Three-Tesla MRI Diagnosis of Meniscal Tears of the Knee

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Objective: *To study and diagnose meniscal tear of the knee using 3-Tesla (3-T) magnetic resonance imaging (MRI) compared with arthroscopy*
Material and Method: *One hundred twenty eight consecutive patients who underwent MRI of the knee using a 3-T magnet between April 2007 and Nov 2008 were included in this study. The inclusion criteria were the patients who had (i) subsequent knee arthroscopy, (ii) available medical records, and (iii) no history of meniscal surgery. Their MR images were retrospectively reviewed by two radiologists with consensus agreement. The diagnostic values for diagnosing meniscal tears were evaluated and compared to the arthroscopic results*
Results: *Thirty-two patients (64 menisci) were included; 26 males and 6 females, mean age was 36.4 years (range 19-62). The mean interval between MRI and arthroscopy was 93 days. To diagnose tear of medial, lateral, and both menisci; the sensitivity was 100%, 90%, 100%; the specificity was 77%, 73%, 50%; the accuracy was 91%, 78%, 84%; the positive predictive value (PPV) was 86%, 60%, 81%; and the negative predictive value (NPV) was 100%, 94%, 100%, respectively. False positive MR findings were found predominantly at the posterior horn and at the peripheral third of the menisci. By dividing the patients into 2 groups according to the mean MRI-arthroscopy interval (< 93 and > 93 days): increased sensitivity and NPV of detecting lateral meniscal tear; increased specificity, accuracy, and PPV of both meniscal tear was observed in the longer duration group, but there was no statistical significance in the present study*
Conclusion: *The present results with 3-T MRI revealed high sensitivity and NPV comparable to the literature, thus supporting previous studies that if a meniscal tear is not seen on 3-T MRI, it is highly unlikely to be present. False positive MR findings found predominantly at the posterior horn and at the peripheral third of the menisci. The longer the MRI-arthroscopy interval yielded increased diagnosing values of meniscal tear but there is no statistical significance in the present study.*

Keywords: *Knee, Arthroscopy, Meniscus, Meniscal tear, MRI, 3-Tesla, Sports medicine, Trauma*

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Previous studies have demonstrated magnetic resonance (MR) imaging at 1.5-T field strength or less to be valuable for diagnosing meniscal tear[1-8], and reported the sensitivity and specificity as 62-97% and 69-91%, respectively[6-10]. The higher signal/noise ratio afforded by 3-Tesla (3-T) imaging allows for better image quality leading to higher diagnostic accuracy[11]. The studies performed with 3-T MR scanners[12-14] addressed the sensitivity and specificity for meniscal tear to be 67-100% and 83-97%, respectively. The sensitivity is low for lateral meniscus (67%)[13]. The accuracy of 3-T MR imaging was 94%[14]. Oei et al[9] conducted a systematic review concerning the MR imaging of menisci and cruciate ligaments, concluded that higher magnetic field strength improves diagnostic performance, but significant result was demonstrated only for the anterior cruciate ligament tears. In the present article, the authors present our initial experience with 3-T MR imaging of the knee in detection of the meniscal tears compared with arthroscopy.

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Material and Method

Patient population

Prior to this retrospective study, the authors obtained approval from the hospital Ethics committee to review the medical records, arthroscopic studies, and images of the patients who had been clinically diagnosed as having meniscal tear and undergone 3-T MR imaging

At Ramathibodi Hospital, 128 consecutive MR examinations of the knee with 3-T magnet were performed between April 2007 and November 2008. The indications to use the 3-T machine were knee injuries and degenerative changes, which do not need intravenous contrast media injection. The authors then selected all patients who met the following criteria: (i) having subsequent knee arthroscopy, (ii) having the medical records available, and (iii) no history of meniscal surgery. Overall, 32 patients (64 menisci) met the selection criteria.

Each of the 32 patients' medical records and their arthroscopic studies were reviewed. We used the arthroscopic results to determine the presence or absence of meniscal tears.

