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RESEARCH ARTICLE

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Medial meniscus extrusion is associated with meniscus tears in US and MRI: A case control study

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Abstract

Objectives: To study the medial meniscus extrusion (MME) in subjects with and without medial meniscal tears on magnetic resonance imaging (MRI), supine ultrasound (US), and weight-bearing US.

Methods: Forty-seven cases (mean age 43.7 years) with medial meniscus tears and 53 healthy controls (mean age 36.6 years) were assessed. Two experienced sonographers performed the US evaluations, and a fellowship-trained musculoskeletal radiologist assessed the menisci on MRI. Independent and paired *T*-tests and ICC were used for statistical analyses.

Results: On supine US, the mean MME was 3.9 mm for the cases and 2.3 mm for the controls ($p < 0.001$). On weight-bearing US, the values were 4.2 and 2.8 mm ($p < 0.001$), and on MRI 3.0 and 2.0 mm ($p < 0.001$), respectively. The mean difference between supine and weight-bearing US extrusion was 0.38 mm for the cases and 0.49 mm for the controls ($p = 0.291$). Correlation between supine US and MRI MME measurements was good (ICC = 0.660, CIs [0.533–0.758]).

Conclusions: MME can be assessed using US with good correlation to MRI. US-observed extrusion was significantly increased in supine and standing positions for medial meniscus tears. The mean difference between examination positions was reduced with medial meniscus tears although this result was statistically insignificant.

KEYWORDS

knee, knee injuries, magnetic resonance imaging, menisci, tibial, tibial meniscus injuries, ultrasonography

1 | INTRODUCTION

The menisci are two semicircular fibrocartilaginous discs, positioned between the tibia and femur in the medial and lateral compartments of the tibiofemoral knee joint. They serve as load distributors and shock absorbers while simultaneously resisting radially oriented body weight-induced hoop stresses.[1] Medial and lateral meniscus differ in their shape, size, capsular attachments, and laxity with the medial meniscus being more rigid and prone to injury. The anterior and posterior horn insertion sites of the medial meniscus are larger compared with the lateral meniscus, and the central medial meniscus body is attached to a recognized knee joint capsule condensation known as the deep medial collateral ligament.[2] Medial meniscal extrusion (MME) is defined as the radial displacement of the meniscal body beyond the cortical margin of the tibial plateau. In magnetic resonance imaging (MRI), MME is usually measured from coronal images as the greatest horizontal distance from the tibiofemoral joint line to the most peripheral aspect of the medial meniscus, excluding any osteophytes, with high inter- and intra-observer reliability.[3] Some MME is physiological and dependent on loading conditions, whereas abnormal extrusion alters the normal load distribution and subjects the knee joint to excessive mechanical forces, similarly to complete meniscectomy.[4–9] A limit of 3 mm has been typically used as a definition for abnormal MME, originally by Gale et al.,[3,10,11] although different thresholds have also been derived and suggested.[12–16] Abnormal MME is associated with the severity and progression of knee OA, the risk of knee joint replacement,[10,15,17] knee pain,[15,17–19] and meniscal root[11,20–24] and nonroot tears.[7,10,11,23–25] Although MRI is the most accurate modality for meniscal pathology and knee structures overall,[26] MME can also be reliably assessed using ultrasound (US).[4–6,18,19,27–34] Modern US technologies allow the visualization of key medial knee stabilizing structures: the superficial and deep fibers of the medial collateral ligament, meniscofemoral and meniscotibial ligaments, as well as the outer third of the medial meniscus.[34,35] Using US, the radial displacement of the medial meniscus can be visualized as the distance between the outer border of the medial meniscus body and the tibiofemoral joint line increases.[4,35] Eventually, as the degree of MME increases, bulging of the overlying medial collateral ligament as well as thickening of the medial collateral ligament bursa and effusion in the parameniscal recesses can also be appreciated. When assessing symptomatic medial knee pain patients, findings such as medial collateral ligament bursitis and signs of perimeniscal synovitis are also relevant to report.[35] Whereas conventional MRI assesses the medial knee stabilizing structures and MME only in static supine position, dynamic US examination can be used to also determine the increase of MME in weight-bearing compared to non-weight-bearing conditions (ΔMME), a less investigated parameter that could indicate early knee OA and its progression[6,31,32] and the structural status of the medial meniscus.[4,5] US-observed MME and ΔMME increased with conventional radiograph (CR) evidence of osteoarthritis,[6,32] as determined by the Kellgren–Lawrence (KL) classification,[36] and increased ΔMME was associated with increased risk of osteoarthritis progression in a 5-year follow-up study.[31] With medial meniscus root tears, US-observed MME was significantly increased compared with healthy control patients, and normally observed ΔMME was diminished (KL grades 3 and 4 were excluded).[4] Accordingly, the objective of this study was to assess MME in patients with and without medial meniscus tears using dynamic US and MRI.

