Medial meniscus extrusion correlates with disease duration of the sudden symptomatic medial meniscus posterior root tear


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**Abstract**

Introduction: Medial meniscus posterior root tear (MMPRT) leads to abnormal biomechanics of the knee by inducing the medial meniscus extrusion (MME). However, a time-dependent increase of the MME is not fully elucidated in patients suffering from the acute MMPRT. The aim of this study was to investigate the relationships among disease duration of the MMPRT and severity of the MME. We hypothesized that MME measurement correlates with disease duration after a sudden onset of the minor traumatic MMPRT during the short-term follow-up period.

Materials and methods: Forty-six patients who had an accurate episode of the posteroomedial painful popping were investigated. All the patients were diagnosed having a symptomatic MMPRT with magnetic resonance imaging (MRI) examinations. Absolute MME was measured using MRI scans within 12 months after painful popping events. A correlation coefficient between duration from injury to MRI examination and absolute MME was evaluated.

Results: Mean absolute MME was $4.5 \pm 1.6$ mm (range, $1.1 \text{ to } 8.8 \text{ mm})$ on MRI measurements. A good correlation was observed between MME measurement and disease duration from injury to MRI examination ($R^2 = 0.612$). The best-fit equation for predicting each value was: $\text{MME} = 0.014 \times \text{disease duration} + 3.288$ mm.

Discussion: This study demonstrated that absolute MME increases progressively within the short duration after the onset of symptomatic MMPRT. Our results suggest that preoperative MME assessment may be important in determining disease duration and treatment strategy of the MMPRT.

Level of evidence: Retrospective cohort study level IV.

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1. Introduction

Medial meniscus posterior root tear (MMPRT) can occur especially in middle-aged or older female patients who have a single event of posteroomedial painful popping sensation during light activities such as using stairs and squatting [1,2]. Deep flexion of the knee leads to repetitive impingement of the meniscal disc (MM) posterior root, resulting in subsequent degenerative changes and MMPRT. A single event of painful popping has a high positive predictive value (96.5%) in identifying a minor traumatic onset of MMPRT [2]. The MM posterior root can serve as an anchor to regulate the meniscal shift during the knee motion and load bearing [3–5]. Injuries of the MM posterior root, including complete radial and/or oblique tears adjacent to the ligamentous insertion and posterior horn, lead to accelerated degeneration of the knee joint articular cartilage by disrupting meniscal functions [3]. In addition, the MMPRT leads to abnormal biomechanics of the tibiofemoral joint and the inability to convert axial loads into hoop stresses by inducing radial displacement of the MM, also called the MM extrusion (MME) [4,5]. MME is a frequent finding on magnetic resonance imaging (MRI) of patients having the MMPRT [6,7]. Severity of the MME is associated with a loss of medial compartment cartilage volume [8], medial joint space narrowing [9], severity of osteoarthritis as reflected by radiographic Kellgren–Lawrence (KL) grade [10,11], degenerative knee abnormalities [12], knee joint pain [13], increase in subchondral bone lesions and tibial plateau expansion [14] in patients with osteoarthritic knees. MME of ≥ 3 mm is more frequent in painful osteoarthritic knees than in contralateral painless knees and more frequent in osteoarthritic knees that have a higher radiographic grade (KL grade: 3) [13]. Radially displaced MM forms a bulged (or swelled) meniscal shape on a coronal MR image during the progression of osteoarthritic knees [15].

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MME in osteoarthritic knees (KL grade: 2/3) shows more extrusion (2.64 mm) than that in reference subjects (0.53 mm, KL grade: 0) [15]. MME in asymptomatic knees (KL grade: 0/1) shows a minor extrusion value (1.64 mm). There is a slight increase in MME over 4 years (0.04 mm/year) [16]. On the other hand, MME associated with the MMPRT patients reaches a mean of 4.1–4.2 mm (KL grade: 0–4) during the short-term symptomatic period [17,18]. In addition, a degree of the MME can affect postoperative clinical outcome of the MMPRT pullout repair. Pullout-repaired patients with decreased MME have more favorable clinical scores and radiographic findings than those with increased MME [19]. Several authors describe that MME is not completely reduced by MMPRT repair [20,21]. Based on these findings, MME following the MMPRT may progress more rapidly than that in osteoarthritic knees with intact MM posterior roots. Therefore, it may be important to assess preoperative MME for determining surgical indication and timing of the MMPRT repair. However, a time-dependent increase of the MME in patients suffering from the symptomatic MMPRT remains unclear. The aim of this study was to investigate the correlation between severity of the MME and disease duration after a painful popping event defined as the sudden onset of symptomatic MMPRT. We hypothesized that measurement value of the MME would associate with symptomatic duration from the onset of MMPRT to the MRI examination.

