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

Minoru Yamato[1)]　Tsuneo Yamagishi[2)]

1) Department of Radiology, Dokkyo University, School of Medicine
2) Department of Orthopedic Surgery, Kyosai Aoyama Hospital

MRIにより前十字靭帯の急性部分断裂と完全断裂の鑑別は可能か？

大和　実[1)]　山岸　恒雄[2)]

MRIによる前十字靭帯の部分断裂と完全断裂の鑑別が可能か否かにつき検討を行った．

受傷後6週以内にMRI，関節鏡を行い，前十字靭帯の部分断裂と診断された8例(男性2，女性6)を対象とした(部分群)．後十字靭帯断裂合併例は除外した．また同様にMRIで前十字靭帯断裂と診断され，受傷後6週以内に関節鏡で確認された完全断裂例(N＝14)を完全群，関節鏡で正常前十字靭帯の確認された例を正常群(N＝10)として，部分断裂群と比較した．プロトン密度，T2強調矢状断像について前十字靭帯断裂の直接所見(連続性，走行，信号強度の変化)と間接所見(bone bruise，脛骨外側顆後縁の大腿骨外顆後縁に対する前方移動量，PCL curvature value)の有無を検討した．使用装置は1.5T超伝導装置である．

直接所見：部分群ではプロトン密度像では全例靭帯の連続性はなく，走行の異常，信号強度の上昇が見られたが，全く低信号帯の消失した例はなかった．T2強調像では8例中4例で靭帯の連続性が保たれており，信号強度の上昇があったのは3例であった．完全群中，7例でプロトン密度像上全く低信号帯が消失しており，T2強調像で連続性の保たれた例はなかった．また全例T2強調像で信号強度の上昇を認めた．関節所見：bone bruiseは部分群の5例，完全群の6例に見られた．脛骨外側顆の大腿骨外顆後縁に対する前方移動量は正常群と完全群の間にのみ有意差(危険率5%)を認めた．

プロトン密度矢状断像では前十字靭帯の急性部分断裂を正常靭帯と鑑別することは容易であったが，完全断裂との鑑別は困難である．T2強調像で靭帯の連続性が保たれていることが部分断裂を示唆する所見である．

Research Code No. : *505.9*

Key words : *Knee ligaments, Injury, Tibia, MR imaging*

Received Mar. 1, 1995 ; revision accepted Jun. 7, 1995

1) 獨協医科大学放射線科
2) 都共済青山病院整形外科

INTRODUCTION

Partial anterior cruciate ligament (ACL) tear has been recognized for many years[1),2)]. It is generally treated conservatively because prognosis is considered better than complete tear[3)], 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 tear[4),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 medial records and it was included in the criteria to exclude cases with only few fibers of ligament remaining intact. Those who underwent arthroscopy over six weeks following trauma and those with concomitant posterior cruciate ligament (PCL) tear were excluded. There were fourteen MR examinations in fourteen patients with

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 midsagittal 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 y represents the distance between the anteriormost tibial and femoral insertion points of the ligament and x represents the maximal distance of a perpendicular line drawn between line y and the undersurface 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, 93 (turbo spin echo), slice thickness 4 to 5 mm, gap 0-1 mm, 14-16 cm field of view and matrix 192 or 256 × 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 lack 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. Noyes et al[8] 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[3] used 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 test scored zero or 1+ (less than 5mm); 3) the pivot shift was negative or only trace-positive. Lehnert et al[9] 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 functional, 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.

