cartilage associate with bone bruise should be taken into account in clinical treatment for acute knee injury.

**FRONTAL PLANE MALALIGNMENT AND CARTILAGE T1ρ AND T2 RELAXATION TIMES IN KNEE OSTEOARTHRITIS**

D. Kumar, Z.A. Zarins, J. Schooler, W. Vitayavanich, X. Li, T.M. Link, S. Majumdar. *Univ. of California San Francisco, San Francisco, CA, USA*

**Purpose:** Frontal plane malalignment is a known risk factor for development and progression of knee osteoarthritis (OA). In established disease, using standard MR imaging has shown that varus malalignment is associated with morphological changes like meniscal degeneration, bone attrition and cartilage loss. Using quantitative MRI, T1ρ and T2 relaxation times have emerged as promising markers of early cartilage changes. The purpose of this study was to examine the association of frontal plane malalignment with cartilage composition using quantitative MR imaging.

**Methods:** 38 subjects with knee OA were stratified into varus (n = 12, age: 61±2.9yrs; BMI: 28±6.7kg/m2; axis: 174±4.5°), neutral (n = 19, age: 56±6.5yrs; BMI: 27±5.9kg/m2 axis: 179±1.2°) or valgus (n = 7, age: 57±1.2yrs; BMI: 25±4.5kg/m2; axis: 183±8.2°) groups based on the anatomical alignment from weight-bearing flexed PA radiographs. MRI was done using a 3T GE Excite Signa MR Scanner. Sequences used were (i) high-resolution fat suppressed spoiled-gradient-echo (SPGR) (for cartilage thickness), (ii) T2-weighted fat-suppressed FSE (for clinical WORMS grade for OA severity), (iii) T2 and (iv) T2 maps. T1ρ and T2 relaxation times were quantified for the medial and lateral tibial and femoral condyles. Medial-lateral (M/L) ratio of T1ρ, T2 and thickness were calculated for tibia, femur. Pearson’s correlation was used to correlate alignment with T1ρ and T2 relaxation times of individual compartments and M/L ratios in subjects from varus and neutral groups pooled together. One way ANOVA was used for differences in M/L ratios between the 3 groups.

**Results:** Greater varus angle was associated with a higher M/L T1ρ ratio at the tibia and higher M/L T2 ratio at the femur and tibia (Table 1).

<table>
<thead>
<tr>
<th>Medial-Lateral Ratio</th>
<th>Femur</th>
<th>Medial-Lateral Ratio</th>
<th>Tibia</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1ρ</td>
<td></td>
<td>T2</td>
<td></td>
</tr>
<tr>
<td>Pearson/sr</td>
<td>0.073</td>
<td>0.012</td>
<td>0.002</td>
</tr>
<tr>
<td>p</td>
<td></td>
<td>0.041</td>
<td>0.010</td>
</tr>
</tbody>
</table>

M/L T1ρ ratio in femur showed a similar trend but did not reach significance. Greater varus was associated with a lower M/L ratio of cartilage thickness in femur and tibia. There were no significant correlations between alignment and T1ρ and T2 times of individual compartments. Varus group had lower M/L T1ρ ratio (p = 0.013) compared to the neutral group, and a lower M/L T2 ratio compared to the neutral and valgus groups (p = 0.004). The M/L ratios for femur did not show any group differences. Varus group had lower M/L of cartilage thickness in femur (p = 0.024) and tibia (p = 0.026) compared to valgus group, and lower ratio in femur compared to neutral group (p = 0.020).

**Conclusions:** The results show that varus is associated with higher T1ρ/T2 times at the medial tibio-femoral compartments relative to lateral, along with greater loss of cartilage in medial compartment. T1ρ times have been shown to be inversely related to proteoglycan content and T2 is more related to collagen anisotropy. The fact that malalignment was related to the M/L of T1ρ/T2 times rather individual compartment values, suggests that the relative loss of proteoglycan content and collagen disruption between the two compartments is more important than degeneration in any one compartment. These results are supported by literature suggesting that during functional activities, altered load sharing between medial and lateral tibial condyles, due to malalignment might be more related to OA progression than absolute loading. Hence, it is likely that strategies aimed at improving the medio-lateral load sharing could be more effective clinically than those aimed at reducing absolute loading. The results from this study also indicate that metrics from the interaction of T1ρ/T2 relaxations times and severity of malalignment could be very useful clinically in early identification of people with malalignment who are at risk of developing knee OA and those who have early pre-radiographic changes. Such a measure would be extremely useful to develop early and subject-specific interventions aimed at preventing or delaying the OA disease process. Analysis of additional subjects for laminar composition, meniscus T1ρ/T2 and longitudinal follow-up over 3 years is currently underway to assess the impact of malalignment on progressive changes in M/L cartilage composition.