2. Methods

This study received the approval of our Institutional Review Board and written informed consent was obtained from all patients. Fifty-five patients were diagnosed having the true MMPRT at the posterior root ligament with MRI examinations between September 2012 and August 2016. The presence of the MMPRT was defined according to characteristic MRI findings (radial tear/cleft/truncation sign of the MM posterior root within 9 mm from the attachment, giraffe neck sign, white meniscus/ghost sign, and/or MME) within 12 months after painful popping events (Fig. 1) [6,7]. Posterior horn tear and posterior segment tear of the MM were excluded. Forty-six patients (42 women and 4 men) who had an accurate episode of the postero medial painful popping involved in a minor traumatic onset during daily activities were included (Table 1). Patients who had the MMPRT without a memory of painful popping (n = 7, 12.7%) and the MMPRT with previous meniscal injury and/or knee surgery (n = 2) were excluded (Fig. 2). Mean age of the patients was 64.7 years (range, 48–76 years) at the diagnosis of the MMPRT with a sudden onset. Patient demographics were shown in Table 1. No patient was lost during the follow-up.

2.1. MRI-based measurements

MRI evaluation was performed using an Achieva 1.5T (Philips, Amsterdam, The Netherlands) with a knee coil. Standard sequences of the Achieva included sagittal [repetition time (TR)/echo time (TE) 742/18], coronal (TR/TE 637/18), and axial (TR/TE 499/18) T2-weighted fast-field echo with a 20° flip angle (FA). Slice thickness was 3 mm with a 0.6-mm gap. Field of view (FOV) was 16 cm with an acquisition matrix size of 205 × 256 [22–24]. Absolute MME was measured from the medial margin of the tibia plateau to the outer border of the MM on the coronal MR image that crossed the midpoint of the anteroposterior length of the MM [22,24]. Two orthopaedic surgeons (Y.K. and Y.O.) independently measured the MME in a blinded manner. Each observer performed each measurement twice, at least 2 weeks apart. The reliability of the measurements was assessed by examining the interobserver and intraobserver reliabilities with the intraclass correlation coefficient (ICC). An ICC > 0.80 was considered to represent a reliable measurement.

2.2. Statistical analysis

Data were presented as means ± standard deviations. Linear regression analysis was used to assess the correlation between absolute MME and duration from injury to MRI examination. A good correlation was represented by $R^2 \geq 0.60$, fair correlation by $R^2 \geq 0.50$ and poor correlation by $R^2 < 0.50$. Statistical analyses were

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**Fig. 1.** Characteristic signs of the MMPRT on MR images. A 60-year-old woman (the left knee). Giraffe neck sign of the MM posterior segment (dotted area and dotted black arrow). Cleft sign (dotted white arrow). Medial extrusion of the MM (MME, arrow).

**Fig. 2.** Patient exclusions and final cohort.

<table>
<thead>
<tr>
<th>Table 1: Demographics and clinical characteristics.</th>
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<tr>
<td>Number of patients</td>
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<tr>
<td>Gender, men/women</td>
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<tr>
<td>Age (years)</td>
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<td>Height (m)</td>
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<tr>
<td>Body weight (kg)</td>
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<tr>
<td>Body mass index (kg/m²)</td>
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<tr>
<td>Duration from injury to MRI examination (days)</td>
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<td>Absolute MME (mm)</td>
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Data of age, height, body weight, body mass index and duration are displayed as a mean ± standard deviation.
performed using EZR (Saitama Medical Center, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing).

