Osteoarthritis and Cartilage 25 (2017) 76–84

Osteoarthritis and Cartilage

The relationship between meniscal pathology and osteoarthritis depends on the type of meniscal damage visible on magnetic resonance images: data from the Osteoarthritis Initiative

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ARTICLE INFO

Article history:
Received 14 September 2015
Accepted 9 August 2016

Keywords:
Meniscus
Tear
Bone marrow lesions
Knee pain
End-stage knee osteoarthritis

SUMMARY

Objective: To determine the association of different types of meniscal pathology with knee pain, bone marrow lesion (BML) volume, and end-stage knee osteoarthritis (esKOA).
Design: Participants were selected from an ancillary project to the Osteoarthritis Initiative (OAI) who had at least one knee with symptomatic osteoarthritis. Baseline magnetic resonance images (MRI) were evaluated for meniscal pathology using a modified International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (ISAKOS) classification system. We collapsed 10 types of meniscal pathology into five categories: normal, intrameniscal signal, morphological deformity/extrusion (altered meniscal shape and/or extrusion but no apparent substance loss), tear, and maceration. Outcomes included Western Ontario and McMaster Universities osteoarthritis index (WOMAC) knee pain and BML volume at baseline and after 2 years. We defined the prevalence of esKOA based on a validated algorithm. We performed logistic regression and adjusted for age, sex, and body mass index (BMI).
Results: The 463 participants (53% male) included in the analysis had mean age 63 (9.2) years, BMI 29.6 (4.6) kg/m^2, and 71% had Kellgren–Lawrence grade $\geq$2. Morphological deformity/extrusion and maceration, but no other types of meniscal pathology, were associated with BML volume (morphological deformity/extrusion odds ratio [OR] = 2.47, 95% CI: 1.49, 4.09, maceration OR = 5.85, 95% CI: 3.40, 10.06) and change in BML volume (morphological deformity/extrusion OR = 2.17, 95% CI: 1.37, 3.45, maceration OR = 3.12, 95% CI: 1.87, 5.19). Only maceration was associated with baseline WOMAC knee pain (OR = 2.82, 95% CI: 1.79, 4.43) and prevalence of esKOA (OR = 7.53, 95% CI: 4.25, 13.31).
Conclusions: Based on MRI, morphologic deformity/extrusion and maceration rather than intrameniscal signal or tear were associated with osteoarthritis severity and progression, which highlights the importance of differentiating distinct types of meniscal pathology.

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http://dx.doi.org/10.1016/j.joca.2016.08.004
1063-4584/

Introduction

Meniscal damage is common among older adults[1] and is an important risk factor for the incidence[2] and progression of knee osteoarthritis (KOA)[3]. Damage to a meniscus can compromise its ability to absorb, transmit, and distribute mechanical stress over a large area of the joint cartilage[4]. Meniscal pathology increases the risk for structural changes commonly associated with KOA (e.g., bone marrow lesions (BMLs)[5,6], cartilage volume loss[7], and altered subchondral bone mineral density[8]). However, there are different types of meniscal pathology, which range from subtle intrameniscal signal to tears (e.g., horizontal tear, radial tear) and maceration. Certain types of meniscal pathology (e.g., maceration) may alter joint loading more than other types of subtle meniscal pathology (e.g., intrameniscal signal). Hence, certain types of meniscal pathology, like maceration (meniscal destruction), may influence structural and clinical progression of KOA more than other types of meniscal pathology. Major meniscal pathology (comparable with maceration) is associated with BML progression[5] and knee pain[9] among individuals without KOA. Furthermore, the presence of major meniscal pathology is more likely in knees that receive a knee replacement than among knees that do not[10,11]. While only 5% of adults without KOA have meniscal destruction (e.g., maceration), one in four have at least one type of meniscal pathology, which suggests that certain types of meniscal pathology (e.g., tears) may not be a major catalyst for OA progression[1]. It is important to determine if certain types of meniscal pathology are associated with structural and symptomatic changes because this could help us more efficiently identify individuals at risk for progression.

We aimed to determine the association of different types of meniscal pathology with common measures of OA severity and progression. Specifically, we evaluated knee pain, change in knee pain over 2 years, BML volume, and change in BML volume over 2 years because these measures of OA severity and progression have been previously associated with meniscal pathology in studies that did not account for different types of meniscal pathology[5,6,9,12,13]. We also tested the association of different types of meniscal pathology with a validated definition of end-stage KOA (esKOA), which is a unique outcome that accounts for radiographic disease severity and self-reported knee pain and function[14]. We hypothesize that only certain types of meniscal pathology that severely alter meniscal function (i.e., maceration, change in meniscal shape [morphological deformity/extrusion]) relate to common measures of KOA severity and progression.

