

Comparison of magnetic resonance imaging for patients with acute and chronic anterior cruciate ligament tears

Bin Xu, MM, Hanyuan Zhang, MM*, Bo Li, MM, Weichao Wang, MM

Abstract

To compare the direct and indirect signs on magnetic resonance imaging (MRI) for patients with acute and chronic anterior cruciate ligament (ACL) tears.

Two independent reviewers retrospectively evaluated the MRI images of 377 patients with ACL tear confirmed by arthroscopy. There were 160 cases with acute ACL tear and 217 cases with chronic ACL tear. Direct signs in T1- and T2-weighted images and indirect signs including meniscus injury, the collateral ligament injury, cartilage damage or osteoarthritis, kissing contusion, Notch syndrome and abnormal posterior cruciate ligament (PCL) and other indirect signs were evaluated.

For direct signs on MRI, no significant differences were found between the acute and chronic ACL tear in prevalence of focal high signal in substance of T2-weighted images and in that of abnormal orientation, discontinuity, thickening, or focal masses in substance of T1-weighted images. However, higher incidence of diffuse high signal of T2-weighted images for acute ACL tear was found compared to that for chronic ACL tear (55.0% vs 3.2%). For indirect signs on MRI, the collateral ligament tear (20.6% vs 2.3%), cartilage damage or osteoarthritis (14.4% vs 25.8%), kissing contusion (57.4% vs 0%), Notch syndrome (28.1% vs 3.2%), and bowing type of PCL (33.1% vs 47.0%) can differentiate the acute from chronic ACL tear.

Some direct and indirect signs on MRI are closely related to the acute and chronic ACL tear.

Abbreviations: ACL = anterior cruciate ligament, ADT = anterior drawer test, MRI = magnetic resonance imaging, PCL = posterior cruciate ligament, PST = pivot shift test.

Keywords: acute and chronic anterior cruciate ligament tear, direct signs, indirect signs, magnetic resonance imaging

1. Introduction

Anterior cruciate ligament (ACL) tear is one of the most common diseases in sports injuries,^[1,2] but it has a high rate of missed diagnosis due to a period of time bracing, relief of pain after the disappearance of hematoma and the limitation of the examination methods. If not timely treated, ACL tear can cause the joint instability, consequently leading to the cartilage degeneration, meniscus tear and even the occurrence of osteoarthritis.^[3] Thus, it is very important for the diagnosis of ACL tear, and the

distinction between acute and old ACL tear is more important for the better clinical treatment.

Magnetic resonance imaging (MRI) is the preferred imaging technique to evaluate the intact, ruptured, or healed ACL and is reliable in the evaluation of acute ACL ruptures.^[4] MRI provides good image evidence before arthroscopy examination.^[5] Direct signs on MRI for patients with ACL tear include focal or diffuse high signal intensity within the substance of the ACL on T2-weighted images as well as the lack of continuity of the ACL.^[6,7] The use of indirect signs of ACL was advocated to improve accuracy and numerous indirect signs have been described. These include orientation of the ACL, bone contusions and osteochondral fractures, posterior cruciate ligament (PCL) line, PCL angle, PCL bowing, and posterior displacement of the lateral meniscus.^[8–10] The definitions of these signs are listed as following. Kissing contusion refers to the bone contusions in both femoral and tibial surfaces of the knee.^[10] Notch syndrome refers to the enlarged and deepened lateral femoral condyle.^[11] Anterior displacement of tibia refers to increased distance from the posterior cortex of the lateral tibial plateau to the posterior cortex of the femur.^[12] Blumenseat angle is the angle that is formed by the lines between the line of the femoral condyle groove and the distal part of the ACL.^[13] The PCL angle was the angle measured between a line through the center of the proximal and a line through the distal portion of the PCL.^[14] Second fracture refers to the avulsion fracture of the anterior lateral tibial plateau.^[15]

This retrospective study aimed at analyzing the direct and indirect signs on MRI to compare the acute and chronic ACL tear

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Department of Sports Medicine and Arthroscopic Surgery, The First Affiliated Hospital of Anhui Medical University, Hefei, China.

* Correspondence: Hanyuan Zhang, Department of Sports Medicine and Arthroscopic Surgery, The First Affiliated Hospital of Anhui Medical University, Hefei, China (e-mail: marklee687@126.com).

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for improving the accurate diagnosis of ACL tear and providing the imaging evidence for the effective treatment.

