Can MRI Distinguish between a Partial Anterior Cruciate Ligament (ACL) Tear and a Normal ACL?

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Abstract: *Objective*: The purpose of this study was to determine whether Magnetic resonance imaging (MRI) can distinguish between a partial anterior cruciate ligament (ACL) tear and a normal ACL.

Materials and Methods: MR images of 20 patients with an arthroscopically confirmed partial ACL tear were retrospectively interpreted by the author, comparing with normal ACLs.

Results and Discussion: All knees with a partial ACL tear had a continuous band of low signal, of which 15 had no increased signal intensity on proton density-weighted images. MRI could not distinguish between a partial ACL tear and a normal ACL. Orthopedic surgeons had better consider an ACL tear when a patient has traumatic hemarthrosis or anxiety provoked by the sensation of the knee 'going out' or 'giving way' during the pivot shift test, even if the ACL has a continuous band of low signal on the oblique sagittal view on MRI.

Keywords: A partial anterior cruciate ligament tear, MRI, arthroscopy.

1. INTRODUCTION

Anterior cruciate ligament (ACL) injuries are among the most frequent injuries of the knee, and they have been reported to occur with an incidence of 8.1/100,000 per year [3]. This is probably under-estimated, because this incidence refers only to patients treated surgically, and there is no consensus on the definition of a partial ACL tear. A subset of patients with partial ACL tears suffer persistent pain and disability and are prone to both re-injury and progression to complete ligamentous deficiency [7, 8, 11, 13, 14]. Therefore noninvasive diagnosis of this injury might identify patients who would benefit from early intervention. Magnetic resonance imaging (MRI) has become an essential tool for the evaluation of complete ACL injuries, with high degrees of accuracy and sensitivity reported in the literature [2, 4]. However, MRI evaluation of partial ACL tears has received little attention in the radiologic literature [6, 18, 19]. A case-control study comparing MRI findings in patients with arthroscopically proven partial ACL tears with those in patients with normal ACLs was performed. The purpose of this study was to determine whether MRI can distinguish between partial ACL tears and normal ACLs.

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2. MATERIALS AND METHODS

Between 2006 and 2014, preoperative MRI of the knee was obtained in all 254 patients who underwent arthroscopic surgery by a single surgeon (YM) at our hospital. Their operative reports were likewise available. Arthroscopic results are currently considered to be the gold standard for diagnosing partial ACL tears. After review of the arthroscopic reports, each ACL was classified as normal, partial tear, or complete tear. The definition of a partial ACL tear is at least one bundle was in continuity and was potentially functional as judged by palpation with a probe and arthroscopic anterior drawer testing. There were 198/254 complete ACL tears, 20/254 partial ACL tears (Group P), and 36 normal ACLs. All of the partial tears were in the posterolateral (PL) bundle (Figure **2b, c**). Twenty arthroscopically proven normal ACLs were randomly selected as a control group (Group N). Group P included 10 men and 10 women, with a mean age of 24 years (standard deviation (SD), 10 years). Group N included 13 men and 7 women, with a mean age of 51 years (SD, 16 years). All patients in Group P had only one injury. Fifteen patients in Group P had an acute hemarthrosis of the knee, and three patients had a history of blood aspiration. Two patients in Group P did not undergo aspiration because their knee had no effusion. Two patients in Group P had a popping sensation at the time of injury. The mean interval between injury and MRI evaluation was 8 days (SD 7 days). Group N included 17 patients with medial

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meniscus tears and 3 patients with lateral meniscus tears. In Group N, there were 3 patients with an injury. None of them had a popping sensation at the time of injury. The mean interval between injury or onset of pain and MRI evaluation was 22 days (SD 22 days). Lachman's test was negative in 7 patients and 1+ (less than 5mm) in 13 patients in Group P. All patients in Group P felt anxiety with a sensation of the knee 'going out' or 'giving way' during the pivot shift test. Lachman's test was negative in all patients in Group N, and none of them felt anxiety during the pivot shift test.

