In vivo effects of unloading and compression on T2 and T1Gd (dGEMRIC) relaxation times of healthy knee articular cartilage at 3 Tesla

M. E. Mayerhoefer[1], G. Welsch[2], T. C. Mamisch[3], and S. Trattnig[4]

[1]Department of Radiology, Medical University of Vienna, Vienna, Vienna, Austria, [2]Medical University of Vienna, Austria, [3]Inselspital Bern, [4]Medical University of Vienna

INTRODUCTION

T2 mapping and T1 mapping after delayed gadolinium enhancement (dGEMRIC) are well-accepted biochemical MRI techniques for the quantitative evaluation of the 3D collagen network structure and the glycosaminoglycan concentration of articular cartilage, respectively (1). While these techniques have been used for *in vitro* assessment of biomechanical properties of cartilage in the majority of studies (2), the present study investigates the effects of unloading and compression on T2 and T1Gd relaxation times of human knee articular cartilage *in vivo*.

MATERIALS AND METHODS

Ten asymptomatic volunteers (7 men and 3 women; mean age, 27.2 ±4.5 years) were enrolled in the study. MRI of the right knee was performed using a 3.0 Tesla MR scanner (Magnetom Trio; Siemens, Erlangen, Germany) with a gradient strength of 40 mT/m, equipped with a dedicated flexible eight-channel knee array coil (Noras, Wuerzburg, Germany). An isotropic 3D-double echo steady state sequence was used for morphological evaluation. For T2 mapping, a multi-echo spin-echo sequence was used: TR, 1650 msec; TE, 13.8 ms, 27.6 ms, 41.4 ms, 55.2 ms, 69 ms, and 82.8 ms; FoV, 160x160 mm; MTX, 384x384; voxel size, 0.4x0.4x3.0mm; bandwidth, 228 Hz/pixel; 18 slices. For T1Gd mapping, a 3D GRE sequence was used: TR, 15 ms; TE, 1.95 ms; flip angles, 5° and 18.6°; FoV, 160x160 mm; MTX, 384x384; voxel size 0.4x0.4x3.0mm; bandwidth, 480 Hz/pixel; 22 slices.

Both T2 and T1Gd maps were obtained at three points in time: (1) "baseline", 90 minutes after a bolus injection of 0.2 mmol per kilogram body weight Gd-DTPA(2-) (Magnevist, Schering, Berlin, Germany), including a time period of 20 minutes during which the patient actively exercised the knee; (2) "unloading", following the first mapping, i.e., 20 minutes after unloading of the knee joint in a lying position inside the MR scanner; and (3) "compression", following the second mapping, during application of a compressive force (50% of the body weight of the volunteer). This compressive force was generated by a custom-made loading device (Noras, Wuerzburg, Germany), and was transmitted to the knee joint via a foot plate (see Fig.1).

All images were analyzed in consensus by a senior musculoskeletal radiologist and a fourth-year resident in radiology. Independently for each of the three T2 and T1Gd maps, seven regions of interest (ROI) were manually defined on either of two reconstructed, adjacent sagittal sections, that depicted the central portion of the medial femoro-tibial compartment: anterior, central, posterior and dorsal femoral cartilage; and anterior, central and posterior tibial cartilage, with respect to the position of the meniscus (see Fig. 2). Each ROI was further subdivided into a superficial and a deep layer of approximately equal size, yielding a total of 28 ROIs per subject for each point in time. Sites and ROI positions were identical between the different measurements. Three-way ANOVA with random effects and paired t-tests were used for group comparisons. The specified level of significance was 5%.

Fig. 1: Custom-made loading device with footplate for generation of compressive force on knee articular cartilage.

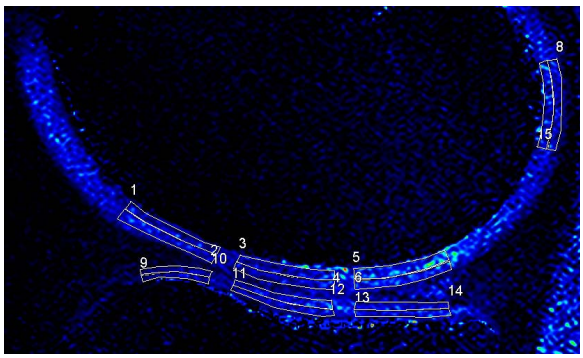

Fig. 2: Sagittal T1Gd (dGEMRIC) MR image with 7 different cartilage zones (4 femoral, 3 tibial) and 14 ROIs.

RESULTS

The mean T2 relaxation time of all cartilage zones (ROI positions) decreased minimally from 31.6±11.2 at baseline to 31.5±11.6 ms after unloading ($p>.05$), and then increased to 33.0±12.1 ms during compression ($p<.01$). The mean T1Gd relaxation time of all cartilage zones decreased from 696.5±151.4 ms at baseline to 682.2±154.5 ms after unloading ($p>.05$), and then to 640.1±150.5 ms during compression ($p<.001$).
Individual analyses of the different cartilage zones revealed a significant mean T2 increase from unloading to compression in the superficial central femoral zone (+3.8, $p<0.01$), and a significant mean T1Gd decrease from unloading to compression in the central femoral (superficial: -45.4, $p<0.05$; and deep: -47.8, $p<0.01$) and tibial (superficial: -72.6, $p<0.01$; and deep: -77.5; $p<0.01$) zones.

DISCUSSION

In vivo, unloading has no significant effect on T2 and T1Gd relaxation times of knee articular cartilage of healthy subjects. On the other hand, compression leads to a moderate increase of T2 values, in particular in the central weight-bearing zones of the femoral cartilage, and to a drastic decrease of T1Gd values, especially in the central weight-bearing zones of both femoral and tibial knee joint cartilage. This indicates a high sensitivity of T1Gd to mechanical stress, which may be useful for the detection of early stages of degenerative cartilage disease.

REFERENCES

1. Burstein D, Gray ML. Is MRI fulfilling its promise for molecular imaging of cartilage in arthritis? Osteoarthritis Cartilage. 2006:14:1087-90.
2. Kurkijärvi JE, Nissi MJ, Kiviranta I, et al. Delayed gadolinium-enhanced MRI of cartilage (dGEMRIC) and T2 characteristics of human knee articular cartilage: topographical variation and relationships to mechanical properties. Magn Reson Med. 2004:52:41-6.