MRI technique

All patients underwent MR imaging of the knee in similar protocol and using the same coil. The imaging was performed in the coronal, axial, and oblique sagittal planes on a 3.0-T scanner (Achiva, Phillips Medical System, The Netherland) using 8-channels extremity coil. The following standard MR sequences were performed: sagittal T2 weighted (TR 3000-3240, TE 100 msec), proton density with fat suppression (PDFS) (TR 2000-3971, TE 20-30); coronal T1 weighted (TR 500-577, TE 20), PDFS (TR1744-3665, TE20-30); axial T1 weighted (TR 577, TE 20), T2 weighted (TR 3000, TE 100-120), T2FS (TR 3000-4275, TE 20-100) sequences. Slice thickness was 3 mm with a 1-mm interslice gap on all sequences. A field of view of 16x16 cm and 292x218 to 384x266 acquisition matrix were used.

MR evaluation

The MR images were retrospectively reviewed by two radiologists who were blinded to arthroscopic results. The MR images were assessed for meniscal tears. The MR criteria for diagnosis of meniscal tears include (i) abnormal meniscal signal touching an articular surface, or (ii) abnormal morphologic features of the meniscus on one or more MR images. A meniscal tear was reported when the signal was definitely seen to touch a surface in one view. The MR interpretations were then correlated to the arthroscopic findings. The arthroscopic report as "fraying" of the meniscus was not considered tear in the present study.

Statistical analysis

The diagnostic values of 3-T MR imaging for the detection of meniscal tears including sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV), were calculated using diagnostic test in STATA 10.0 (Stata corp. Texas) and used each corresponding arthroscopic finding as a reference standard.

Results

The 64 menisci of 32 patients were included in the present study (32 medial and 32 lateral menisci). The right side-to-left side ratio was 14:18. The mean interval between MR imaging and arthroscopy was 93 days. The age range of the patients was 19-62 years (mean 36.4 years), and the male-to-female ratio was 26:6.

Twenty-nine meniscal tears (19 medial and 10 lateral) were detected in these 32 patients (6 patients had meniscal tears on both medial and lateral sides) as reported by arthroscopy

The diagnostic values for the medial and lateral meniscal tears are summarized in Table 1.

There were 19 torn and 13 intact medial menisci, with the MR sensitivity, specificity, and accuracy of 100%, 76.92%, and 90.63%, respectively. For the lateral meniscus, 10 torn and 22 intact menisci were diagnosed, resulting in the MR sensitivity, specificity, and accuracy of 90%, 72.73%, and 78.13%, respectively.

Compared with arthroscopic findings, there was only one false negative meniscal tear by MR imaging in the present study. The arthroscopic result was detachment of the anterior horn of the lateral meniscus. However, this meniscal detachment still cannot be detected even in retrospect (Fig. 1).

There were nine false positive meniscal tears by MR imaging (3 medial and 6 lateral menisci) (Table 2). There was one patient with false-positive MR findings on both medial and lateral menisci.

Of the three false positive medial meniscal tears, two occurred at the body and another at the posterior horn. The locations of tear were at peripheral one-third of the menisci (Fig. 2). The arthroscopic result was "fraying" in one case, which was not considered tear in the present study

Table 1. Diagnostic analysis of medial and lateral menisci

Meniscus	Prevalence	Sensitivity	Specificity	Accuracy	PPV	NPV
Medial	59.38	100	76.92	90.63	86.36	100
	(40.64, 76.30)	(82.35, 100)	(46.19, 94.96)	(74.98, 98.02)	(65.09, 97.09)	(69.15, 100)
Lateral	31.25	90	72.73	78.13	60	94.12
	(16.12, 50.01)	(55.5, 99.75)	(49.78, 89.27)	(60.03, 90.72)	(32.29, 83.66)	(71.31, 99.85)
All	68.75	100	50	84.38	81.48	100
	(49.99, 83.88)	(84.56, 100)	(18.71, 81.29)	(67.21, 94.72)	(61.92, 93.70)	(47.82, 100)

Numbers in parentheses are 95% confidence intervals (CI)
PPV = positive predictive value; NPV = negative predictive value

Table 2. Distribution of 9 false positive meniscal tear by MR imaging

	Anterior horn	Body	Posterior horn
Medial medical	x	2	1
Lateral meniscus	1	1	4
Total	1	3	5

Of the six false positive lateral meniscal tears; the location of five tears were also at peripheral one-third of the menisci, except one case in whom there was a radial tear of the lateral meniscal body. In another case, the arthroscopic result was "abnormal" but not "tear".

When the authors divided the patients into 2 groups: the group with MR imaging-arthroscopy interval $\leq$ 93 day (short duration group) and > 93 days (long duration group) according to our mean interval; the authors found obviously increased sensitivity and NPV for lateral meniscal tear; increased specificity, accuracy, and PPV for both meniscal tear, in the long duration group (Table 3). When the authors compared the duration and type of meniscal injury between these two groups, there was no statistical significance (Table 4).