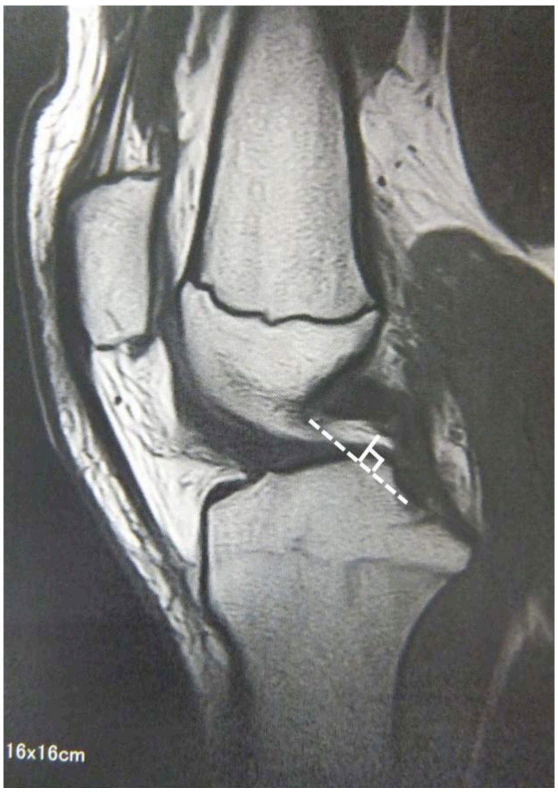

Figure 1: Curvature of the PCL. The distance between the anterior most tibial and femoral insertion points of the PCL is indicated by line *y* (dashed line). At the point of greatest curvature, a second line, *x* (short, solid line), is drawn to the inferior surface of the PCL, perpendicular to line *y*. The PCL curvature value is defined as the length of line *x* divided by the length of line *y*.

Proton density-weighted, T1 and T2-weighted sagittal fast spin echo images of the two groups were retrospectively reviewed by the author (YM) with attention to the primary and secondary signs of an ACL tear. Axial images were not included in this study. The primary signs of an ACL tear include discontinuity of the low signal band, abnormal axis of the ligament (any deviation of the ligament from the expected course), and focal or diffuse increased signal intensity on proton density-weighted sagittal images. The secondary signs of an ACL tear include a bone bruise with T2 star-weighted coronal images, a fluid sign on proton density-weighted sagittal images, and PCL curvature on T1-weighted sagittal images. The PCL curvature value was defined according to Tung [17] as x/y, where y represents the distance between the anteriormost tibial and femoral insertion points of the ligament, and x represents the maximal distance of the perpendicular line drawn between line y and the undersurface of the PCL, measured on T1-weighted sagittal images (Figure **1**). The data were analyzed by Student's *t*-test, with the level of significance set at $p < 0.05$.

Interpretations of MRI were also performed by two experienced radiologists, neither of whom had prior knowledge of the arthroscopic findings or the original MR interpretations. Interpretations were performed individually on two separate days using a standardized score sheet defining the ACL as either intact, partially torn, or completely torn. MRI diagnoses of partial ACL tears were compared to the arthroscopic reports. Inter- and intraobserver variabilities were determined using the kappa statistic, comparing the diagnostic consistency of each of the two readers both with himself, using two readings on separate days, and with each separate interpretation by the other radiologist. Kappa values above 0.75 denote excellent agreement, 0.60-0.75 denotes good agreement, 0.60-0.40 is fair agreement, and below 0.40 is poor agreement [9].

MRI examinations of the knee were performed with 1.5-T magnets (Excelart Vantage, Toshiba) using a dedicated knee coil. The imaging parameters included 2000/18 (TR/TE excitations), fast spin echo, slice thickness 2.0mm, gap 0.4mm, 14cm x 14cm field of view, and matrix 224 x 416. The proton-density-weighted oblique sagittal images were obtained in the plane parallel to the ACL.

The study was approved by the institutional review board, and informed consent was obtained from all patients.

3. RESULTS

3.1. Primary Signs (Table 1)

All knees in Group P had a continuous low signal band, and 15 knees did not have increased signal intensity on proton density-weighted images (Figure **2a**, Figure **3**). All knees in Group N also had a continuous low signal band with no increased signal intensity. An abnormal axis on proton density-weighted images was noted in only two knees in Group P (Figure **4**) and no knees in Group N.