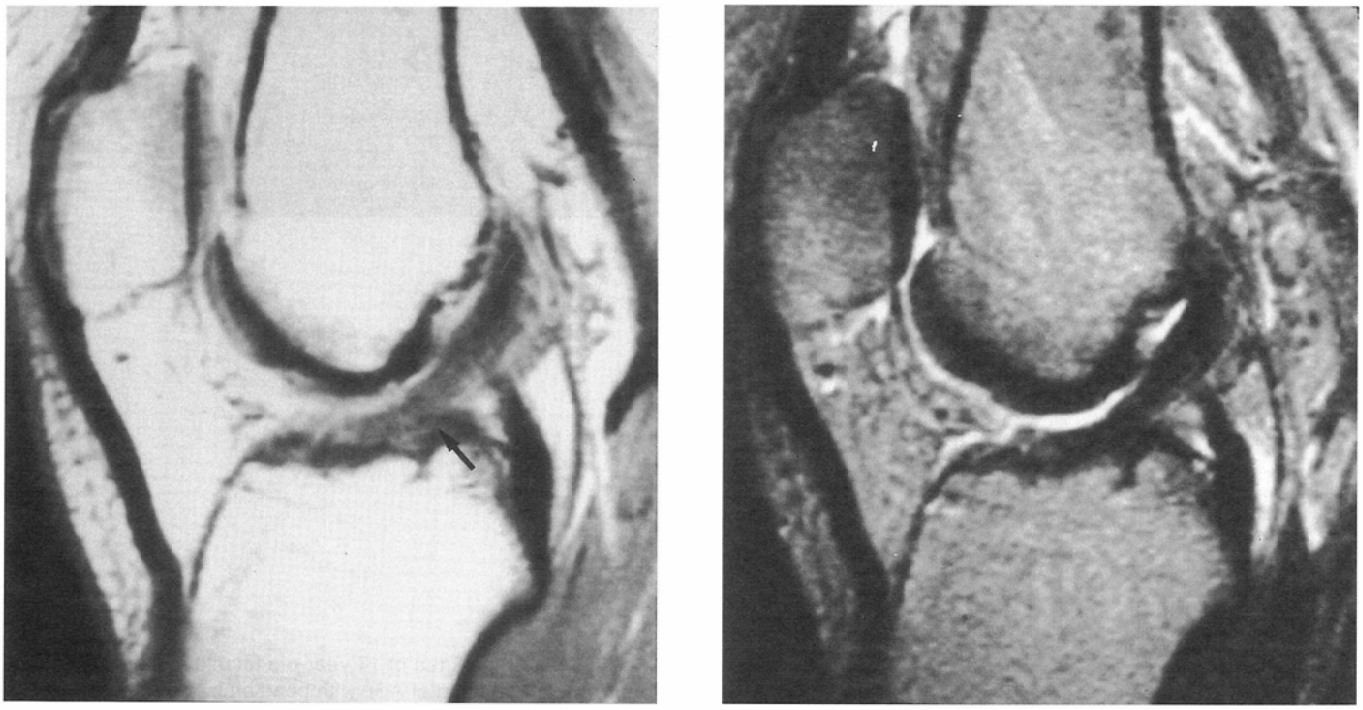
Although partial tears are thought to have better prognosis[3], long-term follow-up results are controversial in terms of frequency of ACL deficient knee, ranging from 14 to 56%[8)-10)]. These differences may account for difference in patient population, amount of ligament tearing[8], presence or absence 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 increase in 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 liga-

Table 1 Primary signs of ACL tear

	proton density-weighted image			T2-weighted image		
	discontinuity	abnormal axis	increased signal	discontinuity	abnormal axis	increased signal
partial tear	8/8	8/8	8/8	4/8	8/8	3/8
complete tear	14/14 (NV6)*	13/14	14/14	14/14	13/14 (NV4)*	14/14
control	0/10	0/10	0/10	0/10	0/10	0/10

* Numbers in parentheses indicate cases with non-visualized low signal band of the ligament



(A) (B)

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.

ment. 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 depicted 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

	bone bruise	anterior translocation of the tibia	PCL curvature value
partial tear	5/8	4.3(3.6)mm	0.18(0.07)
complete tear	6/14	6.1(4.4)mm	0.21(0.08)
control	0/10	0.78(3.6)mm	0.18(0.5)

