

## T2\* of the Osteochondral Junction Measured by VTE at 7T and Correlated with Histology

Vladimir Juras<sup>1</sup>, Maria Isabel Menedez<sup>2</sup>, Jochen Hofstaetter<sup>3</sup>, Martin Brix<sup>3</sup>, Sonja Walzer<sup>3</sup>, Pavol Szomolanyi<sup>1</sup>, Oliver Bieri<sup>4</sup>, Xeni Deligianni<sup>4</sup>, and Siegfried Trattnig<sup>1</sup>  
<sup>1</sup>MR Centre of Excellence, Department of Radiology, Medical University of Vienna, Vienna, Austria, <sup>2</sup>The Wright Center of Innovation in Biomedical Imaging, The Ohio State University Wexner Medical Center, Columbus, Ohio, United States, <sup>3</sup>Department of Orthopaedics, Medical University of Vienna, Vienna, Austria, <sup>4</sup>Department of Radiology, Division of Radiological Physics, University of Basel Hospital, Basel, Switzerland

### Target audience

Musculoskeletal radiologists, physicists developing sequences for imaging of fast relaxing tissues, OA specialists

### Purpose

The integrity of the calcified cartilage as well as tidemark (calcified cartilage front) is one of the signs of osteoarthritis (OA) progressing. In the later OA stages tidemark duplicates or multiplies, is compromised or even disrupted and calcified cartilage becomes thicker<sup>1</sup>. MRI is a great tool for non-invasive assessment of the cartilage condition<sup>2</sup>. However, the MRI of the calcified cartilage is challenging due to high demands on image resolution (the thickness is in a range of hundreds  $\mu\text{m}$ ) as well as short echo times ( $T_2 \ll 10\text{ms}$ , due to massive presence of type X collagen). The aim of this study was to test the feasibility of gradient echo-based variable echo time sequence (GRE-vTE)<sup>3</sup> to visualize the osteochondral junction. The MRI measures were correlated with histological findings.

### Methods

Six ex-vivo human knees were used in the study (mean age 76  $\pm$  7 years). Institutional review board approval was obtained. The ex-vivo knees were examined with a 3T whole-body system and 7T investigational whole body system using similar 8-channel knee coils. T2\* maps were calculated from an isotropic 3D multi-echo vTE-sequence using ten sequentially shifted echo times TE = [0.75, 3.51, 5.87, 8.23, 10.6, 12.96, 15.33, 17.69, 20.06, 22.42] ms using a mono-exponential fit least square analysis performed in IDL 6.3 (Interactive Data Language, Research Systems, Inc, Boulder, CO). The fitting function was  $S = S_0 \times e^{-TE/T_2^*} + \text{offset}$ , where *offset* was estimated from the TE=0.75ms image noise. The thickness measurements were performed on subtracted vTE images with TE=0.75ms and TE=22.42ms with highlighted fast relaxing tissues (optimized for T2\* in range of 1 to 10 ms) in JiveX software (Visus Technology Transfer GmbH, Bochum, Germany). Moreover, the ROI on femoral cartilage (medial and lateral, weight-bearing zone only) were drawn and transferred to T2\* maps. The histological photographs were performed after safranin O staining and evaluated according to Mankin score<sup>4</sup> (cartilage structure, cartilage cells, staining, tidemark integrity; range best-to-worse was 0 to 38). The correlation between T2\* in weight-bearing zone of femoral cartilage and osteochondral junction thickness (measured histologically and from MR images) was calculated using Pearson correlation coefficient. The correlation between calcified cartilage thickness and cartilage OA grading was assessed as well.

### Results

Mean T2\* value was 5.46  $\pm$  3.24 ms in medial femoral cartilage and 7.98  $\pm$  3.25 in lateral femoral cartilage (no statistically significant differences,  $p=0.396$ ). In medial and lateral femoral cartilage (combined), the correlation between T2\* and osteochondral junction thickness was quite high ( $r=0.629$ ). Mean Mankin score was 5.5  $\pm$  1.8. The correlation between T2\* and the Mankin score was  $p=0.377$ ; in case of T2\* vs the osteochondral junction thickness measured from vTE images the Pearson correlation coefficient was  $p=0.576$ . The mean thickness of osteochondral junction measured from histological images was 66 $\pm$ 32  $\mu\text{m}$  for medial-lateral femoral cartilage (weight-bearing zone, no statistically significant differences,  $p=0.49$ ). The same thickness measured from subtracted MR images was 0.66 $\pm$ 0.17 mm.

