A quantitative study of knee cartilage in osteoarthritis using parallel imaging method

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Introduction   Several quantitative methods have been proposed to study osteoarthritis (OA). However, it is not clear if these measurements can differentiate OA at different stages. In this study, we measured mean cartilage thickness, T1rho and T2 on severe OA patients, mild OA patients as well as healthy volunteers to investigate if these biomarkers will change accordingly with the severity of OA. The measurements were performed with a newly developed parallel imaging method [1].

Method   An 8 channel phase array knee coil (General Electric Medical Systems, WI) was used for parallel imaging on a 3T GE Signa scanner. Seven severe OA patients with radiological findings (Kellgren-Lawrence (KL) scores =3 or 4), 10 mild OA patients with KL scores = 1 or 2, and 15 healthy volunteers were recruited for the study and gave the informed consent. The knees of the subjects were scanned with a previously developed parallel imaging protocol that includes: a 3D spoiled gradient echo (SPGR) sequence for knee morphological parameter measurements (matrix 512×512, locations per slab (LPS) = 100, slice thickness = 1mm, flip angle = 18°), a previously developed 3D T1rho mapping using segmented elliptic-centric SPGR sequence [2] that acquires data during transient signal evolution (tsT1rho)(matrix 256×128, LPS = 36, slice thickness = 3mm, time of spin lock (TSL) = 0/10/40/80 ms, spin lock frequency = 500 Hz, views per segment = 48, flip angle =12°), a 3D T2 mapping by adding a nonselective T2 prep imaging sequence to the same SPGR sequence (tsT2) (matrix 256×128, LPS = 36, slice thickness = 3mm, 4 different images were acquired with TE = 4.1/14.5/25/45.9 ms) [3]. Field of view was 14-16cm for all the sequences which acquired cartilage images at sagittal plane. Cartilage measurements were evaluated in 5 segmented knee compartments: Medial/Lateral Femur Chondyle (MFC/LFC), Medial/Lateral Tibia (MT/LT) and Patella (P). The 3D high resolution SPGR images were segmented to calculate cartilage volume and mean cartilage thickness. For T1rho/T2 maps, the regions of interest (ROI) were defined by the SPGR segmentation that was mapped by the registration with the images with the shortest TSL/time of echo (TE) of the T1rho/T2 images, respectively. All post-processing was performed on a Sun workstation (Sun Microsystems, Palo Alto, CA). A student's t-test was performed to compare cartilage thickness, average T1rho and T2 values between severe OA patients, mild OA patients and healthy volunteers. The result was considered significant if $p < 0.05$.

Results   Representative T1rho overlaid maps of a severe OA patient, a mild OA patient and a healthy control are shown in figure 1. It can be observed that the T1rho values increases with the severity of OA. Significant differences were found between all groups for both T1rho and T2 values: control subjects vs mild OA patients (p =0.004 for T1rho, p = 0.01 for T2), mild vs severe OA patients (p = 0.007 for T1rho, p = 0.006 for T2), and control subjects vs severe OA patients (p < 0.001 for both T1rho and T2) (Table 1). Table 2 shows mean and standard deviation of cartilage thickness in each compartment for different group. Significant difference was only found in MFC (p = 0.002) and MT (p = 0.01) between severe and mild OA patients, in MFC (p = 0.04995) between mild OA patients and controls, and in MT (p =0.03) between severe OA patients and controls. T1rho and T2 values correlated significantly (R =0.67, p <0.001). No significant correlation was found between T1rho and cartilage thickness or T2 and cartilage thickness (p > 0.05).

Figure 1. Representative T1rho maps from **a**: a severe OA patient, **b**: a mild OA patient, and **c**: a healthy control. Note the enhanced T1rho values in OA patients.

	Severe OA	Mild OA	Control
T1rho	46.64±3.80	41.50±2.47	38.13±2.59
T2	38.91±3.50	34.24±1.35	31.53±2.28

Table 1. Comparison of T1rho/T2 values (in ms, mean ± SD) in different groups.

	LFC	MFC	LT	MT	P
Severe OA	2.11±0.49	1.64±0.77	1.45±0.30	1.12±0.42	2.30±0.43
Mild OA	2.00±0.23	1.92±0.16	2.30±0.38	1.76±0.53	2.42±0.84
Control	1.81±0.29	1.72±0.33	2.18±0.29	1.59±0.23	2.51±0.40

Table 2. Cartilage thickness (in mm, mean ± SD) in segmented compartment for different groups.

Discussion   Previous study showed significant difference in T1rho and T2 between OA patients and control subjects [4]. This study demonstrated that both T1rho and T2 values increases with the severity of OA. Significant differences were found between all groups for both T1rho and T2 mapping, indicating the severity of OA may be differentiated by these 2 parameters. Depending on the groups compared, significant differences of cartilage thickness were only found within specific compartments, mainly in medial knee cartilage in our study. This indicated that the severity of OA may not be differentiated by the measurement of cartilage thickness. With further study and more subjects included, a more robust conclusion is expected.

References   [1] Zuo, et al. J Magn Reson Imaging 2007; 26: 1001-1009. [2] Li, et al. ISMRM 2007. [3] Oh, et al. Magn Reson Imaging 2006; 24:33-43. [4] Li, et al. Osteoarthritis Cartilage 2007; 15: 789-797.