2. Materials and methods

2.1. Demographic data and clinical details of patients

We obtained approval and a waiver of patient informed consent from our institutional review board for this retrospective study. We reviewed a database of 377 knee MRI examinations performed between August 2013 and August 2016 in Department of Sports Medicine and Arthroscopic Surgery, The First Affiliated Hospital of Anhui Medical University. All patients were confirmed to have ACL tear under arthroscopy and underwent ACL reconstruction. Among them, 160 cases underwent MRI within 6 weeks with an average of 3.2 weeks (range: 1 to 47 days) after tear (acute ACL tear) and 217 cases underwent MRI more than 6 weeks with an average of 1.3 years (range: 11 week to 10 years) after tear (chronic ACL tear).

2.2. MRI examination

MRI Scanner (Signa HDxt 3.0T, GE Company, Louisville, Kentucky) was used in this study. The knee joint of patient is naturally straight and in the relaxed posture. The MRI image parameters were knee coil (QUADKNEE), sagittal T1WI (TR/TE 460 ms/10 ms), T2WI (TR/TE 2000 ms/45 ms), STIR (TR/TE 2000 ms/30 ms), FOV (16 × 16 cm), matrix (320 × 224) and thickness/distance of layer (4 mm/1 mm). The MRI examinations were read independently by 2 musculoskeletal fellowship-trained radiologists who were blinded to both the original MRI interpretation and the arthroscopic findings. Each MRI study was reviewed by the radiologists twice at 2 different sittings spaced 1 week apart. Image analysis was done by 2 reviewers with interobserver agreement.

2.3. Protocol

The direct and indirect signs on MRI were analyzed using the PACS workstation. Direct signs of ACL tear included the thickening low signal and diffuse high signal as well as thinned low signal and local high signal within the substance of the ACL on T2-weighted images, and the disruption of fascicles, discontinuity, thickening, or local mass within the substance of the ACL on T1-weighted images. Indirect signs of ACL tear included the meniscus tear, lateral collateral ligament tear, osteoarthritis, kissing contusion, femoral bone notch, anterior displacement of tibia, meniscus injury, posterior displacement of the lateral meniscus, abnormal Blumenseat angle, abnormal PCL including arch syndrome, abnormal wave syndrome, PCL line, PCL angle and PCL index, and Segond fracture. Posterior displacement of the lateral meniscus was measured as displacement of the posterior horn of the lateral meniscus behind the most posterior margin of the tibial plateau.^[13]

2.4. Statistical analyses

Categorical variables are presented as the number (%), while numerical variables are presented as the mean (range). Comparisons were performed using Chi-square tests for categorical variables and independent-samples *t* tests for numerical variables respectively. A *P*-value ≤ .05 was considered statistically significant.

Table 1

Demographic data of patients.

Item	Acute ACL tear (n = 160)	Chronic ACL tear (n = 217)	<i>P</i>
Male	117 (73.1%)	157 (72.4%)	.505
Female	43 (26.9%)	60 (27.6%)	.496
Age (range), y	31.2 (14–55)	32.2 (13–55)	.348

Categorical variables are presented as the number (%), while numerical variables are presented as the mean (range). Comparisons were performed using Chi-square tests for categorical variables and independent-samples *t* tests for numerical variables respectively. A *P*-value ≤ .05 was considered statistically significant.

ACL = anterior cruciate ligament.

3. Result

The demographic data showed no significant differences in mean ages (31.2 vs 32.2 years) and ratio of male to female (2.7 vs 2.6) between the patients with acute and chronic ACL tear respectively (Table 1).

As shown in Table 2, for direct signs in MRI, no significant differences were found between the acute and chronic ACL tear in the prevalence of focal high signal in substance on T2-weighted images and in that of abnormal orientation, discontinuity, thickening, or local masses in substance on T1-weighted images. However, higher prevalence of diffuse high signal on T2-weighted images for acute ACL tear was found compared to that for chronic ACL tear (55.0% vs 3.2%). For indirect signs in MRI, the lateral collateral ligament tear (20.6% vs 2.3%), cartilage damage or osteoarthritis images from MRI (14.4% vs 25.8%), kissing contusion (57.4% vs 0%), edema (14.4% vs 4.6%), Notch (28.1% vs 3.2%), and bowing type of PCL (33.1% vs 47.0%) can differentiate the acute and chronic ACL tear (Table 2). These results suggested that some direct and indirect signs in MRI are closely related to the acute and chronic ACL tear.

