Sub-compartmental analysis of the meniscus and cartilage in healthy subjects and patients with osteoarthritis using T1rho quantification

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INTRODUCTION

Osteoarthritis (OA) is a multifactorial disease that affects all aspects of the joints including articular cartilage, subchondral bone, synovium, and the meniscus. Although the relationship between meniscus and articular cartilage has been studied in the past, few studies have investigated the correlation between meniscal damage and the region-specific areas of articular cartilage surrounding the meniscus most significantly affected by OA using quantitative MRI. Such correlative analysis may be valuable to further understand the role of meniscal damage to the progression of OA. Quantitative MRI, including T1rho and T2 quantification and delayed gadolinium enhanced MRI in cartilage (dGMRIC) GEMRIC techniques, allows us to evaluate changes in cartilage matrix. The goal of this study was to investigate the interrelationship between meniscal lesions and the subregional cartilage degeneration using 3T MR T1rho relaxation time quantification.

METHODS

MRI was performed on 34 subjects (17 controls with Kellgren-Lawrence [KL] score = 0 and 18 OA subjects with KL > 1) using a 3-T GE MR scanner (GE Healthcare) and an 8 channel phased-array knee coil. The mean age of the subjects was 47 years (± 11.8), mean BMI of 24.3 kg/m² (± 4.14) and 38% of the subjects were female. The clinical assessment of the meniscus was performed by 2 experienced radiologists using a sagittal fat-saturated FSE T2-weighted clinical imaging sequence (matrix 512x256, FOV=16cm, slice thickness=2mm) and graded using modified semi-quantitative Whole-organ magnetic resonance imaging scoring (WORMS). The meniscus WORMS scoring was based on a scale of 0-6 (0= intact, 1= minor radial tear or parrot-beak tear, 2= non-displaced tear or prior surgical repair, 3= displaced tear or partial resection, 4= complete maceration/destruction or complete resection) Cartilage T1rho maps were generated using a 3D T1rho mapping technique based on SPGR sequences previously developed in our lab (matrix 256x128, slice thickness=4 mm, time of spin lock (TSL)=0/10/40/80 ms, spin lock frequency =500 Hz). The cartilage was segmented on a fat-saturated 3D SPGR sequence (matrix 512x512, FOV=16cm, slice thickness=1mm) using in-house developed software on MATLAB. Five compartments were defined: lateral femoral condyle (LFC), medial femoral condyle (MFC), lateral tibia (LT), medial tibia (MT), and patella. The femoral condyles (MFC and LFC) were further divided into 5 sub-compartments while the tibia cartilages (MT and LT) was sub-divided into 3 sub-compartments with regard to meniscus (Figure 1). LFC-3/MFC-3 and LT-2/MT-2 presents the contacting regions of femoral and tibial cartilage during standing. LFC-2/MFC-2 and LT-1/MT-1 are regions above and below the anterior horn of meniscus, and LFC-4/MFC-4 and LT-3/MT-3 are regions above and below the posterior horn of meniscus. LFC-1/MFC-1 and LFC-5/MFC-5 presents the anterior and posterior non-weight bearing portion of the femoral condyle during standing, respectively. T1rho maps were registered to SPGR images and T1rho values were calculated for each defined sub-compartments and compared between OA and controls, and between subjects with or without meniscal lesions using t-tests.

RESULTS

When looking at cartilage compartments, the MT showed statistically elevated T1rho values in OA subjects compared to controls (p = 0.017). Based on sub-compartmental analysis, MT-2, MFC-5 and LFC-5 had significantly elevated T1rho values in OA subjects compared to controls (P < 0.05, Table 1). 34% of the patients had at least one meniscal tear in a compartment as revealed by MRI with the posterior horn of medial meniscus (PHMED) having the highest incidence of meniscal lesions and containing 42% of the meniscal tears. When comparing the subjects with meniscus WORMS scoring of grade 0-1 with those of grade 2-6, significant elevated T1rho values was found in MT cartilage. Further subcompartmental analysis showed that this difference was primarily driven by significant elevation of T1rho values in MT-3 (35.3ms in grade 0-1 and 38.76ms in grades 2-6, p = 0.05, Figure 2).

DISCUSSION

Quantitative MRI T1rho has shown to be a promising diagnostic tool for detecting cartilage degeneration in OA knees. Sub-compartmental analysis will help to identify the heterogeneous degeneration within the joints. With limited number of subjects, our results suggested that the weight bearing regions (such as MT-2) and the regions with loading during flexion activities (such as MFC-5 and LFC-5) may have more accelerated degeneration during OA. Further analysis including other factors such as alignment will be performed. Meniscus tears have shown to be a major proponent of the development of osteoarthritis. In this study, we found significant elevation of T1rho in MT and MT-3 in subjects with tears in the posterior horn of medial meniscus. This may be explained by that MT, in particular MT-3, lies adjacent to the area of meniscal damage and withstands the greatest weight-bearing load. Our findings of elevated T1rho in these regions suggested local interrelationship between cartilage and meniscus degeneration in OA. With further investigation, we will explore the osteoarthritis progression in the different cartilage compartments with respect to meniscal tears.

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Figure 1. SPGR images showing the MFC and MT sub-compartments definition.

Figure 2. T1rho values of MT and MT-3 for subjects with and without lesions in posterior horn of medial meniscus. (* denotes p <0.05)