Oblique sagittal MR image. (B) Oblique coronal MR image.

Fig. 3.

An oblique coronal MR image from patient with an ACL tear from its femoral attachment with a continuous remnant. Hypotonicity of ACL fibers and their attachment to the lateral femoral condyle in the lower position than normal can be observed (arrow heads).

Illustrations

Fig. 1.

Fig. 2.

A

Fig. 2.

B

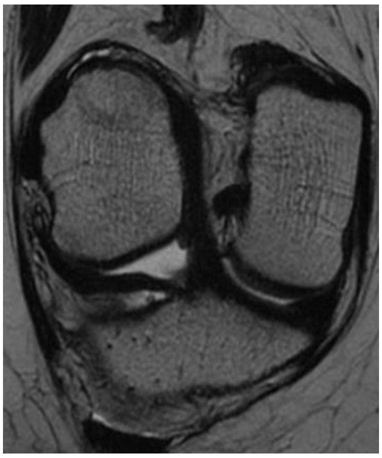

Fig. 3.