2 | MATERIALS AND METHODS

Forty-seven subjects with medial meniscus tears were recruited from our hospital patient records using the PACS database. The initial search pool included patients having undergone knee MRI in the year 2019. Radiologist's reports were read over, MR images reinterpreted by a fellowship-trained musculoskeletal radiologist, and patients with medial meniscus tears were recruited as the case group for this study. Fifty-three control subjects without meniscus tears on MRI were recruited from the Northern Finland Birth Cohort 1986 (NFBC1986). Ethical permit was received from the Ethical Board of the Northern Finland Hospital District.

Subjects' medical imaging records were searched for CRs of the knee taken prior to knee MRI. A fifth-year resident radiologist (AK) assessed and graded all CRs using the KL classification for osteoarthritis.[36] The case and control group underwent US examination in supine and weight-bearing positions between December 2019 and May 2020. Two experienced sonographers (with 6 years of musculoskeletal US experience) performed the US evaluations on both groups (no inter-rater data). Routine US scanning technique of the knee joint was applied (Figure 1). The medial femoral epicondyle was palpated, and the tibiofemoral joint space was identified. Using a linear US probe placed parallel to the medial collateral ligament, the hypoechoic triangular structure between the femoral and tibial cortex representing the outer third of the medial meniscus was identified. MME was measured from the edge of the tibiofemoral joint line (excluding possible osteophytes) to the outermost edge of the medial meniscus. MME was measured first in the supine and then in weight-bearing position.[4]

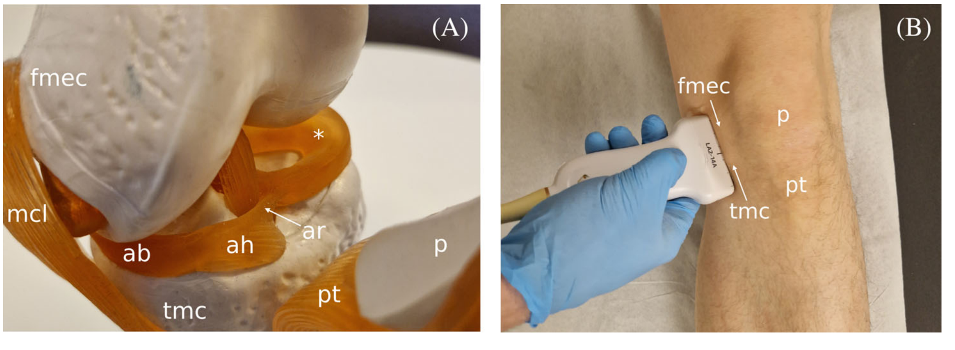

FIGURE 1 Photographic images of a simplified anatomic model of the knee joint from an anteromedial view (A) and typical ultrasound (US) probe placement in routine knee US examination of a supine patient in assessing the medial meniscus (left leg) (B). In the anatomic model, additional structures such as the anterior cruciate ligament and trochlea are visible but not denoted, and more intricate structures such as the meniscofemoral and meniscotibial ligament or the transverse ligament are not depicted. The lateral meniscus is denoted by an asterisk. ab, anterior body of the medial meniscus; ah, anterior horn; ar, anterior root; fmec, medial femoral epicondyle; mcl, medial collateral ligament; p, patella; pt, patellar tendon; tmc, medial tibial condyle.

