Influence of Loading on Cartilage T1rho and T2 Value in the Porcine Knee Joint

Hidetoshi Hamada[1], Takashi Nishii[2], Satoru Tamura[2], Tetsuya Wakayama[3], Hisashi Tanaka[4], Kenya Murase[5], Hideki Yoshikawa[1], and Nobuhiko Sugano[2]

[1]Department of Orthopedic surgery, Osaka university graduate school of medicine, Suita, Osaka, Japan, [2]Departments of Orthopedic Medical Engineering, Osaka University Graduate School of Medicine, Suita, Osaka, Japan, [3]GE Healthcare Applied Science Laboratory, Asia Pacific, Hino, Tokyo, Japan, [4]Department of Radiology, Osaka University Medical School, Suita, Osaka, Japan, [5]Department of Medical Physics and Engineering, Osaka University Medical School, Suita, Osaka, Japan

Target audience: musculoskeletal radiologists and orthopaedic surgeon associating joint surgery

Purpose: Quantitative knee MR imaging, such as delayed gadolinium enhanced MRI of cartilage (dGEMRIC), T2 mapping, and T1rho provides non-invasive assessment of microstructure compositions and degenerative changes of the articular cartilage. T1rho value of cartilage was assumed sensitive to changes in proteoglycan content, while T2 value was assumed sensitive to changes in collagen and water content. In examining load responsiveness of the articular cartilage assuming physiological conditions such as standing position, assessment of cartilage T1rho and T2 values may be more useful than assessment in change of cartilage thickness, by reflecting microstructure compositional change associated with external loading. In previous studies, change in cartilage T2 value was correlated with applied pressure on cartilage, while MR imaging of T1rho under loading was poorly investigated. The purpose of this study is to assess influence of loading on cartilage T1rho and T2 of the femoral cartilage in the porcine knee joint and to analyze relationship between change of those values and deformity of cartilage under loading.

Methods: Thirteen porcine knee joints were harvested en block with intact capsule and surrounding muscle, and were imaged using the custom-made pressure device and 3.0T MR imaging system. Sagittal T1rho and T2 maps were obtained at knee neutral alignment without external compression (load 0), under external compression equivalent to 140 N along the long axis of the knee (load 140), under compression equivalent to 300 N (load 300), and under no loading ten minutes after decompression (post-load). T1rho maps were obtained using a spin-lock technique followed by SPGR acquisition using transient signals evolving towards steady-state. The parameters were as followed: FOV=16cm, matrix=384X256 interpolated to 512 ×512, slice thickness=3 mm, TSL=0/10/30/60/80 ms, FSL= 500Hz, acquisition time=13 min. T2 maps were calculated from 2D multi-spin echo sequences. The parameters were as followed: TR=1500 ms, 8 evenly spaced echo times between 10–80 ms, slice thickness=3 mm, FOV=12 cm, matrix=384X256 interpolated to 512 ×512, acquisition time=12 min 54 s. The region of interest (ROI) was defined semi-atutomatically on the weight-bearing area of the medial and lateral femoral condyle using our custom-made software. The ROI was subdivided into six regions, which were superficial and deep layers with half thickness of cartilage at each anterior, middle, and posterior zone with one-third length of the original ROI. Change rates of T1rho and T2 values of each region at load 140, load 300 and post-load from load 0 were calculated. Change rate of thickness of cartilage at each zone were also measured to analyze relationship with change in T1rho and T2 value.

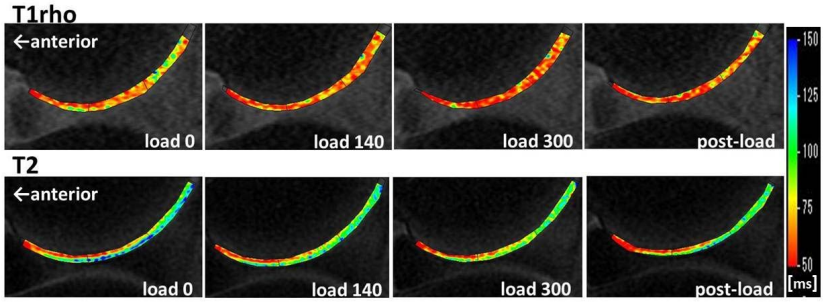

Fig1: Sagittal T1rho and T2 mapping in the lateral femoral condyle

Results: Both mean T1 rho and T2 values decreased according to the magnitude of applied load, and recovered partially after release of loading (Fig1, 2). Mean decrease rate of T1rho and T2 values was between 3.7 % to 5.8 % under load 140 and between 8.4 % to 11 % under load 300 as full thickness in the medial condyle, and between 3.2 % to 6.8 % under load 140 and between 7.7 % to11.6 % under load 300 as full thickness in the lateral condyle. T1rho and T2 values showed statistically similar changes at deep and superficial zones in the medial condyles, while, in the lateral condyle, T2 values in the deep zones showed significantly smaller changes in response to loading as compared with change of T1rho value (Fig 2). The thickness of cartilage decreased by loading, and change rate of thickness of cartilage under load 300 correlated significantly with change rate of T2 value on anterior and posterior zone in medial cartilage. (P< 0.05, r= 0.645 and 0.655).

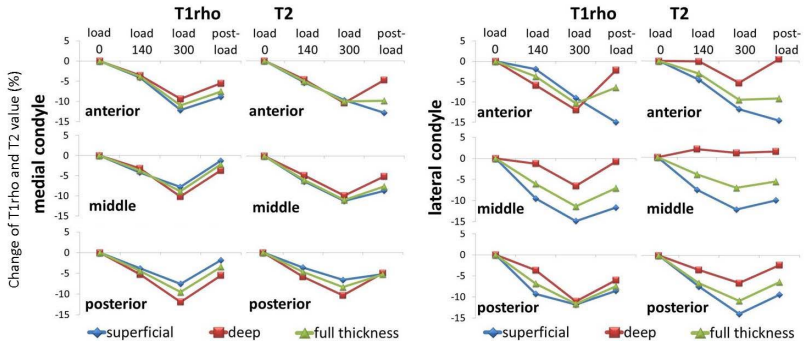

Fig2: Change rate of T1rho and T2 value

Discussion: In our previous studies, full-thickness cartilage T2 value of porcine knee joints at the weight- bearing area decreased between 4.0 % to 17.3 % under compression force of 300 N[1]. In the present study, both T1 rho and T2 values showed similar magnitudes of decrease in general, dependent on loading force. Interestingly, both values showed different load- response in the deep zones of the lateral condyles, with less sensitive changes to loading in T2 values. This may partly reflect different mechanisms of microstructure compositional change to loading, such as depth-dependent movement of water content or deformation of the collagen architecture as related with T2 change, and condensation of proteoglycan distribution as related with T1 rho change [2]. Clinically, assessment of cartilage T1rho and T2 changes under loading may be useful to evaluate physiological and biomechanical status of the knee and to explore the disorders of stress resistance function of the cartilage associated with various degenerative pathologies.

Conclusion: Quantitative assessment of MRI for the cartilage by T1rho and T2 mapping under static loading may become potent indexes to allow non-invasive biomechanical assessment of site-specific stress distribution in the cartilage.

References: [1] T.Shiomi et al. Osteoarthritis Cartilage 2012; 20:1283-90. [2] Nishioka H, et al. J.Magn Reson Imaging 2012; 35:147-155.