3. Results

Duration from acute painful popping event to MRI examination was a mean of 93.1 ± 83.9 days (range, 1–289 days; Table 1). Mean absolute MME was 4.5 ± 1.6 mm (range, 1.1–8.8 mm) on MRI measurements (Table 1). MRI-based measurement of the MME within 1 week after the MMPRT onset was a mean of 2.7 ± 0.8 mm. However, mean of posttraumatic MME reached 3.3 ± 1.1 mm at 4 weeks following the sudden onset of MMPRT. The interobserver and intraobserver reliabilities for the measurements were considered satisfactory (mean ICC values > 0.94). A good correlation was observed between MME measurement and duration from injury to MRI examination ($R^2 = 0.612$). The best-fit equation for predicting each value was the following: $\text{MME} = 0.014 \times \text{duration} + 3.288$ mm (Fig. 3).

4. Discussion

The most important finding of this study was that absolute MME correlated with disease duration of the symptomatic MMPRT after the painful popping event (Fig. 3). These results confirmed our hypothesis that MME associates with symptomatic duration from the sudden MMPRT onset to MRI examination.

The positive predictive value of the painful popping in identifying the MMPRT is 96.5% and the specificity is 99.5% [2]. In our study, 87.3% (48 cases out of 55) of the MMPRT patients remembered having a single event of acute painful popping. Although the sensitivity of a painful popping for the detection of a MMPRT is low (35%) [2], hearing of the painful popping memory seems to be necessary to determine the MMPRT onset and a timing of MRI examination. The presence of a painful popping sensation in the MMPRT appears to be an adjunctive clinical sign of less degenerative status in the articular cartilage. Bae et al. describe that the MMPRTs with a painful popping sensation are associated with less degenerative changes in the articular cartilage than those without a painful popping sensation [2]. In addition, a single event of painful popping has not been reported as typical of the clinical history of other meniscal tears and chondral lesions. We consider that a non-recurrent posteromedial painful popping in a sudden onset of the MMPRT is different from impingement or catching sensation of the other knee joint disorders. In the treatment of the MMPRT, early diagnosis and appropriate surgical intervention are important in obtaining a successful clinical outcome and preventing rapid progression of degenerative knee diseases [3,25]. MRI-based characteristic findings such as radial tear, cleft, ghost and giraffe neck signs provide high diagnostic accuracy and specificity [6,7]. However, these MRI findings cannot give us appropriate information about disease duration following the MMPRT onset and/or the timing of surgical intervention. Our study revealed that MRI-based measurement of the MME considerably correlated with duration from acute onset of the MMPRT to MRI examination (Fig. 3). Absolute MME measurements may be useful to determine disease duration of the symptomatic MMPRT even if the patients have wrong or no memory of the painful popping event.

The status of the MME can affect postoperative clinical outcome of the MMPRT transtibial pullout repair [26]. Patients with decreased MME (3.5 ± 1.4 mm) at 1-year post-MMPRT pullout repairs have more favorable clinical outcomes and radiographic findings at 5-year follow-up than those with increased MME (5.1 ± 1.4 mm) at 1 year postoperatively [19]. Our study demonstrated that the mean absolute MME was 3.3 ± 1.1 mm even in the early duration less than 1 month after the painful popping. Kwak et al. have reported that 35% of the patients received arthroscopic meniscal repair during 3 months of conservative treatment [27]. They conclude that the large MME-medial femoral condyle ratio is a poor prognostic factor of conservative treatment for the MMPRT [27]. Based on these findings, MRI-based MME assessment may be important to predict disease duration after a sudden onset of the MMPRT and determine a severity of the minor traumatic MMPRT.

There are several limitations in this study. Our study was not longitudinal with serial MRI examinations by the same patient. Thus, our findings cannot be adopted for all the types of MMPRT. MRI examinations were performed differently (duration from the onset to MRI assessment). We evaluated the MRI-based MME in a single knee flexion angle (10°) under non-weight-bearing condition. Open MRI assessments of meniscal movement using thin slices in several knee flexion angles under loading condition will be required. In addition, three-dimensional reconstruction of the MRI using dynamic MRI may be useful to understand a time-dependent MME increase after the MMPRT onset. Our study was a retrospective study with a small sample size. Finally, a posteromedial painful popping is not an event that is observed in all the MMPRT patients.
5. Conclusions

This study demonstrates that absolute MME increases progressively within the short duration after the onset of symptomatic MMPT. Our results suggest that MME assessment may be important in determining disease duration and treatment strategy of the MMPT.

Funding information

No funding sources were provided for this study.

Disclosure of interest

The authors declare that they have no competing interest.

References


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