Discussion

Previous studies using 3-T MR imaging to diagnose meniscal tear have reported the sensitivity to be 96-100%, 67-94%, and 95-96% for medial meniscus, lateral meniscus, and both menisci, respectively. The sensitivity is low for lateral meniscus (67%)[13]. The present study found the sensitivity of 100%, 90%, and 100%, respectively, which is comparable to literature.

The specificity to diagnose meniscal tear in the present study is 77% and 73% for the medial and

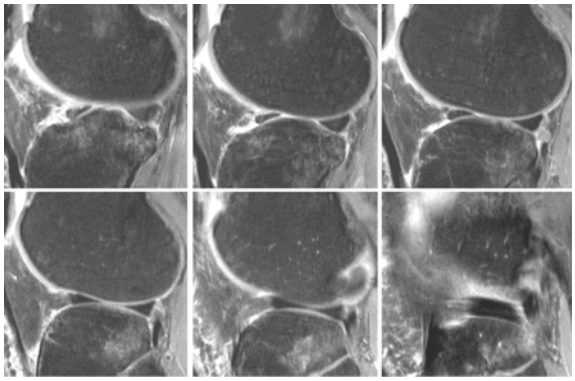

Fig. 1 False negative tear. Fat-saturated proton density sagittal MR images (TR/TE;3000/20) from central to peripheral portion, show normal appearing anterior horn of the lateral meniscus. Detachment of anterior horn was detected by arthroscopy, which still cannot be seen even in retrospect. The time interval between MRI and arthroscopy is 36 days. We considered this as unavoidable false negative tear

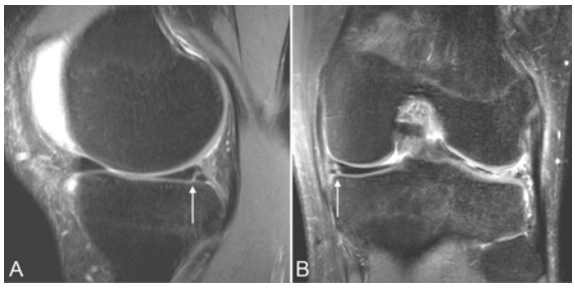

Fig. 2 False positive tear. Fat-saturated proton density sagittal (A) and coronal (B) MR images (TR/TE; 3000/20) show findings consistent with medial meniscal tear at peripheral third of posterior horn (arrows). Arthroscopy result is "fraying" of posterior horn. The time interval between MRI and arthroscopy is 55 days in this case. Comminuted tear of the lateral meniscus is observed

Table 3. Results for the medial and lateral meniscus based on 93 days cutoff point

Meniscus	Prevalence	Sensitivity	Specificity	Accuracy	PPV	NPV
Medial	57.89	100	75	89.47	84.62	100
≤ 93 days (n = 19)	(54.07, 79.75)	(71.51, 100)	(34.91, 96.81)	(71.51, 100)	(54.55, 98.08)	(54.07, 100)
Medial	61.54	100	80	92.31	88.89	100
> 93 days (n = 13)	(31.58, 86.14)	(63.06, 100)	(28.36, 99.49)	(63.97, 99.81)	(51.75, 99.72)	(39.76, 100)
Lateral	31.58	83.33	76.92	78.95	62.50	90.91
≤ 93 days (n = 19)	(12.58, 56.55)	(35.88, 99.58)	(46.19, 94.96)	(54.43, 93.95)	(24.49, 91.48)	(58.72, 99.77)
Lateral	30.77	100	66.67	76.92	57.14	100
> 93 days (n = 13)	(9.09, 61.43)	(39.76, 100)	(29.93, 92.51)	(46.19, 94.96)	(18.41, 90.10)	(54.07, 100)
All	68.42	100	33.33	78.95	76.47	100
≤ 93 days (n = 19)	(43.45, 87.42)	(75.29, 100)	(4.33, 77.72)	(54.43, 93.95)	(50.10, 93.19)	(15.81, 100)
All	69.23	100	75	92.31	90	100
> 93 days (n = 13)	(38.57, 90.91)	(66.37, 100)	(19.41, 99.37)	(63.97, 99.81)	(55.50, 99.75)	(29.24, 100)

