The Effect of Bone Marrow Edema-Like Lesions on Knee Articular Cartilage Laminar MR Relaxation Time

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Introduction

Increasing evidence suggests bone marrow edema-like lesion (BMEL) due to osteoarthritis (OA) is a contributing factor in the progression and severity of the disease as detected by radiography[1] and clinical magnetic resonance imaging (MRI) [2]. T1ρ and T2 relaxation examine the interaction between motion-restricted water protons and their encapsulating extracellular matrix (ECM) [3,4]. Degenerative changes to the ECM associated with OA have been revealed to increase both T1ρ and T2 relaxation times [5,6]. Significant correlations between elevated local T1ρ relaxation time in cartilage adjacent to bone marrow edema lesions has been established [7]. Both T1ρ and T2 relaxation represent non-invasive modalities from which early biochemical changes in the micro-architecture of cartilage may be monitored. This study aims to track laminar (i.e.: bone and articular layer) changes in cartilage T1ρ and T2 relaxation times associated with BMEL. In study of this, we may be able to more accurately discern spatial patterns of cartilage degeneration associated with BMEL.

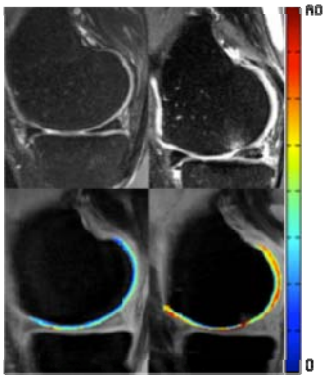

Figure 1: Representative clinical FSE images of control (top left) and a BME subject (top right). Matching T1ρ color maps are shown for the same slice below for control (bottom left) and BME (bottom right). Color scale is in

Materials and Methods

MR data for 93 subjects (mean age of 50 years (± 14.3), mean BMI of 26.1 kg/m2 (± 5.4), 54% female.) were acquired on a 3T Signa HDx MR (GE Healthcare, Piscataway, NJ) scanner with an 8-channel phased array knee coil. Sagittal cartilage T1ρ and T2 maps were generated using 3D MAPSS mapping technique (TR/TE=9.3/3.7 ms; FOV=14cm, matrix=256 × 128, slice thickness=4 mm, BW=31.25 kHz, views per segment=64, recovery time =1.5 s, for T1ρ: Time of Spin-Lock=0, 10, 40, 80 ms, spin-lock frequency=500 Hz; for T2: prep TE=4.1, 14.5, 25, 45.9 ms) [8]. A fat-suppressed, high-resolution sagittal 2D fast spin echo (FSE) sequence (GE Healthcare, Piscataway, NJ) (TR/TE 2500/38ms, matrix 512x256, FOV=14cm, slice thickness=2mm) was acquired for clinical diagnosis, while a fat-saturated T1-weighted 3D SPGR sequence (TR/TE=15/6.7 ms, flip angle=12, FOV=14cm, matrix=512 × 512, slice thickness=1 mm, bandwidth=31.25 kHz, NEX=1) was used for cartilage segmentation. Assessment of BMEL were performed by 2 UCSF experienced Radiologists using the aforementioned FSE imaging sequence and graded using a modified semi-quantitative Whole Organ Magnetic Resonance Imaging scoring (WORMS) [9]. BMEL was noticed by a diffuse signal increase located within the bone.

Six cartilage knee compartment regions of interest (ROIs) (lateral femoral condyle (LFC), medial femoral condyle (MFC), lateral tibia (LT), medial tibia (MT), patella (PAT), and trochlea (TRO)) were segmented in a MATLAB (MathWorks, Natick MA) based in-house software package. Compartments were partitioned into a bone and articular layer, using a Euclidean distance algorithm with the same in-house software. A random effects linear regression model adjusting for age, gender, and BMI was performed in JMP software version 8 (SAS Institute, Cary NC).