Table 1: Primary Signs of an ACL Tear

	Proton Density-Weighted Image		
	Discontinuity	**Abnormal Axis**	**Increased Signal**
Partial Tear	0 / 20	2 / 20	5 / 20
Normal ACL	0 / 20	0 / 20	0 / 20

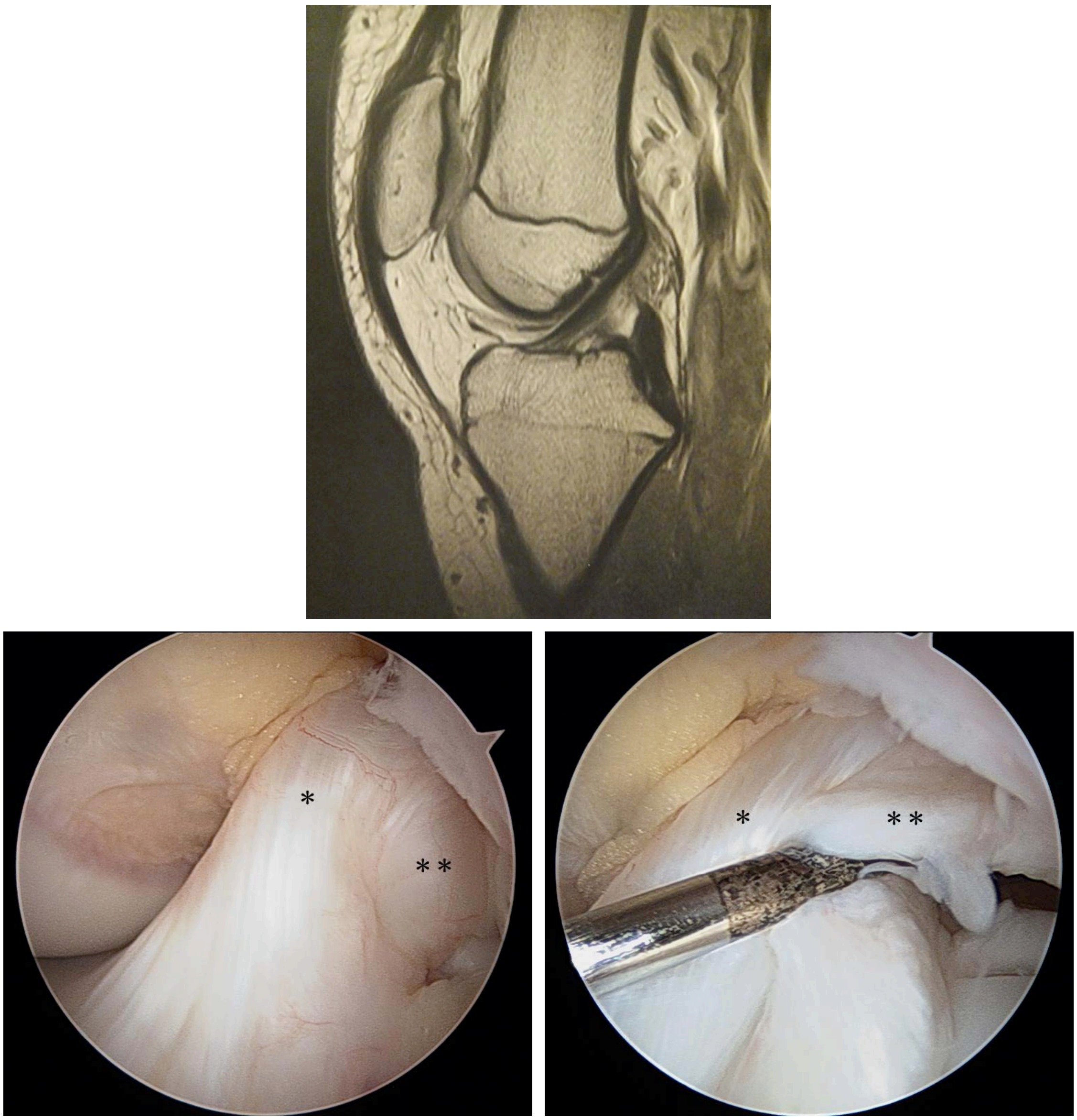

Figure 2: A 14-year-old male with a partially torn ACL proven on arthroscopy. **A**. MR image: The proton density-weighted oblique sagittal image shows the continuous low signal band of the ACL. **B**. Arthroscopic images 71 days after the injury. The arthroscopic image shows that the ACL is continuous. *: Anteromedial (AM) bundle. **: PL bundle. **C**. The arthroscopic image shows that the PL bundle is not functional, whereas the AM bundle is functional, with a probe during the anterior drawer stress test. *: AM bundle. **: PL bundle.