Numbers in parentheses are 95% confidence intervals (CI)
PPV = positive predictive value; NPV = negative predictive value

Table 4. The comparison of ROC curve between duration and type of meniscal injury

Meniscus	ROC* area	Standard error	95% confidence interval	p-value
Medial				
≤ 93 days	0.87	0.0818	0.71, 1.00	0.8466
> 93 days	0.90	0.1000	0.70, 1.00	
Lateral				
≤ 93 days	0.80	0.1032	0.60, 1.00	0.8090
> 93 days	0.83	0.0833	0.67, 0.99	
All				
≤ 93 days	0.67	0.1054	0.46, 0.87	0.2026
> 93 days	0.87	0.1250	0.63, 1.00	

lateral menisci, respectively, which is lower than previous reports of 3-T MR studies: 83-89% and 94-97%, respectively. These diagnostic values, however, are within the reported range of 1.5-T MR studies (69-91%).

The present study has NPV of 100%, 94%, 100% for medial, lateral, and both menisci, respectively, which is comparable to previous reports (89-100%). When combined with the high sensitivity, the authors' experience supports the previous results that if a meniscal tear is not seen on 3-T MR imaging, it is highly unlikely to be present[11].

There was only one patient with false negative tear by MR imaging occurring in lateral meniscus. While the arthroscopy reported detachment of its anterior horn, this finding was not seen in MR images even in retrospect and knowing arthroscopic result (Fig. 1), and therefore considered as an unavoidable false negative finding. The false negative rate in the present study is thus 1.11%, which is quite favorable compared to 5-10% in other reports[10,15-17]. The failure rate to detect a clinically significant tear with MR imaging is thus regarded as low.

There were nine false-positive interpretations of meniscal tears in eight patients from MR images in this present study. In an attempt to identify and explain the authors' interpretative errors, the authors undertook a critical review of the presented false positive findings. The authors found that five of nine tears (55.6%) involved the posterior horns, the area known to be most difficult for arthroscopist to thoroughly examine[15,16]. Arthroscopy is a highly subjective procedure. It has been reported to have a varying degree of accuracy depending on the experience of the examiners and the types or location of the tear, and the false negative arthroscopic results are well documented[10,15,17]. Another reason for the false positive result is that the presented study is "routine-to-research" type, conducted in retrospective manner and based on the routine practice of treating meniscal tear. The initial treatment of meniscal tear is typically conservative and non-surgical. If the knee is stable and does not lock, the non-surgical treatment may be all that is needed[18]. In addition, experimental studies in animals revealed that tears involved the outer or peripheral third of the meniscus have the potential

to heal by means of synovial ingrowths and vascular proliferation from the capillary plexus derived from the genicular arteries[19-21]. The meniscus can heal almost completely with fibrovascular scar tissue by 10-16 weeks[22-24]. This mechanism may partly explain false negative result in the present study, and may be accounting for the lower accuracy (for lateral meniscus; 78% vs. 94%) and the lower PPV (61-86% vs. 89-96%) in the present study compared to previous reports of 3-T studies[13,14].

The mean of MR imaging-arthroscopy interval in the present study was 93 days, which within the range of meniscal healing reported in the literature (10-16 weeks: equal to 70-112 days). The authors therefore divided the patients into two groups according to the presented mean interval: the short duration group ($\leq$ 93 days) and the long duration group (> 93 days). The authors found obviously increased sensitivity and NPV for lateral meniscal tear; increased specificity, accuracy, and PPV for both meniscal tear, in the long duration group. When the authors compared the duration and type of meniscal injury between these two groups, there was no statistical significance. These results rather contradict the healing mechanism, and may be explained by the fact that the patients who underwent arthroscopy had to have persistent symptoms, whereas the patients who were more likely to have no persistent symptom (recovered) did not undergo arthroscopy. Therefore, the present study included only patients who had persistent symptoms and had indication for arthroscopy, resulted in higher incidence of meniscal injury even in the long duration group.