4. Discussion

Ultrasound is a reliable, noninvasive method for diagnosing injuries to the tendons, ligaments, and muscles of the knee. It is important to recognize the limitations of this method for examining the menisci and bony lesions.^[16] MRI is the preferred imaging technique to evaluate the intact, ruptured, or healed ACL and is reliable in the evaluation of acute ACL ruptures.^[4]

In the present study, we compared the direct and indirect signs on MRI for patients with acute and chronic ACL tears and found that, for direct signs, higher prevalence of diffuse high signal of T2-weighted images occurred in acute ACL tear compared to that in chronic ACL tear. For indirect signs in MRI, the lateral collateral ligament tear, cartilage damage, or osteoarthritis images from MRI, kissing contusion, edema, Notch syndrome, and bowing type of PCL can be used as predictors for the acute and chronic ACL tear.

Single beam tear in ACL, namely partial tear, is frequently misdiagnosed mainly due to the continuous signal of ACL in MRI sagittal and coronal images as well as the false negative presentation in the anterior drawer test (ADT), Lachman test and pivot shift test (PST).^[17,18] In addition, the fact that the torn ACL attaches to the PCL and maintains the partial function makes it difficult to be correctly diagnosed during the routine physical examination.^[19] Therefore, analysis of multiple signs at MRI might be of value for the diagnosis of acute and chronic ACL tear.

Table 2
Comparison of signs on MRI between acute and chronic ACL tear.

Item	Acute ACL tear (n=160)		Chronic ACL tear (n=217)		P
	n	%	n	%	
T2-weighted images					
Diffuse high signal	88	55.0	7	3.2	<.001
Focal high signal	72	45.0	111	51.2	.273
T1-weighted images					
Abnormal orientation	40	25.0	60	27.6	.374
Discontinuity	35	21.9	38	17.5	.229
Thickening or local masses	77	48.1	111	51.2	.403
Meniscus injury	95	59.4	121	55.8	.390
Medial	39	24.4	62	28.6	.282
Lateral	44	27.5	46	21.2	.161
Both	12	7.5	13	6.0	.366
Collateral ligament injury	33	20.6	5	2.3	<.001
Medial	26	16.3	4	1.8	<.001
Lateral	4	2.5	0	0	.034
Both	3	1.9	1	0.5	.045
Kissing contusion	87	54.4	0	0	<.001
Bone marrow edema	23	14.4	10	4.6	.002
Notch syndrome	45	28.1	7	3.2	<.001
Alone	4	2.5	0	0	.034
Combined with kissing contusion	41	25.6	0	0	<.001
Anterior displacement of tibia	38	23.8	58	26.7	.349
Posterior displacement of meniscus	18	11.3	20	9.2	.338
Abnormal Blumenseat angle	40	25.0	60	27.6	.374
Abnormal posterior cruciate ligament (PCL)	61	38.1	129	59.4	.011
Bowing	53	33.1	102	47.0	.047
Wavy	18	11.3	27	12.4	.442
Segond fracture	1	0.6	0	0	.426
Cartilage damage or osteoarthritis	23	14.4	56	25.8	.018
Patellofemoral joint	21	13.1	27	12.4	.490
Tibiofemoral joint	10	6.3	13	6.0	.544
Both	6	3.8	16	7.4	.118

Data are presented as the number (%). Comparisons were performed using Chi-square tests. A P-value ≤.05 was considered statistically significant. ACL=anterior cruciate ligament, MRI=magnetic resonance imaging, PCL=posterior cruciate ligament.

Many studies showed the various indirect signs of ACL tear on MRI.^[20,21] According to the features of the mechanism, we divided these indirect signs into the following groups: accompanied symptoms (meniscus tear, lateral collateral ligament tear and Segond fracture, etc.); axis shift type bone contusion (kissing contusion, Notch syndrome and bone marrow edema, etc.); anterior displacement of tibia (anterior displacement of tibia and posterior displacement of meniscus, etc.); abnormality of PCL (bowing syndrome, wavy syndrome, abnormal PCL line, PCL angle, and PCL index, etc.); and degenerative changes (exfoliative cartilage and osteoarthritis, etc.).