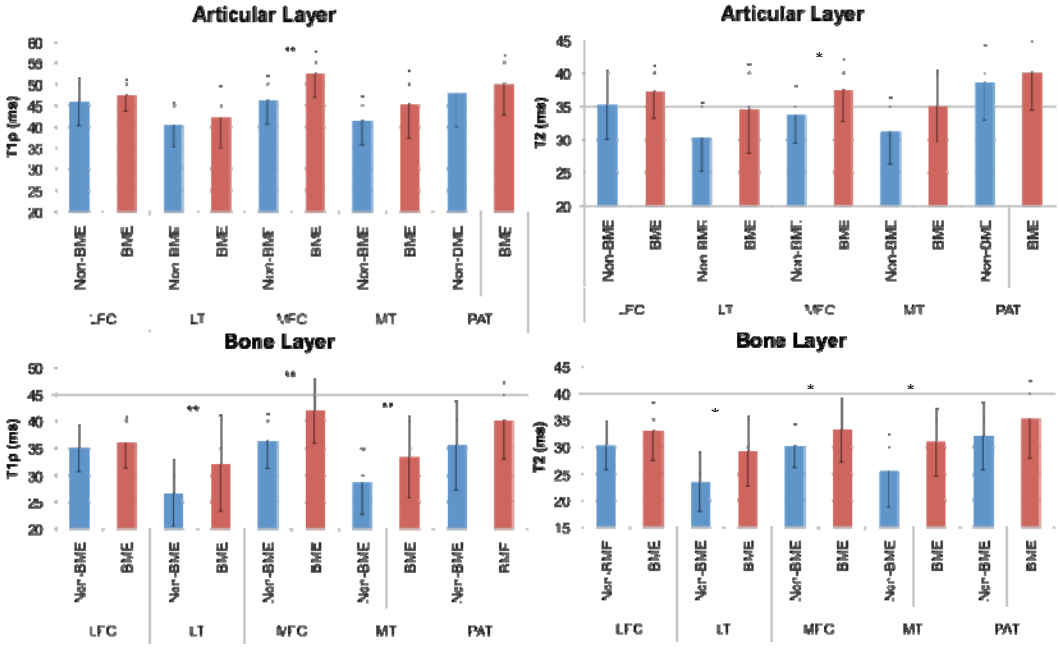

Figure 2 – Bone and articular layer of cartilage T1ρ and T2 relaxation times in each compartment with and without bone marrow edema. Single asterisk indicates P < 0.05 and double asterisk indicates P < 0.01.

Results

Articular layer T1ρ and T2 relaxation times were significantly elevated in MFC that showed BMEL compared to those without BMEL (figure 2). In the bone layer, T1ρ (P < 0.01) and T2 (P < 0.05) relaxation times were significantly elevated in both tibial compartments (LT and MT) and the MFC that showed BMEL compared to those without BMEL.

Discussion

These results suggest differences in how distinct cartilage layers are effected by BMEL. While these data are consistent with Bining et al [10], who noticed elevated T2 relaxation time in the presence of BME, laminar analysis of cartilage in the presence of BMEL in OA is a novel methodology. The significant increases tibial bone layer T1ρ and T2 relaxation times, and the absence of such patterns in the articular layer, seem to suggest that BMEL has a more degrading effect on the cartilage layer closer to the BMEL, which may be explained by potential biochemical/molecular exchanges between cartilage and subcondral bone and/or biomechanical factors. The similar trends in both T1ρ and T2 relaxation indicate rather comprehensive bone layer cartilage degradation, especially in the tibia. Further study into the possible causality of BME related increase on bone layer T1ρ and T2 relaxation time is warranted.

Conclusion

Bone marrow edema-like lesions are more frequently associated with increased T1ρ and T2 relaxation time in the cartilage layer proximal to the cortical bone when compared to healthy controls.

References:
1) Felson DT et al Ann Intern Med. 2003 Sep 2;139 :330-6.
2) Brem et al Acta Radiol. 2008 Nov;49(9):1031-7.
3) Duvvuri et. al. Magn Reson Med 1997;38:863–867.
4) Dunn TC et al. Radiology. 2004;232(2):592-8.
5) Menezes NM et al. Magn Reson Med. 2004;51(3):503-9.
6) Mosher TJ et al. Radiology. 2000;214(1):259-66.
7) Zhao et al Skeletal Radiol. 2010 June; 39(6): 523–531.
8) Li X, et. al. Magn Reson Med 2008; 59(2): 298-307.
9) Peterfy CG et al. O&C. 2004;12(3):177-90.
10) Bining et al Skeletal Radiol. 2009 May;38(5):459-65.

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