ΔMME was determined as the difference of the two measurements. On MRI, the MME was measured as suggested by Gale et al. and Karpinski et al.[3,4]; a fellowship-trained musculoskeletal radiologist assessed and measured the medial menisci on MRI. IBM SPSS Statistics software paired *T*-test and independent samples *T*-test and ICC were used for statistical analysis of the acquired data.

3 | RESULTS

The case group consisted of 47 subjects and the control group 53 subjects. The cases had a mean age of 43.7 years (range 18.3–62.2 years) and controls 36.6 (range 20.5– 69.9 years), respectively; there was a statistical significance between the ages of the groups ($p < 0.001$). CRs of the knee were available for 96% (45/47) of the cases and 100% (53/53) for the controls. For the cases, the mean time between CR and US examination was 193 days (range 0–519 days). For the controls, all CRs had been done on the same day as the US examination. In the case group, medial KL classification was KL0 in 42% (19) subjects, KL1 in 38% (17) subjects, and KL2 in 20% (9) subjects. In the control group, medial KL classification was KL0 in 53% (28) subjects, KL1 in 45% (24) subjects, and KL2 in 2% (1) subjects.

Figure 2 shows US-MRI correlation images of the medial meniscus in medial meniscus tear and control subjects. Statistical analysis showed that on supine US the mean MME was 3.9 mm for the cases with medial meniscus tears and 2.3 mm for the controls without tears ($p < 0.001$). On weight-bearing US, the values were 4.2 and 2.8 mm ($p < 0.001$), and on MRI 3.0 and 2.0 mm ($p < 0.001$), respectively. The mean difference between supine and weight-bearing US extrusion of the medial meniscus (ΔMME) was 0.38 mm for the cases and 0.49 mm for the controls, however the result was statistically insignificant ($p = 0.291$). Correlation between supine US and MRI meniscus extrusion measurements was good (ICC = 0.660, CIs [0.533–0.758]). Table 1 shows the type and location of medial meniscus tears as classified on MRI.

4 | DISCUSSION

In this study, we assessed MME in subjects with MRI-confirmed medial meniscus tears and healthy controls using dynamic US and MRI. In concordance with previous publications,[5,27,28,33] we saw a good correlation between MME measured using US and MRI. US-observed MME was significantly increased in supine and weight-bearing position when an MRI-confirmed medial meniscus tear was present. Mean ΔMME was also lower than in the control group, although the observed difference was statistically insignificant. These findings are similar to previous work by Karpinski et al. who reported

