BIOMECHANICAL MR IMAGING OF THE HUMAN KNEE CARTILAGE IN VIVO.

Toshiyuki Shiomi[1], Pavol Szomolanyi[1,2], Vladimir Juras[1,2], Stefan Zbyn[1], Takashi Nishii[3], and Siegfried Trattnig[1]

[1]*MR Centre of Excellence, Department of Radiology, Medical University Vienna/Vienna General Hospital, Vienna, Austria,* [2]*Department of Imaging Methods, Institute of Measurement Science, Slovak Academy of Sciences, Bratislava, Slovakia,* [3]*Department of Orthopaedics, Osaka University Medical School, Osaka, Japan*

Introduction

MRI measurement of knee cartilage morphology is not sensitive enough to detect the changes associated with the early stages of osteoarthritis. Biochemical MRI, such as delayed gadolinium-enhanced MRI of cartilage (dGEMRIC), sodium MRI, T2*, and T2 mapping, provides reliable and non-invasive assessment of articular cartilage, predominantly the proteoglycan content and collagen matrix composition. T2 mapping of the articular cartilage is one technique in joint MR imaging that elucidates degenerative changes associated with changes in water contents and damage to the collagen network. [1] The aim of this study was to show that changes in T2 values of human knee cartilage during biomechanical MRI correlate with load applied on that cartilage. The purpose of this study was to characterize the time-dependence of cartilage stiffness under static loading using T2 mapping of the femoral cartilage of the knee joint *in vivo* in healthy volunteers.

Materials and Methods

All participants provided informed consent to participate in the study, which was approved by the Institutional Review Board. Eight healthy subjects (mean, 31 years ± 8; 6 male and 2 female; 2 left and 6 right) with no knee pain and no previous history of knee injury participated. Each subjects' knee was imaged using an multi-slice multi-echo (MSME) T2 mapping technique on a 3 T MR imaging system (Siemens Healthcare, Erlangen, Germany) in the sagittal plane with the subject lying supine. A Tx/Rx 8-channel knee coil (InVivo Corp, Gainesville, FL, USA) was used. A resting phase of 15 minutes preceded the measurements. After the first load-free measurement, a half body weight load was applied on the knee, using the MR-compatible, custom-made pneumatically controlled compression device. The compression device applied load to the heel, while the pelvis was fixed to the MR bed using a dedicated belt. Five consecutive T2 measurements were performed in 10min intervals under static loading. The load-free T2 measurement was repeated at the end of the series. Offline post-processing was used to calculate and evaluate T2 maps. A sequence parameters were as follow: TR: 1110 ms; 6 echoes between 12-72 ms; field of view: 14 cm; matrix: 350 × 350; slice thickness: 3 mm; signal averaging: 2; total acquisition time: 7min 35s). ROIs were drawn manually by an experienced radiologist in the deep and superficial zones of the weight-bearing area on the femoral cartilage (Figure 1). Central medial, as well as central lateral slices, were evaluated in each subject. Mean, standard deviation, and pixel count were recorded and statistically analyzed by t-test.

Results

T2 values for human knee cartilage exhibited a significant decrease in the loading phase (60.8ms±7.5 → 54.6ms±6.2, $p< 0.05$ in the superficial layer; 47.2ms±8.6 → 44.2ms±8.6, $p< 0.05$ in the deep layer), and a significant increase in the unloading phase (54.6ms±7.4 → 61.5ms±7.5, $p< 0.05$ in the superficial layer; 43.7ms±8.3 → 46.4ms±8.1, $p< 0.05$ in the deep layer). During the first loading period (10 minutes), the largest decrease of -8.2% of the T2 value was observed. Another 4 loading periods of 10 minutes each showed only minor T2 changes. At the end of the experiment, the load was released and T2 values returned to original values within 10 minutes. Figure 2. shows T2 development over time. Changes in T2 values were more obvious in the superficial layer (-10.0 %) than in the deep layer (-6.4 %).

Conclusion

Previous studies have shown that cartilage does not behave like an elastic tissue mechanically, and the relation between load and deformation was non-linear and time-dependent. [2] In our study, T2 values exhibited a nonlinear dynamic change over time and reached stable values after 10 minutes of loading/unloading. In summary, loading of the knee during MRI can provide biomechanical characteristics of the human knee cartilage. Statistically significant changes in cartilage T2 during the loading and unloading phases provide insight into cartilage properties. This can help in the diagnosis of patients with cartilage transplants when morphological changes are not sensitive enough. The next step will be the application of loading MRI in patients after cartilage surgery.

References [1] Burstein D, et al. Invest Radiol 35:622-38,2000. [2] Ecstein F, et al. Anat Embryol 203:147-173, 2001.

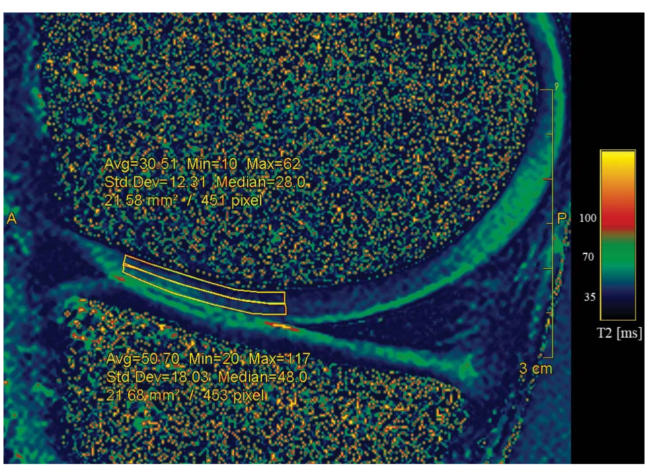

Fig 1.: Example of T2 map under loading in the central medial condyle. Deep and superficial ROIs are shown. Mean values, stand. deviation, and pixel count were evaluated.

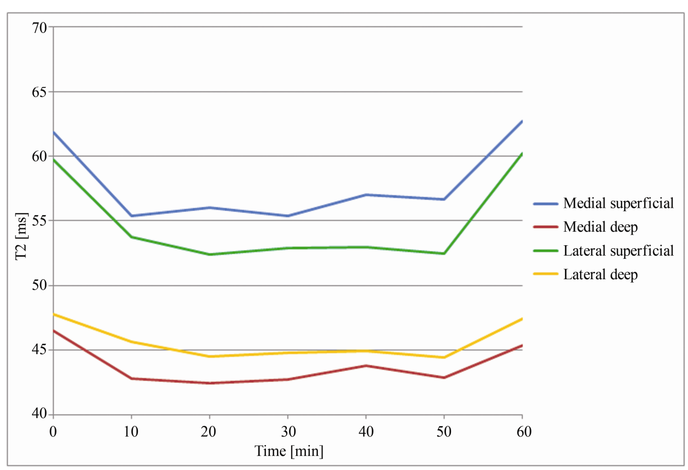

Fig 2.: Time development of T2 values in ms. Characteristic "U" shape demonstrates initial drop of T2 values after load application (10 min), stable T2 values during load and increase of T2 values without load (last 10 min).