Quantitative 3D T1ρ Dispersion Imaging at 3T for Bilateral Leg Muscles

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INTRODUCTION

- **Purpose:** T1ρ dispersion imaging is an emerging MRI technique for characterizing muscle tissue changes associated with aging, fibrosis, and metabolic conditions. However, it is typically restricted to research settings, utilizing single-slice imaging and dedicated transmit-receive coils. This study evaluates the feasibility of a fast 3D T1ρ dispersion imaging technique for quantitative, bilateral leg muscle assessment using a clinical body receive-only array coil on a 3T scanner.
- **Innovation/Impact**: While T1ρ dispersion imaging provides valuable functional and metabolic insights for muscle evaluation, its clinical adoption is hindered by long acquisition times. The requirement for multiple independent repetitions at varying spin-lock frequencies (F_{SL}) and spin-lock times (T_{SL}) becomes clinically prohibitive when high F_{SL} resolution is needed. In this work, we demonstrate the feasibility of quantitative 3D T1ρ dispersion imaging of bilateral leg muscles within a clinically viable scan duration using a standard clinical setup. This advancement facilitates broader clinical utility of T1ρ dispersion imaging for musculoskeletal evaluation.

METHODS AND MATERIALS

- **Data Acquisition**: Imaging was performed on a 3T Philips Ingenia scanner using a modified 3D MAPSS sequence with unpaired phase cycling [1]. To generate T1ρ dispersion curves, 20 FSLs (0–300 Hz, 15.75 Hz increments) were acquired at TSL = 20 and 30 ms, plus a shared TSL = 0 ms, totaling 41 independent 3D acquisitions (9:37 total scan time). Parameters included: FOV = 400x207x180mm^3, voxel size=1.2x1.6x6mm^3, TR/TE = 8.0/3.7 ms, TFE factor = 128, IR delay = 1s, and Compressed SENSE (CS) factor = 4. For each acquisition, unique k_y-k_z undersampling patterns were applied (central size 14x8). A reference "Full Acquisition" protocol with paired phase cycling was applied on the same thigh muscle bilaterally (19:14 total scan time).
- **Image Reconstruction**: Images were reconstructed via BART using *l2*-norm compressed sensing (λ =0.005) followed by non-linear curve fitting for T1ρ dispersion map generation. Region of interest analysis was performed to quantitatively compare the results from the two datasets.
- **T1ρ Map Generation**: T1ρ maps at different FSLs were iteratively reconstructed voxel-by-voxel using a mono-exponential signal model as described in [1, 2]. Specifically,

$$Signal\ model:\ S^*\left(T_{1\rho}(FSL), TSL\pm\right) = \pm S_A e^{-\frac{TSL}{T_{1\rho}(FSL)}} + S_B,$$

$$S_A, S_B, T_{1\rho} = \underset{S_A,S_B,T_{1\rho}(FSL)}{\arg\min} \left\{ \sum_{FSL,TSL\pm} \left\| S\left(T_{1\rho}(FSL), TSL\pm\right) - S^*\left(T_{1\rho}(FSL), TSL\pm\right) \right\|^2 \right\},$$