Limitation of the present study, as partly mentioned above, is its retrospective nature and based on the routine practice of treating meniscal tear. Some torn menisci may have healed at the time of arthroscopy. Second, the number of arthroscopy is not large and resulted in a rather wide confidence interval in the statistical analysis. The third limitation is related to the arthroscopic evaluation that may be limited by the location and type of tears, and the examiners' experience. In conclusion, despite certain limitations, the presented initial results with 3-T MR imaging for diagnosing meniscal tear reveals the sensitivity and negative predictive value to be high and comparable to literature. The specificity, accuracy, and positive predictive value are in the range of 1.5-T MR studies. The authors' experience seems to support the previous result that if a meniscal tear is not seen on 3-T MR imaging, it is highly unlikely to be present. However, further studies with a larger number of arthroscopy and performing in prospective manner are needed to assess the diagnostic performance of 3-T MR machine.

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ภาวะหมอนรองข้อเข่าขาด: การศึกษาด้วยเครื่องสร้างภาพด้วยคลื่นแม่เหล็กไฟฟ้าที่มีกำลังสนามแม่เหล็ก 3 Tesla

สุภนีวรรณ เชาว์วิศิษฐ, วราพัฒน์ วิระยะวานิช, ภัทรวัณย์ วรธนารัตน์, พิมใจ ศิริวงศ์ไพรัช

ได้ทำการศึกษาภาวะหมอนรองข้อเข่าขาดแบบย้อนหลังในลักษณะของงานประจำสู่งานวิจัย จากจำนวนผู้ป่วย 128 รายที่เข้ารับการตรวจข้อเข่าด้วยเครื่องสร้างภาพด้วยคลื่นแม่เหล็กไฟฟ้าที่มีกำลังสนามแม่เหล็ก 3 Tesla (3-T MRI) ตั้งแต่เดือนเมษายน พ.ศ. 2550 ถึงเดือนพฤศจิกายน พ.ศ. 2551 เปรียบเทียบกับผลการตรวจข้อเข่าโดยการส่องกล้อง ทั้งนี้โดยเป็นไปตามเกณฑ์และขั้นตอนของการวินิจฉัย และการรักษาภาวะหมอนรองข้อเข่าขาดตามปกติของโรงพยาบาล มีผู้ป่วยที่ได้รับการตรวจทั้ง 2 อย่าง จำนวน 32 ราย (หมอนรองข้อเข่า 64 อัน) อายุเฉลี่ย 36.4 ปี ระยะเวลาเฉลี่ยระหว่างการตรวจ MRI และการส่องกล้องข้อเข่าเท่ากับ 93 วัน ผลการศึกษาพบว่าการตรวจหมอนรองข้อเข่าขาดด้านใน, ด้านนอก, และทั้งสองอันรวมกันโดยเครื่อง MRI มีความไวร้อยละ 100, 90, 100; ตามลำดับ ความจำเพาะร้อยละ 77, 73, 50; ความแม่นยำร้อยละ 91, 78, 84; ค่าการทำนายผลบวกจริงร้อยละ 86, 60, 81; และค่าการทำนายผลลบจริงร้อยละ 100, 94, 100 ผลบวกลวงเกิดกับการขาดของหมอนรองข้อเข่าทางด้านหลัง และทางด้านนอก เมื่อแบ่งผู้ป่วยออกเป็น 2 กลุ่มที่มีระยะเวลาระหว่างการทำ MRI กับการส่องกล้อง ≤ 93 วันและ > 93 วัน พบการเพิ่มขึ้นที่ชัดเจนของความไว และค่าการทำนายผลลบจริง ของการตรวจหมอนรองข้อเข่าขาดด้านนอก รวมถึงการเพิ่มขึ้นของความจำเพาะ, ความแม่นยำ, และค่าการทำนายผลบวกจริงของการตรวจหมอนรองข้อเข่าขาดทั้งสองอันในกลุ่มที่ระยะเวลานานกว่า 93 วัน แต่ไม่พบนัยสำคัญทางสถิติของความต่างดังกล่าว

โดยสรุป ผลการศึกษานี้ได้แสดงค่าความไวและค่าการทำนายผลลบจริงสูงเทียบเท่ากับการศึกษาก่อนหน้า สนับสนุนผลการศึกษาก่อนหน้าที่ว่าหากไม่เห็นหมอนรองข้อเข่าขาดโดยเครื่อง 3-T MRI แล้ว มีโอกาสสูงมากที่จะไม่มีภาวะนี้ การศึกษาแบบไปข้างหน้าที่มีจำนวนการส่องกล้องข้อเข่ามากกว่านี้ จะช่วยในการประเมิน การใช้เครื่อง 3-T MRI ในการวินิจฉัยภาวะหมอนรองข้อเข่าขาดได้ดียิ่งขึ้น