In this study, we showed that among direct signs on T1- and T2-weighted images, diffuse high signal on T2-weighted image was the strong predictor for acute ACL tear rather than chronic ACL tear (55% vs 3.2%). However, no differences in other direct signs including abnormal orientation and discontinuity were found between acute and chronic ACL tears. These results are consistent with the report from Fadale and coworkers^[22] showing the similar prevalence (58% vs 15%) of diffuse high signal for acute and chronic ACL tears, respectively. These studies suggested that diffuse high signal is valuable for differentiating the acute from chronic ACL tears. Robertson et al^[23] reported that the discontinuity and abnormal orientation on the MRI had higher sensitivity and specificity in the diagnosis

of ACL. We did not find the differences in discontinuity and abnormal orientation between acute and chronic ACL tears, implying that these 2 signs can be used for the diagnosis of ACL rather than for the differentiation of acute from chronic tears.

Injuries of the meniscus is frequently associated with ACL tears.^[24] The present study showed that 59.4% of meniscus seen in acute ACL tear were associated with tears of the medial meniscus (24.4%), lateral meniscus (27.5%), or both (7.5%) and 55.8% of meniscus seen in chronic ACL tear were associated with tears of the medial meniscus (28.6%), lateral meniscus (21.2%), or both (6.0%) respectively. This high incidence of meniscal tears is similar to that reported in other series when arthroscopy or MRI was used to diagnose meniscal tears. However, no difference in each corresponding incidence was found between acute and chronic ACL tears. This is not consistent with that reported by Fadale and coworkers^[22] showing that 78% incidence of meniscal tears in the 27 cases of chronic ACL tear compared with a 40% incidence in the 60 cases of acute ACL tears. The reason for this discrepancy remains unknown and needs further investigation.

Collateral ligament injury is also associated with ACL tears.^[17-19] The present study showed that 20.6% of collateral ligament injury seen in acute ACL tear were associated with tears of the medial collateral ligament (16.3%), lateral collateral

ligament (2.5%), or both (1.9%) and 2.3% of collateral ligament injury seen in chronic ACL tear were associated with tears of the medial collateral ligament (1.8%), lateral collateral ligament (0%), or both (0.5%) respectively. Statistical analysis showed the differences in each corresponding incidence between acute and chronic ACL tears. These results suggested that collateral ligament injury is useful for the differentiation diagnosis of acute and chronic ACL tears.

Bone contusion is a direct result of the mechanism of ACL disruption.^[21] In this study, we found that the incidences of kissing contusion (54.4% vs 0%), edema (14.4% vs 4.6%), and Notch syndrome (28.1% vs 3.2%) in acute ACL tear are higher than that in chronic ACL tear, suggesting that these indirect signs of MRI can be the strong predictors of acute and chronic ACL tears. However, we did not find the differences in anterior displacement of tibia, posterior displacement of meniscus and abnormal Blumenseat angle between acute and chronic ACL tears, suggesting the less value of these signs for distinguishing diagnosis of acute and chronic ACL tears.

Abnormal PCL including bowing and wavy was assessed in both acute and chronic ACL tears.^[11] The results showed that the incidences of bowing (33.1% vs 47%) instead of wavy (11.3% vs 12.4%) can be as the predictor for distinguishing diagnosis of acute and chronic ACL tears. ACL tear accelerates the occurrence of cartilage damage or osteoarthritis.^[2] This study showed that the incidence of cartilage damage or osteoarthritis (14.4% vs 25.8%) in acute ACL tear was lower than that in chronic ACL tear, which may be related to the secondary intercondylar notch or osteophyma proliferation due to the non-steady state. Velázquez-Saornil et al^[25] found that supplementing the rehabilitation protocol of surgically reconstructed ACL rupture patients with quadriceps vastus medialis TrP-DN increases ROM (short-term) and functionality (short- and mid-term) and that this is accompanied by an immediate increase in pain intensity.

There are some limitations in the present study. One is that we did not consider the age factor as an independent factor and did not do the statistical analysis regarding the effect of age-dependent degeneration on the acute and chronic ACL tears. Another is that we did not compare the patients with ACL tear with normal control. Therefore, practical value needs to be evaluated in the future.

In summary, higher prevalence of diffuse high signal of T2-weighted images occurred in acute ACL tear compared to that in chronic ACL tear. The collateral ligament tear, cartilage damage or osteoarthritis, kissing contusion, edema, Notch syndrome, and bowing type of PCL can be used as predictors for the acute and chronic ACL tear.

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