where S* and S are the modeled and acquired signals, respectively

RESULTS

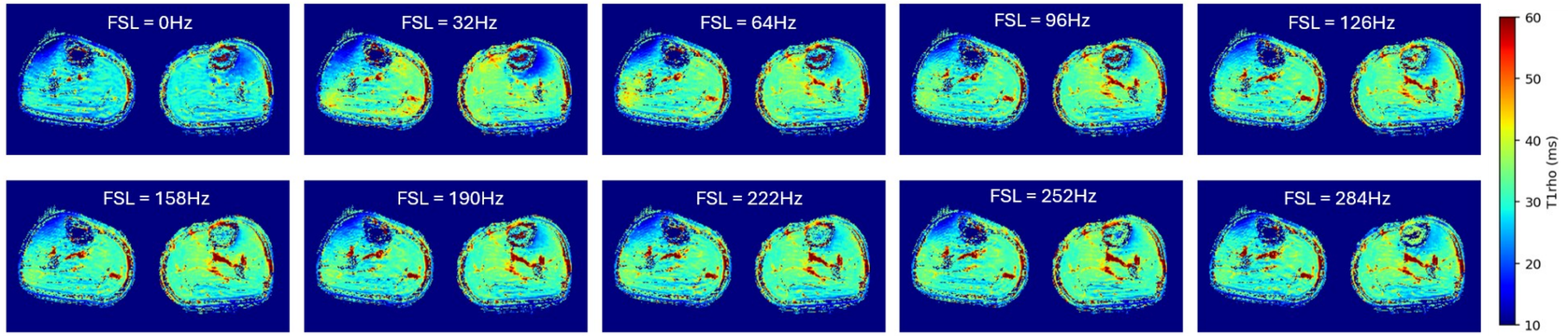

Figure 1: Representative T1ρ maps at different FSL using the fast T1ρ dispersion imaging sequence and the proposed image processing for map generation.

- **Visual Inspection Results (Figure 1)**:
  - T1ρ maps had high spatial resolution, which could minimize signal contamination and partial-volume effects from fat, bone, and blood tissues.
  - T1ρ maps obtained from the accelerated T1ρ dispersion protocol presented expected general trend of T1ρ dispersion for muscle tissues.
  - Additionally, localized quantitative deviations occurred in anatomical regions prone to B0 and B1 inhomogeneities, specifically the anterior bilateral corners
- **Quantitative Results**: The accelerated T1ρ dispersion protocol yielded values slightly lower than the reference (average difference 4.7%) but maintained an increasing T1ρ trend at higher FSL, consistent with the full acquisition protocol **(Figure 2)**.
- **Discussion**: Our findings demonstrate the clinical feasibility of a fast 3D T1ρ dispersion imaging protocol for bilateral lower extremity evaluation at 3T. By leveraging an unpaired phase cycling 3D MAPSS sequence coupled with Compressed SENSE undersampling, we successfully reduced the total acquisition time by roughly 50% (9:37 vs. 19:14 minutes) compared to the reference protocol. Visually, the accelerated T1ρ maps exhibited high spatial resolution, effectively mitigating partial-volume artifacts from adjacent fat, bone, and vasculature.

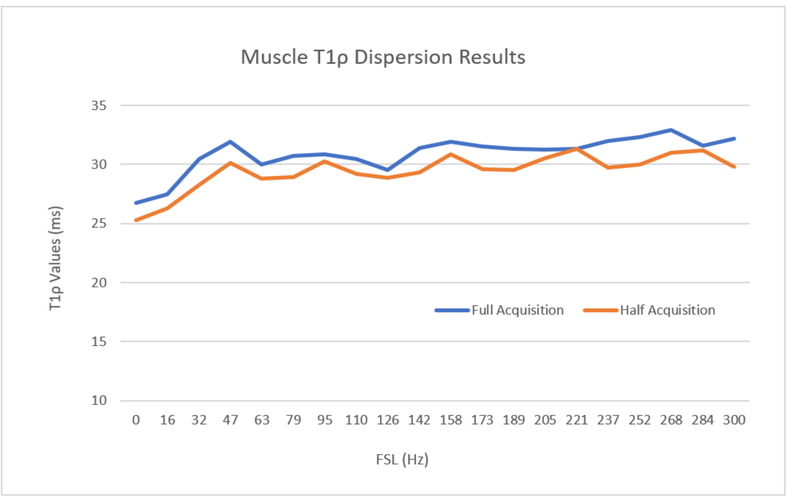

Figure 2: Quantitative T1ρ dispersion comparison between full acquisition and accelerated acquisition protocols.

- **Outlook:** Given these promising results, implementing more aggressive undersampling patterns could further curtail scan times, paving the way for the broader translation of T1ρ dispersion mapping into routine clinical musculoskeletal research.

CONCLUSIONS

- This work demonstrates that 3D T1ρ dispersion imaging of the lower extremities is feasible under regular clinical settings.
- The high consistency between the accelerated and reference protocols suggests that further undersampling may be possible, facilitating broader clinical research adoption.

REFERENCES

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2. Peng Q, Peng GW, Wu C. Integrated T1rho Dispersion Imaging and Quantification, *Proc Intl Soc Mag Reson Med* 30, London, p3441, 2022.