Numbers in parentheses indicate one standard deviation

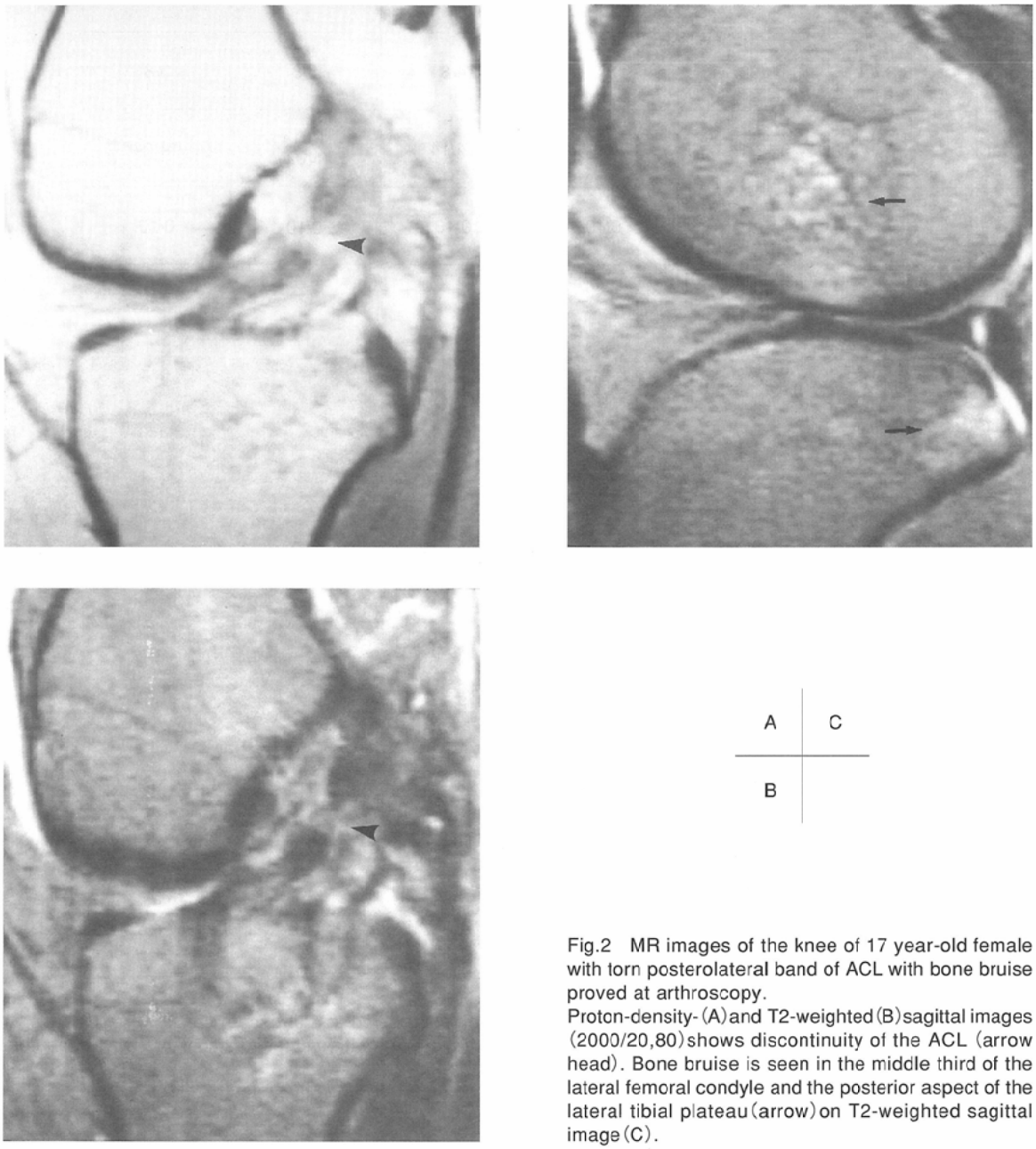


Fig.2 MR images of the knee of 17 year-old female with torn posterolateral band of ACL with bone bruise proved at arthroscopy.
Proton-density-(A)and T2-weighted(B)sagittal images (2000/20,80)shows discontinuity of the ACL (arrow head). Bone bruise is seen in the middle third of the lateral femoral condyle 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 [11]. 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 anterolateral instability may be difficult to perform due to muscular spasms 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[12]. Murphy et al[12] 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[13] 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 torn ligament may account for presence or absence of bone bruise. Further study is necessary to determine whether bone bruise 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 finding, suggestive of partial ACL tear.

REFERENCES

1) Liljedahl S-O, Lindvall N, Wetterfors J : Early diagnosis and treatment of acute ruptures of the anterior cruciate ligament : a clinical and arthrographic study of forty-eight cases. J Bone Joint Surg[Am]47-A : 1503-1513, 1965

2) McDaniel WJ, Dameron TB Jr : Untreated ruptures of the anterior cruciate ligament : A follow-up study. J Bone Joint Surg [Am]62-A : 696-705,1980

3) Barrack RL, Buckley SL, Bruckner JD : Partial versus complete acute anterior cruciate ligament tears : The results of nonoperative treatment. J Bone Joint Surg [Br]72-B: 622-624, 1990

4) Mink JH, Levy BA, Crues JV : Tears of the anterior cruciate ligament and menisci of the knee : MR imaging evaluation. Radiology 167 : 769-774, 1988

5) Lee JK, Yao L, Phelps CT, et al : Anterior cruciate ligament tears; MR imaging compared with arthroscopy and clinical test. Radiology 166 : 861-864,1988

6) Vahey TN, Hunt JE, Shelbourne KD : Anterior translocation of the tibia at MR imaging : A secondary sign of anterior cruciate ligament tear. Radiology 187 : 817-819,1993

7) Tung GA, Davis LM, Wiggings ME, Fadale PD : Tears of the anterior cruciate ligament : Primary and secondary signs at MR imaging. Radiology 188 : 661-667, 1993

8) Noyes FR, Mooar LA, Moorman CT III, et al : Partial tears of the anterior cruciate ligament : Progression to complete ligament deficiency. J Bone Joint Surg[Br]71-B: 825-833, 1989

9) Lehnert M, Eisenshenk A, Zellner A : Results of conservative treatment of partial tears of the anterior cruciate ligament. International Orthopaedics(SICOT)17 : 219-223,1993

10) Oensten M, Lysholm J, Gillquist J : The course of partial anterior cruciate ligament ruptures. Am J Sports Med 13 : 183-6,1985

11) Kaye JJ : Ligament and tendon tears : Secondary signs. Radiology 188 : 616-617,1993

12) Murphy BJ, Smith RL, Uribe JW : Bone signal abnormalities in the posterolateral tibia and lateral femoral condyle in complete tears of the anterior cruciate ligament : A specific sign? Radiology 182 : 221-224, 1992

13) McCauley TR, Moses M, Kier R : MR diagnosis of tears of anterior cruciate ligament of the knee : Importance of ancillary findings. AJR 162 : 115-119, 1994