3.2. Secondary Signs (Table 2)

A bone bruise was noted in 3 (15%) knees in Group P and no knees in Group N. A bone bruise was noted in the middle third of the lateral femoral condyle (Figure **5**). Fluid signs were noted in 18 knees (90%) in Group P (Figure **3**) and 10 knees (50%) in Group N. The PCL curvature value was 0.19 (SD 0.1) in Group P and 0.16 (SD 0.1) in Group N; there was no significant difference between the two groups (p = 0.25).

Table 2: Secondary Signs of an ACL Tear

	Bone Bruise	Fluid Sign	PCL Curvature Value
Partial Tear	3/20	18/20	0.16 (SD0.1)
Normal ACL	0/20	10/20	0.19 (SD0.1)

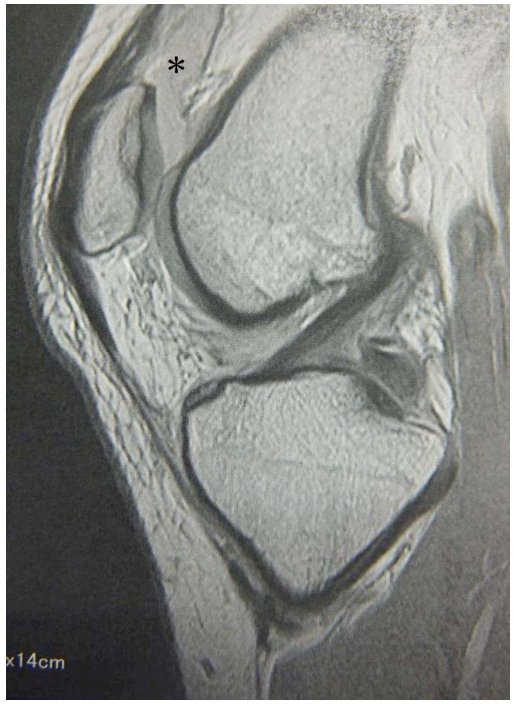

Figure 3: MR image of the knee of a 17-year-old female with a partially torn ACL proven on arthroscopy. This image shows a continuous low signal band of the ACL with the fluid sign. *: hemarthrosis.

Figure 4: MR image of the knee of a 24-year-old female with a partially torn ACL proven on arthroscopy. This image shows an abnormal axis on proton density-weighted images of the ACL.

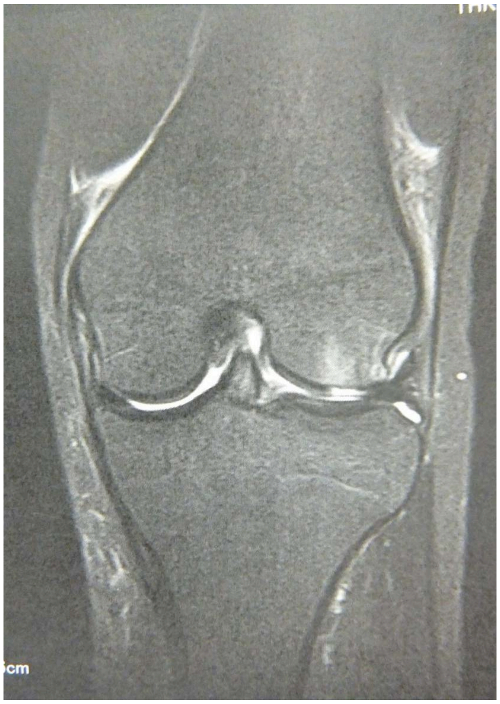

Figure 5: MR image of the knee of an 18-year-old female with a partially torn ACL proven on arthroscopy. This image shows a bone bruise in the middle third of the lateral femoral condyle.

3.3. Interpretations by Two Radiologists (Table 3, 4)

MRI interpretations of the two radiologists are summarized in Table **3**. In Group P, 75% were interpreted as intact, 25% partially torn, and 0% completely torn. In Group N, all knees were interpreted as intact. Kappa values for both inter- and intraobserver interpretations ranged from 0.06 to 0.68 (Table **4**).