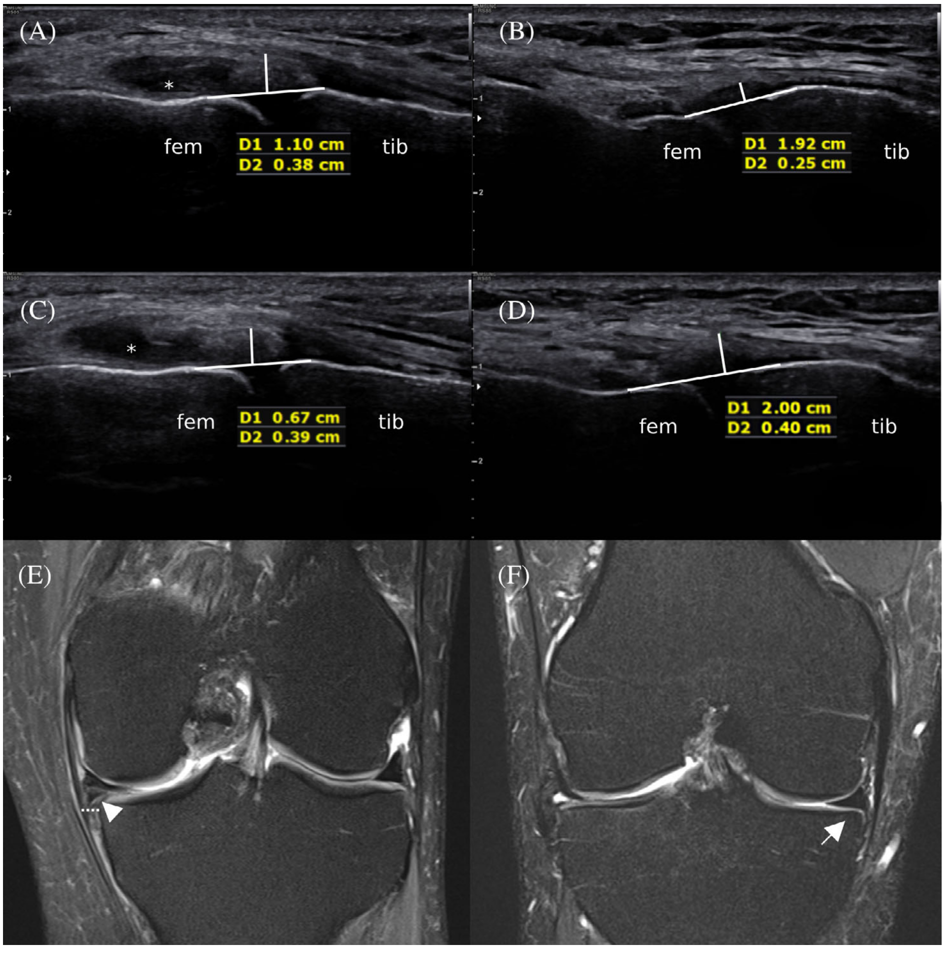

FIGURE 2 More prominent medial meniscus extrusion is seen with meniscus tears on supine ultrasound (US) (A), weight-bearing US (C), and magnetic resonance imaging (MRI) (E). With normal meniscus, less extrusion is visible on respective imaging (B, D, and F). Adjacent to torn medial meniscus, a hypoechoic distension of the superior parameniscal recess can be observed, denoted by an asterisk (A, C). White lines show the extrusion measurements on US, dashed line on MRI, arrowhead horizontal meniscus tear, and arrow normal meniscus. fem, femur; tib, tibia.

TABLE 1 The type and location of medial meniscus tears as classified on magnetic resonance imaging.

$n = 49$ (tears), $N = 47$ (subjects)[a]	Anterior root	Anterior horn	Meniscal body	Posterior horn	Posterior root
Horizontal tear		1	6	9	
Vertical tear				2	
Radial tear		1	3	1	
Complex tear			4	17	1
Bucket handle tear			4		

[a]One of the horizontal tears began in the anterior horn and continued through the medial meniscal body into the posterior horn, which explains the total number of tears ($n = 49$) in this table ($N = 47$ subjects).

an increased US-observed MME and nonexistent ΔMME in patients with medial meniscus root tears when compared with healthy controls.[4] It has previously been reported that the physiological degree of MME in supine and standing positions as well as ΔMME increase with age. In healthy nonsymptomatic volunteers, Achtnich et al. reported a mean US-observed weight-bearing MME of 1.1 mm and ΔMME of 0.3 mm in the 18–30 year age group, MME of 2.0 mm and ΔMME of 0.8 mm in the 30–49 year age group, and MME of 2.5 mm and ΔMME of 1.1 mm in the 50–70 year age group.[5] In their 50–70 year age control group, Karpinski et al. reported an US-observed MME of 1.3 mm in supine and 2.3 mm in standing position, with mean ΔMME of 1.0 mm.[4] In our results, the MME measurements in the control group were similar to the results published by Achtnich et al. In the medial meniscus tear group, MME was clearly increased above expected normal values in both supine and standing positions. Mean ΔMME was also reduced, although comparison between our groups did not show a statistically significant difference. We postulate that this could be at least in part due to the age difference between the groups, underlining the importance of age-appropriate reference values.