**WORMS BONE MARROW LESION SCORES AND SEGMENTATION YIELD SIMILAR FINDINGS**

C. E. Hutchinson1, M. Parkes2, E.J. Marjanovic1, M.J. Callaghan1, L.M. Forsythe3, D.T. Felson3. 1Univ. of Warwick, Walsgrave, United Kingdom; 2Univ. of Manchester, Manchester, United Kingdom; 3Univ. of Manchester, Manchester, United Kingdom

**Purpose:** While extensive work has examined how to quantify cartilage and compared semiquantitative and quantitative approaches, no similar effort has been undertaken to evaluate whether semiquantitative assessments of bone marrow lesions (BMLs) in knees provide results that are close to volumetric measurements of BMLs. Since semiquantitative approaches may use the number of BML’s (count) and score BML size according to their maximal area within an MRI slice, semiquantitative approaches to scoring BML’s might not provide findings close to volumes. If they provided results similar to volumetric approaches, such tedious approaches as manual segmentation might be avoided in favour of quicker semiquantitative assessments.

In 30 patients who met ACR criteria for knee OA all of whom had BMLs on MRI, we tested whether BML volume assessed semiquantitatively using WORMS and a count of the number of BMLs correlated with volume of BML’s measured using segmentation approaches.

**Methods:** To assess BMLs in these 30 patients (11 Male, 19 Female, mean age 54.8yrs [SD 7.3], mean BMI 30.7 [SD 5.9]), we acquired knee MRIs using the following pulse sequences: axial PDW FS (TR 1500, TE 15, FOV 14 cm, 256x256) and sagittal 3D WATSE (TR 20 TE 7.7, FOV 15, 288x288). We manually segmented BML volumes for the whole knee using a strategy outlined (OARSI 2010) by MacLure et al, testing repeatability of BML volumes in 5 knees remeasured (ICC <0.99, p <0.0001). For the WORMS score we summed the scores for each quadrant from each region to give a total knee score and in each quadrant we also counted the number of BMLs and added these to get a count for the knee. To evaluate the relation of BML volumes, counts and WORMS scores in these nonparametric data, we plotted the values and checked Spearman rank correlation coefficients.

**Results:** The volume of BML’s and summed WORMS score correlated highly (see figure) with r = 0.85 (p <0.001). The correlation was also high for each of the patellofemoral and tibiofemoral regions. As shown in the figure, any disagreements between WORMS score and volume tended to be in one direction – an overestimate of volume by WORMS score, presumably because lesions had high maximal 2 dimensional area but this large area did not extend across multiple slices. The number of BML’s in the knee also correlated with BML volume although the association was considerably weaker than for summed WORMS score (r = 0.70, p <0.0001).

**Conclusions:** There was an excellent correlation between the BML score by WORMS and BML volume as determined by segmentation. The WORMS score is an effective method for the rapid assessment of the distribution of BMLs and correlates highly with the more laborious
method of lesion segmentation. Number of BML lesions correlates less well than WORMS score with their volume. There is a fixed error due to the nature of the WORMS method which biases the results in favor of higher WORMS measurements.

384 SENSITIVITY OF CEST MRI OF HUMAN KNEE CARTILAGE IN VIVO AT 3 T AND 7 T

Purpose: To evaluate the sensitivity of chemical-exchange-saturation transfer imaging of glycosaminoglycans (GAG) (gagCEST) on human knee cartilage in vivo at 3 T and 7 T.

Methods: The study was conducted under an approved Institutional Review Board protocol of the University of Pennsylvania. With an informed consent CEST imaging was performed on the knees of six healthy human volunteers using 18-cm diameter, eight-channel transmit-receive phased-array (PA) knee coil on Siemens 3 T (Magnetom Tim Trio, Siemens Medical Solutions, Malvern, PA) and 7 T MR scanner (Siemens Medical Solutions, Malvern, PA). A new pulse sequence was designed to use a frequency selective saturation pulse train followed by a segmented RF spoiled gradient echo (GRE) readout sequence. The sequence parameters were: slice thickness = 5 mm, GRE flip angle = 10°, GRE readout TR = 5.6 ms, TE = 2.7 ms, field of view = 140 × 140 mm², matrix size = 128 × 128, and one saturation pulse and 128 segments acquired every 10 sec to enable full T1 recovery. Multiple CEST images were collected using a saturation pulse with average B1rms of 31 (0.7 mT) and saturation offsets relative to water ranging from −3.0 to +3 ppm in steps of 0.1 ppm. The total scan time was ~30 minutes. To alleviate B0 and B1 inhomogeneity contribution from CEST effect, B0 and B1 maps from the same imaging slices were obtained.

