Osteoarthritis: Regional and Subregional Quantitative Assessment of Trabecular Bone Micro-Architecture via 7T MRI

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Introduction. Osteoarthritis (OA) affects approximately 46 million Americans with annual healthcare costs of approximately $127 billion. The pathogenesis of OA is multifactorial, but especially involves interactions between articular cartilage degeneration and alterations in subchondral bone. OA progression takes places in a spatially heterogeneous fashion, typically affecting the medial compartment to a greater degree than the lateral compartment. The goal of this study was to utilize high resolution 7T MRI to perform a regional and subregional quantitative assessment of trabecular bone micro-architectural changes in the knee for subjects with osteoarthritis and healthy controls.

Methods. Six human subjects (4 OA patients, age: 62 y +/- 4.3; 2 healthy controls (H), age: 36 y +/- 9.9) were recruited for this study. All subjects were scanned on a 7T whole body MR scanner (Siemens, Erlangen, Germany) using a quadrature knee coil (18 cm diameter, transmit-receive). We utilized a high-resolution 3D-FLASH sequence (TR/TE=20/4.5 ms; flip angle, 10°; 130 axial images (195µmX195µm X1000µm resolution); bandwidth 130 Hz/pixel; one signal acquired). The study was approved by the institutional review board. Bone volume fraction (BVf) images were computed from MR images using local marrow intensity-derived linear mapping functions accounting for space varying RF coil signal and requiring no thresholding. Four anatomic compartments, namely, medial femoral condyle (MFC), lateral femoral condyle (LFC), medial tibial plateau (MT), lateral tibial plateau (LT), were manually drawn on each MR image. Each compartment was further subdivided into four or eight angular subregions for analyses (see Figures 1a and 1b). Fuzzy algorithms were applied to determine total bone volume (TBV) and apparent bone density (ABD). Digital topological analysis (DTA) was applied to determine bone surface-curve ratio (S/C, marker of plate-to-rod ratio) and bone erosion-index (EI, marker of topological sparsity). DTA was also applied to marrow volume fraction images (MVF, an inverse of BVF image) to determine marrow S/C and marrow EI. Student's unpaired t-tests were utilized to determine the statistical differences between two groups.

Results. At the compartment level, OA subjects demonstrated decreased TBV compared to healthy subjects for MFC, LFC, MT, and LT (p<0.05). At the 4-subregion (R) level, OA subjects demonstrated decreased TBV within R2 and R4 of MFC, LFC, MT, and LT (p<0.05). In addition, within LT, OA subjects demonstrated decreased marrow EI within R1 and decreased ABD within R2 (p<0.05). Within MT, OA subjects demonstrated decreased TBV within R2 and R4 of MFC, LFC, MT, and LT (p<0.05). In addition, within MT, OA subjects demonstrated decreased TBV in R2 and R4 of MFC, LFC, MT, and LT (p<0.05). At the 8-subregion level, OA subjects demonstrated: decreased TBV within R3, R4, R7, R8 of LFC; decreased TBV, ABD, and bone S/C within R3 of the LT; decreased TBV within R4 and R8 of LT; decreased marrow EI within R2, R6, R7 of LT; decreased TBV within R1, R2, R6 of MT, decreased TBV and ABD of R7 of MT, decreased marrow EI of R3, R6 of MT (p<0.05 for all). Selected results are shown below.

Conclusion. 7 Tesla MRI can detect changes in trabecular bone micro-architecture in subjects with OA compared to healthy controls. While compartmental analysis identified differences only in TBV, subregional analysis allowed detection of topological differences in trabecular bone micro-architecture between groups. This technique could potentially provide more accurate characterization of the spatial distribution of pathologic bone changes within the osteoarthritic knee joint.