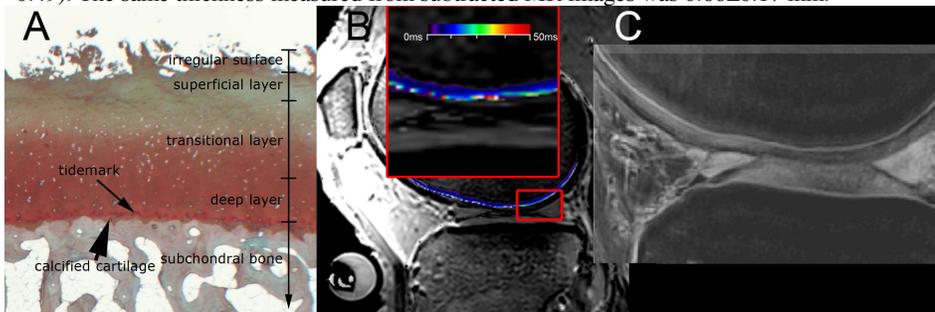


Figure 1. A: Histological slice, safranin O staining with layers labeling; B: subtracted vTE image used for osteochondral junction evaluation overlaid with T2\* map (also magnified, pseudo-color coded); C: subtracted vTE image with highlighted osteochondral junction.

osteochondral junction which may suggest the changes in collagen matrix and calcified cartilage front in different OA stages. It was shown that lead accumulates in the tidemark which may significantly contribute to T2\* alteration<sup>5</sup>. Relatively low number of samples does not allow generating conclusive statements; in the future, it needs to be validated in the higher number of subjects.

### Conclusion

This method has a great potential in helping to diagnose various stages of osteoarthritis through the measurement of osteochondral junction thickness as well as T2\* values, however, some further investigations need to be done.

### Acknowledgement

Funding support provided by Austrian Science Fund P 25246 B24

**References** 1.Pritzker KP, Gay S, Jimenez SA, et al. Osteoarthritis cartilage histopathology: grading and staging. *Osteoarthritis and cartilage / OARS, Osteoarthritis Research Society*. Jan 2006;14(1):13-29. 2.Eckstein F, Cicuttini F, Raynauld JP, Waterton JC, Peterfy C. Magnetic resonance imaging (MRI) of articular cartilage in knee osteoarthritis (OA): morphological assessment. *Osteoarthritis and cartilage / OARS, Osteoarthritis Research Society*. 2006;14 Suppl A:A46-75. 3.Deligianni X, Bär P, Scheffler K, Trattnig S, Bieri O. Water selective high resolution imaging of short T2 components of the knee at high and ultra high field strengths. *Proc. Intl. Soc. Mag. Reson. Med.* 2012;20:3315. 4.Mankin HJ, Dorfman H, Lippiello L, Zarins A. Biochemical and metabolic abnormalities in articular cartilage from osteoarthritic human hips. II. Correlation of morphology with biochemical and metabolic data. *The Journal of bone and joint surgery*. Apr 1971;53(3):523-537. 5.Zoeger N, Roschger P, Hofstaetter JG, et al. Lead accumulation in tidemark of articular cartilage. *Osteoarthritis and Cartilage*. Sep 2006;14(9):906-913.

### Discussion

This study shows that vTE is suitable tool for measuring the thickness of osteochondral junction; however, the measured values from MR images probably combine the signal from deep and calcified layer (it is not purely calcified cartilage) which would explain the discrepancy with histologically obtained values. The optimization of the two TE combinations for the best contrast is necessary. Low TEs in vTE sequence allow accurate calculation of T2\* of osteochondral junction (in the range of ~5-10ms). Histological grading of the cartilage condition corresponds to changes in T2\* in