Results: Without any corrections for B0 inhomogeneity a clear shift (~0.5–0.6 ppm) in the Z-spectra was observed in the human knee cartilage. This shift in the human data is removed after correcting for the B0 inhomogeneity. Without any correction for B0 large gagCEST effect (20–25%) was observed on cartilage (Figures 1, 2). After B0 correction, with the imaging and saturation pulse parameters used, the calculated average gagCEST from cartilage was ~1% at 3 T (Figures 1, 2) and 7.4 ± 0.3% at 7 T (Figure 3). The effect of B1 inhomogeneity was minor in the current study.

Conclusion: Because of the uneven geometry of human knee, despite extensive shimming of B0 field, there is a substantial B0 field variation in knee cartilage. Without correction for the B0 field inhomogeneity, spuriously large (20–30%) gagCEST effect is observed in knee cartilage in vivo. Correction of the B0 inhomogeneity has shown that there is only a very small (~1%) gagCEST observable in cartilage in vivo at 3 T and a significantly larger gagCEST of ~7% at 7 T. Since GAG loss from cartilage is expected to result in further reduction in gagCEST, this method is not expected to lead to accurate quantification of GAG content in healthy as well as in degenerated cartilage at 3 T. However, given the magnitude of gagCEST measured at high fields such as 7 T, this technique holds promise for studying cartilage degeneration at 7 T and higher fields.

385 THE MINIMAL CLINICALLY IMPORTANT DIFFERENCE (MCID) IN CARTILAGE VOLUME AND THICKNESS CHANGE IN PERSONS WITH KNEE OSTEOARTHRITIS
E. Losina1, J. Collins1, D.J. Hunter2, F. Eckstein3, M.C. Nevitt4, S. Cotofana5, C.K. Kwoh5, J.N. Katz1. 1Brigham and Women’s Hosp., Boston, MA, USA; 2University of Sydney, Sydney, Australia; 3Paracelsus Private Med. Univ., Salzburg, Austria; 4Univ. of California, San Francisco, CA, USA; 5Univ. of Pittsburgh and Pittsburgh VAHS, Pittsburgh, PA, USA

Purpose: Investigators use quantitative cartilage morphometry to document longitudinal changes in osteoarthritic knees. With rapid evolution in the capacity of MRI to detect small changes, clinicians confront the question of how much change is clinically meaningful. We sought to establish the minimal clinically important difference in MRI-based longitudinal cartilage evaluation of persons with knee OA.

Methods: We used data from one knee per person of 429 participants of the Progression Cohort of the Osteoarthritis Initiative (OAI), defined by the presence of frequent symptoms and definite radiographic knee OA, who had baseline and 24 month quantitative MRI assessment. Manual tracing of the total subchondral bone area of the medial/lateral tibia (MT/LT) and central (weight-bearing) medial/lateral femoral condyle (cMF/cLF) was performed by Chondrometrics GmbH (Ainring, Germany) and publicly released. We considered the mean cartilage thickness over the entire subchondral bone area with (ThCcAB) and without (ThCtAB) denuded areas. Results for the medial and lateral femorotibial compartments were obtained by summing values of MT + cMF and LT + cLF respectively. We defined the MCID in cartilage volume and thickness changes from baseline to 24 months using the indirect anchor method, in which changes exceeding a previously established minimum "anchor" are considered clinically important. The anchor was defined by worsening by at least 13 points on WOMAC Function scale (Angst, 2001). MRI-based morphologic measures were compared between knees that showed discrimination between those who did and who did not achieve the MCID at a 0.05 significance level.

Results: Among 429 knees, 43% had K-L grade 2 and 54% K-L grade 3. 68% had OA in medial compartment. 11% worsened by at least 13 points in WOMAC Function score over 24 months. A limited set of MRI-based cartilage morphology measures discriminated (at p = 0.05) between those who did and those who did not worsen in WOMAC Function by the MCID. These included cartilage volume, cartilage thickness (including and excluding denuded area) as well as the area of subchondral bone covered by cartilage – all measured in the central (weight-bearing) medial femur.

Fig. 1. 3 T.

Fig. 2. 3 T.

Fig. 3. 7 T.