For diagnosing osteoarthritis, CRs are the most common imaging modality for their simplicity and low cost. In the knee joint, CRs enable the visualization of bony features of osteoarthritis (osteophytes, subchondral sclerosis, and subchondral cysts) and the assessment of the joint space width, which in turn is affected by cartilage loss, meniscus subluxation, and extrusion.[26] Radiographs, however, are not sensitive for early osteoarthritis changes,[37–40] and KL grading correlates poorly with reported knee pain and clinician-diagnosed arthritis.[41] Although MRI is the gold standard examination for assessing the structural integrity of the knee joint,[26] it is generally not utilized in the primary healthcare setting due to the relatively high cost and long image acquisition times. Interest in the complementary role of dynamic US in the diagnosis of osteoarthritis has steadily increased in recent years. US identifies MME and small tibiofemoral osteophytes accurately, comparing well against computed tomography and MRI.[28,42] It has been previously shown that MME increases with KL grading[6] and that higher ΔMME is a risk factor for future progression of knee OA (meniscal tears were excluded in a baseline MRI examination).[31] Therefore an abnormal US-observed MME in conjunction with low CR evidence for OA could potentially indicate a risk for future OA progression. Recently, it has also been reported that MME is increased and ΔMME is significantly reduced in the presence of a medial meniscus tear.[4] As meniscus tears potentially require surgical intervention and "simple" OA typically does not, ΔMME could prove beneficial in deciding whether the patient would require an MRI examination or not.

In this study, we did not assess the medial meniscus or the medial knee compartment with Doppler US. Modern high-frequency US enables the visualization of different layers of the medial collateral ligament: superficial and deep fibers, their femoral and tibial insertions, as well as the meniscofemoral and meniscotibial ligaments. The outer third of the medial meniscus can also be visualized, enabling the assessment of MME and the identification of, for example, parameniscal cysts, peripheral fibrocartilaginous delaminations, and displaced meniscal fragments in, for example, meniscal flap tears.[34,35] Displaced meniscus tears are vital to report, as they are difficult to identify in conventional arthroscopic approach without high suspicion.[43] Recent technical advances in microvascular flow US imaging methods have enabled improved motion artifact suppression and increased sensitivity to slow and small vessel flow compared with conventional Doppler US. Most scientific literature on microvascular flow imaging available today focuses on the detection of synovitis in osteoarthritis, rheumatoid arthritis, and other inflammatory arthropathies, reporting increased sensitivity.[44–46] Systematic US assessment of medial knee structures and their vascularization patterns in patients presenting with MRI-confirmed medial meniscus tears using for example microvascular flow imaging technologies remains a potential subject for future studies.

Our study has several limitations. First, the potentially significant effect of subject age was not accounted for during the planning of this study and therefore NFBC1986, a preexisting database, was used as the control group. Second, subjects for the medial meniscus tear group were screened and recruited from patients who had a previous knee MRI in our hospital area. As such, the distribution of tear types was not uniform but more reflective of symptomatic meniscus tears and cases where imaging was thought to be warranted by the treating physician. Third, although our overall number of subjects was comparably high relative to other similar works, the potential for subgroup analyses between for example different meniscus tear types or KL grades in our study was limited.

5 | CONCLUSIONS

In conclusion, MME can be evaluated using the US with good correlation to MRI. US-observed extrusion was significantly increased in supine and standing positions for meniscus tears. The mean difference between patient positions was reduced with meniscus tears although this result was statistically insignificant. This study further establishes the role of dynamic US when suspecting medial meniscus tears.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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