Materials and methods

Study sample

We selected a convenience sample of the Osteoarthritis Initiative (OAI) Progression Cohort ($n = 1390$) who attended an OAI visit between August 2007 and April 2009 and consented to participate in the Bone Ancillary Study ($n = 629$). The primary aim of the Bone Ancillary Study was to investigate the influence of bone in the structural progression of OA. The inclusion criteria were a willingness to undergo additional knee imaging (i.e., additional magnetic resonance [MR] scans and dual-energy X-ray absorptiometry). Participants with contraindication for MR imaging were excluded. For the Bone Ancillary Study analyses, the 24-month OAI visit was considered baseline and the 48-month visit was considered as the 2 year follow-up. At baseline, these participants had clinical data and MR images that were assessed for meniscal pathology ($n = 463$) and BML volume ($n =$ first 386 knees based on ID as a convenience). At the follow-up visit, 463 participants had clinical data and 386 participants had MR images that were assessed for BML volume. The reduced sample size was due to time and personnel constraints.

We selected one knee per participant. We used the primary OAI imaging knee as the index knee unless there was a contraindication for MR imaging. According to protocol, the primary OAI imaging knee was the right knee, which underwent a complete set of OAI MR sequences. The contralateral knee had an abbreviated MR scan to reduce participant burden. While everyone in this study sample had at least one knee with symptomatic OA, the primary OAI imaging knee was not always the knee with symptomatic OA.

This study received ethical approval from each OAI clinical site (Memorial Hospital of Rhode Island Institutional Review Board, The Ohio State University's Biomedical Sciences Institutional Review Board, University of Pittsburgh Institutional Review Board, and University of Maryland Baltimore–Institutional Review Board), the OAI coordinating center (Committee on Human Research at University of California, San Francisco), and the Institutional Review Board at Tufts Medical Center and Tufts University Health Sciences Campus. All participants provided informed consent to the OAI and the Bone Ancillary Study.

MR imaging

MR images were acquired at the 24- and 48-month OAI visits with one of four identical Siemens (Erlangen, Germany) Trio 3-T MR systems and a USA Instruments (Aurora, OH, USA) quadrature transmit–receive knee coil at the four OAI clinical sites[15]. For purposes of the Bone Ancillary Study these MR images were considered baseline and 2 year follow-up. The following sequence was used for BML evaluation: sagittal intermediate-weighted, turbo spin echo, fat-suppressed MR sequences (field of view = 160 mm, slice thickness = 3 mm, skip = 0 mm, flip angle = 180°, echo time = 30 ms, recovery time = 3200 ms, 313 × 448 matrix (interpolated to 512 × 512), phase encode superior/inferior, x resolution = 0.357 mm, and y resolution = 0.511 mm). We scored menisci using the same sequences used to evaluate BMLs in addition to the coronal intermediate-weighted 2D turbo spin echo, recovery time of 3850 ms, echo time of 29 ms, slice thickness of 3 mm, and field of view of 140 mm. All images are publicly available (https://oai.epi-ucsf.org).

Meniscal pathology scoring

A single experienced fellowship trained musculoskeletal radiologist (RJW) reviewed the baseline MR images for meniscal pathology by location (i.e., anterior horn, body, and posterior horn) within the medial and lateral menisci using a modified International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (ISAKOS) meniscal tear classification system[16]. The original ISAKOS scoring was based on viewing of videos of arthroscopy to evaluate the meniscal tear based on the tear depth, location, tear pattern, length, quality of tissue, and percent of meniscus excised. This was modified to focus on the radiological aspect of MR imaging and 10 classifications were made: normal, intrameniscal signal, morphological deformity/extrusion (shape change including meniscal extrusion but no apparent substance loss), horizontal tear, horizontal flap tear, longitudinal-vertical tear, radial tear, vertical flap tear, complex tear, and maceration (destruction). The presence of these 10 pathologies was evaluated systematically in each region of the meniscus and each region was assigned only one pathology. Intrameniscal signal was defined as an increase in signal intensity within a region without other pathologic features. The reader indicated a type of tear when it was the only tear in a region. Meniscal morphological deformity/extrusion referred to the major loss of meniscal integrity with loss