Balanced SSFP profile asymmetries in cartilage

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Introduction: Osteoarthritis of the knee affects approximately 30% of the American population over 60 [1]. Currently osteoarthritis cannot be detected until after significant cartilage degradation. Early detection of reduced glycosaminoglycans (GAGs) in cartilage would be useful for early diagnosis of osteoarthritis. The gagCEST contrast mechanism succeeds in imaging GAGs thanks to their asymmetric z-spectrum [2]. An alternative way to capture this asymmetry is by using a balanced SSFP sequence, because the SSFP frequency profile is affected by the lineshape of the tissue [3]. Recently it has been shown that the SSFP profile of white matter in the brain has an asymmetry in its frequency profile [4]. We used balanced SSFP to look for the asymmetry in cartilage.

Methods: The full balanced SSFP profile can be obtained by acquiring a series of SSFP images with different RF phase increments. Sweeping the phase increment from $-\pi$ to π is the equivalent of sampling the SSFP profile at frequencies ranging from ±(1/2TR). We obtained the frequency profile of the tibia from one fresh-frozen female (age 67) cadaver. The specimen was scanned on a 1.5T GE Excite system, using a 3-inch surface coil, and a 3D balanced SSFP sequence with bandwidth ±64 kHz, 10cm FOV, 18 slices, and resolution of 0.3x0.3x3mm. Setting TR = 10ms (TE = 5ms) gave us a frequency profile ranging from ±50Hz. We sampled this range of frequencies in increments of 1.5Hz, which resulted in 67 individual scans and a total scan time of 52 minutes. We then looked at the SSFP profile in six regions of interest (in cartilage, bone, and the saline water on which the specimen was placed). For each of the ROIs we computed an asymmetry index $AI = (h_p - h_n)/(h_p + h_n)$ where $h_{p,n}$ is the peak signal for positive and negative frequencies respectively [4].

Results: Figure 1 shows two slices through the specimen, and the frequency profiles at six regions of interest (ROI) labeled A-F. Regions A and D were located in cartilage, and they exhibit the greatest extent of asymmetry. Unlike cartilage, the trabecular bone profile (B,E) is reasonably symmetric. As expected, the saline water profile (C,F) is the most symmetric and was used as a sanity check.

Discussion: We observed an asymmetry in the cartilage spectrum which is likely due to the gagCEST effect. While our scan time is 52 minutes, this can be reduced by a factor of 8 using a stack-of-segmented EPI sequence [4]. However, since this study is a proof of concept, we sacrificed speed for the sake of SNR and robustness. The differences in the general shape of the frequency profiles of cartilage (A, D), bone (B, E) and water (C, F) can be attributed to the different T_1 and T_2 parameters of the material, but the asymmetry in cartilage (A,D) is unique and cannot be explained by T_1 and T_2 alone. Through the asymmetry index, the balanced SSFP technique provides a novel contrast mechanism for imaging cartilage. The observed asymmetry in the cartilage profile is consistent with the work of Ling et al. [3] which showed that glycosaminoglycans (GAGs) in cartilage have an asymmetric z-spectrum. SSFP asymmetry due to gagCEST may provide a new method for assessment of GAG content in articular cartilage.

References: [1] Dillon et al, J Rheumatol. (2006) [2] Ling et al. Proc Natl Acad Sci 105 (2007) [3] Scheffler et al. NMR Biomed 490 (2001) [4] Miller et al. ISMRM 3068 (2008)

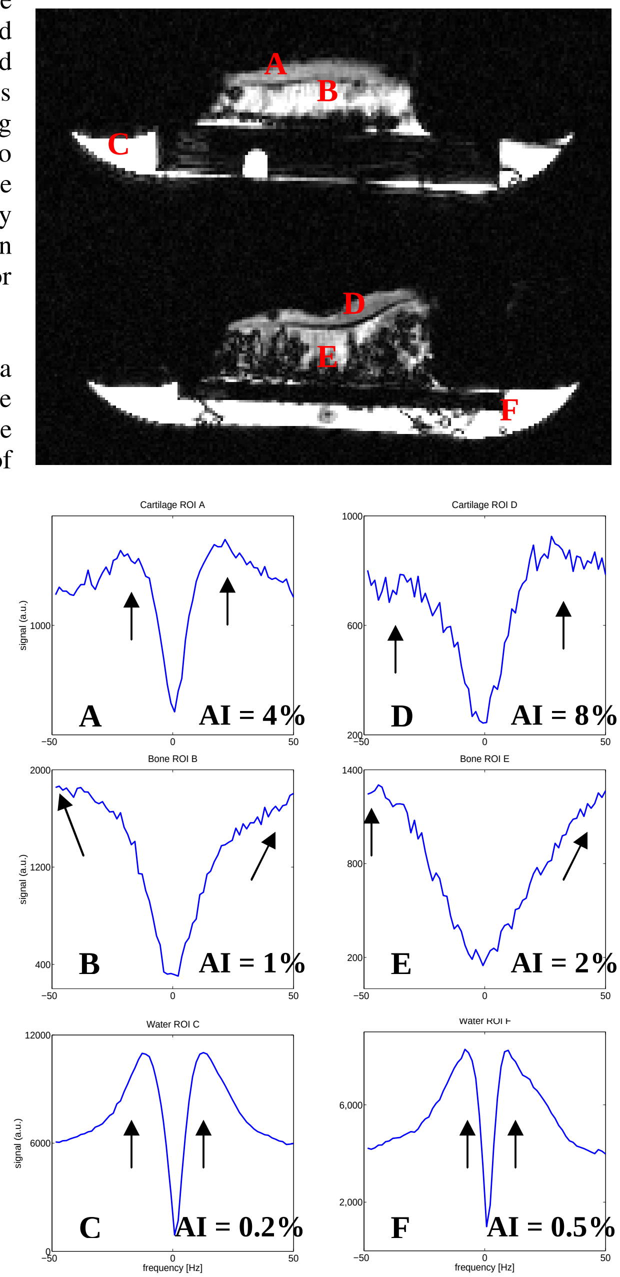

Figure 1: *(Top) Two slices of an ex-vivo tibia specimen, with letters A-F indicating the regions of interest analyzed. (Bottom) Balanced SSFP profiles in the six regions of interest with their corresponding asymmetry index (AI). The arrows indicate the peaks where the AI is computed. The AI in cartilage (A,D) is high compared to the AI in bone (B,E), and saline water (C,F).*