4. DISCUSSION

A partial ACL tear is defined differently by various researchers, and no universal definition is available at the moment. Noyes *et al.* [11] defined partial ACL tears as those with less than 75% tearing, good tension in the remaining intact portion, and a negative pivot shift test. Barrack *et al.* [1] used the following criteria: 1) a significant portion of at 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's test scored zero or 1+(less than 5mm); and 3) the pivot shift was negative or only trace-positive. Lehnert *et al.* [7] defined as partial ACL

Table 3: MRI Interpretations by Two Radiologists of Group P and Group I

Group P			
	Intact	**Partial Tear**	**Complete Tear**
Radiologist A First	16/20	4/20	0/20
Radiologist A Second	12/20	8/20	0/20
Radiologist B First	16/20	4/20	0/20
Radiologist B Second	16/20	4/20	0/20
Group I			
	Intact	**Partial Tear**	**Complete Tear**
Radiologist A First	20/20	0/20	0/20
Radiologist A Second	20/20	0/20	0/20
Radiologist B First	20/20	0/20	0/20
Radiologist B Second	20/20	0/20	0/20

Table 4: Inter- and Intraobserver Variabilities of the Interpretations

	Versus Reader	**Kappa Value**
Radiologist A First	Radiologist A Second	0.63
Radiologist A First	Radiologist B First	0.06
Radiologist A First	Radiologist B Second	0.06
Radiologist A Second	Radiologist B First	0.39
Radiologist A Second	Radiologist B Second	0.39
Radiologist B First	Radiologist B Second	0.68

tears those injuries in which one-quarter to three-quarters of the ligament were torn. My criteria for the definition of partial ACL tear is 1) at least one bundle is in continuity and is potentially functional as judged by palpation with a probe and arthroscopic anterior drawer testing, 2) the Lachman's test scored zero or 1+ (less than 5mm), and 3) a patient feel anxiety with a sensation of the knee 'going out' or 'giving way' during the pivot-shift test. Although partial ACL tears are thought to have a better prognosis [1], long-term follow-up results are controversial in terms of the frequency of ACL-deficient knee, ranging from 14% to 56% [1, 5, 7, 13]. These differences may be due to differences in the patient population, the amount of ligament tearing, the presence or absence of other ligament injuries, and differences in the rehabilitation program [11].

The present study has four main limitations. First, the number of enrolled patients was relatively small, including only 20 patients with partial ACL tears. However, Van Dyck *et al*. [19] reported that partial ACL tears were found infrequently (51 partial ACL tears/690 ACL tears). The present study showed a similar tendency (20 partial ACL tears/214 ACL tears). Second, MRI and arthroscopic reports were evaluated once by an experienced orthopedic surgeon. Third, although knees in Group N had normal ACLs, they were not completely normal knees. From the ethical perspective, arthroscopy could not be performed for a normal knee. Fourth, all partial ACL tears were shown to involve the PL bundle; partial tears of the AM bundle might have little rotational instability and might have been treated conservatively.

A high degree of ACL tear was found in knees with traumatic hemarthrosis, ranging from 72% to 80% [5, 12]. Information relative to intra-articular blood accumulation is also a vital part of the history. The presence of a hemarthrosis or a history of blood aspiration by another doctor strongly suggests that one of the major ligaments may have been disrupted [10]. In the present study, 90% of Group P had hemarthrosis or a history of blood aspiration after injury. These were aids in the diagnosis of ACL tear.

Concerning the medical examination, the pivot-shift test is a special joint test to detect the characteristic instability of an ACL tear. In the present study, all patients in Group P felt anxiety with a sensation of the knee 'going out' or 'giving way' during the pivot-shift test. These findings also suggested an ACL tear.

While conventional MRI has a sensitivity of 92-96% and a specificity of 92-98% for the diagnosis of complete tears [15, 16], accuracy in diagnosing a partial tear in this present study was low. Agreement of both inter- and intraobserver interpretations in this study was also relatively low, with 4 cases of poor agreement and 2 cases of good agreement. These results indicate that diagnosing a partial ACL tear with MRI is very difficult. Van Dyke *et al*. evaluated the use of 3-T MRI and concluded that the diagnosis of partial tears was difficult [19]. Lefevre *et al*. also concluded that the diagnostic performance of 2D-MRI was poor for partial ACL tears and recommended evaluation with 3D-FSE-Cube MRI [6]. We hope that we will be able to diagnose partial ACL tears using 3D-MRI, but it is not yet commonly used.

The present results show that MR evaluation of partial ACL tears is not sufficiently sensitive to establish the diagnosis without arthroscopy. Thus, we concluded that MRI could not distinguish between partial ACL tears and normal ACLs. Orthopedic surgeons had better consider an ACL tear when a patient has traumatic hemarthrosis or anxiety provoked by the sensation of the knee 'going out' or 'giving way' during the pivot shift test, even if the ACL has a continuous band of low signal on the oblique sagittal view on MRI.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

None.

ETHICAL APPROVAL

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

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