Evaluation of Accelerated T1ρ Acquisition of the Cartilage Using a Combination of Compressed Sensing and Data Driven Parallel Imaging

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Introduction:

Advanced MRI cartilage imaging such as T1-rho (T1ρ) provides information associated with cartilage matrix changes and enables early detection of cartilage degeneration [1]. T1ρ acquisition times are relatively long since they require acquisition of multiple echoes. Parallel imaging (PI) methods are commonly used to accelerate the acquisition but the acceleration factor is limited by the number of coils used to acquire the signal. Compressed Sensing (CS) is a new method for accelerating the acquisition and does not require multiple coils. It uses the sparsity and compressibility property of the MRI signals to remove artifacts induced by under-sampling the acquisition [2]. This technique could potentially be used to further reduce the acquisition time or to increase the resolution while keeping similar acquisition time. The aim of this study was to evaluate a combination of CS and data driven PI (ARC) acquisition [3] to accelerate T1ρ quantification.

Methods:

The T1ρ MR images of an ex-vivo porcine knee were acquired using a transmit-receive 8 channels knee coil on 3.0-T scanner with a MAPS pulse sequence [4] (time of spin-lock (TSL) = 0/1/2/4/8/20/40/80ms; spin-lock frequency: 500Hz; matrix resolution 256x128x40; field of view = 140mm). Fully sampled data as well as undersampled data with ARC = 2 combined with different CS acceleration were acquired. The full sampled data were also used to simulate a large range of acceleration. The images from the eight echoes were then reconstructed with CS followed by ARC. The CS reconstruction used a conjugate gradient solver to find an image with the minimum L1 norm of its gradient. The T1ρ maps were reconstructed by fitting the T1ρ weighted images pixel by pixel to the 2 parameter mono-exponential equation. The cartilage were segmented in 6 compartments (LFC: lateral femoral condyle; LT: lateral tibia; MFC: medial femoral condyle; MT: medial tibia; Pat: patella; T: trochlea).

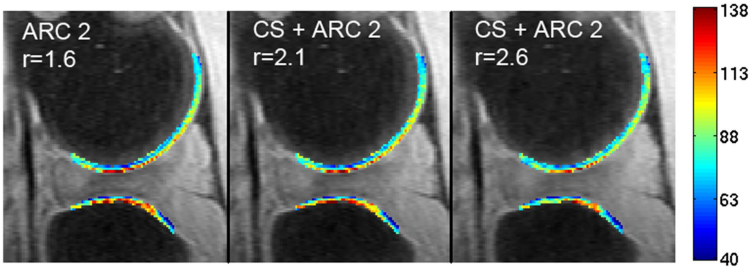

Figure 1 (above): T1ρ maps of the lateral tibia and femoral condyle overlaid on the image corresponding to TSL=0 (gray scale). r: net acceleration.

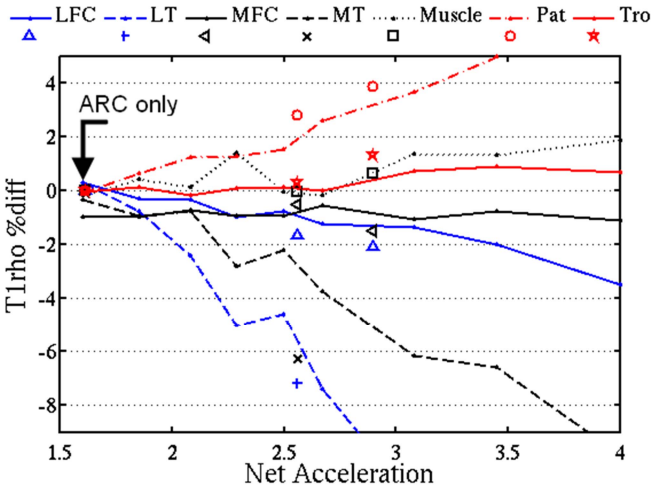

Figure 2 (right): Simulated (lines) and acquired (markers) T1ρ percentage difference measured between non-accelerated and under-sampled images.

Results:

Figure-1 shows the T1ρ maps overlaid on the first echo of the corresponding acquisition. CS combined with ARC results in lower noise in the image but suffers from slight blurring. The T1ρ percentage differences between accelerated and non accelerated acquisitions and simulation are presented in Figure-2. This graph shows good agreement between results from the simulations and from the acquisitions. The T1ρ value of all femur compartments (MFC, LFC and Tro) and of the muscle did not exceed 2% deviation for the acceleration lower than 4 while LT, MT and Patella compartments exceeded a 2% difference for the acceleration greater than 2.1, 2.3 and 2.6 respectively.

Discussion:

This preliminary data shows the feasibility of combining CS and PI to accelerate T1ρ quantification. The in vivo reproducibility of cartilage T1ρ quantification was reported to be approximately 5% [4]. In muscle, the quantification was not significantly affected (< 2%) even at acceleration at 4. However, in cartilage, the effect on quantification was compartment dependent. While the femoral cartilage T1ρ quantification was not affected significantly (< 2% at all acceleration), the tibia compartments were the thinnest structures analyzed here (less than 1mm thickness) and suffer form higher deviation at high acceleration. It may be explained by that the CS reconstruction introduces filtering of the image causing deviation of the T1ρ value. Human cartilage is normally thicker than the pig specimen we examined in this pilot study, except for at late stages of osteoarthritis. Quantitative MRI (T1ρ and T2 quantification) is most promising at evaluating early stages of osteoarthritis (as morphologic MRI is able to provide information at late stages of OA), therefore this advanced acceleration technique can be potentially applied in human studies. We will further explore using correlation between echoes to improve quantification accuracy with higher accelerated acquisition.

Conclusion:

Advanced acceleration techniques combining CS and PI have great promise to improve clinical applications of quantitative MRI. We are currently applying this technique to in vivo human scans and evaluating the clinical significance.

[1] Li et al, Osteoarthritis Cartilage 2007 [2] Lustig et al, MRM, 2007 Dec.; 58(6):1182-1195 [3] King et al, Proc ISMRM, 2010, #4881. [4] Li et al, MRM. 2008-Feb;59(2):298-307.

Acknowledgement: The research was supported by GE Healthcare. .