Multi-parametric Characterization of Polymyositis at 3.0 T: A Preliminary Study

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Introduction: Polymyositis (PM) is a form of Idiopathic Inflammatory Myositis (IIM), which is a collection of chronic autoimmune diseases with muscle inflammation, fat infiltration/replacement, and atrophy. PM patients experience weakness, pain, fatigue, and difficulties in daily activities. Common laboratory tests show elevated serum concentrations of creatine kinase (CK), lactate dehydrogenase (LDH), and Aldolase. However, no correlations have been established between the variations in clinical presentation of these diseases and these lab markers. Magnetic resonance imaging (MRI) and ^{31}P spectroscopy have been used to identify inflammation, fat infiltration and metabolic abnormalities [1-3]. Particularly, diffusion weighted (DW) and diffusion tensor (DT) MRI [3] are of interest as these techniques measure water molecular diffusion, and the resulting quantitative indices are correlated with muscle fiber structure at a microscopic level [4]. In this work, several quantitative methods, including Dixon fat/water imaging [5], transverse relaxation (T_2), and diffusion tensor imaging (DTI) have been applied for the first time in a PM patient at 3.0 Tesla. The quantitative indices are compared to those from a gender- and age-matched control subject. It is shown that these quantitative methods may provide an improved understanding of the pathological processes associated with PM at a microscopic level, and can objectively and quantitatively characterize the severity of muscle damage on an individual basis.

Methods: *Subjects*: The diagnosis of PM was performed by a rheumatologist. A gender- and age-matched subject served as a control. The subjects lay supine in a feet-first position. Forty-eight-hour activity restriction to dietary, exercise, and non-prescription medication was applied for the subjects to achieve a stable physiological condition. *Data acquisition*: Images were acquired from the middle point of foot-head direction on the right leg. Data were collected on a 3.0-T Philips Achieva MR scanner (Philips Healthcare, Best, The Netherlands), with a two-channel body coil for excitation and a six-channel SENSE cardiac coil for signal reception. The DTI sequence parameters were: FOV = 256×256 mm^2, slice thickness = 7 mm, 11 slices, TR = 4000 ms, TE = 48 ms, b-value = 450 s·mm^{-2} in 15 directions (and one $b = 0$ image), SENSE factor = 1.5, matrix size = 128×128, single-shot spin-echo echo-planar imaging (EPI) readout. The Dixon imaging sequence had a first echo time of 1.34 ms and the spacing of the subsequent two echoes was 1.53 ms. The multi-echo sequence T_2 sequence had specially designed 180° composite refocusing pulses and crusher gradient patterns [6], with thirty-two echoes acquired with a spacing of 10 ms. High-resolution T_1-weighted (T_{1w}) images were acquired for anatomical reference. *Data analysis*: DTI data were fitted to a tensor model. Multi-echo data were fitted to a single exponential decay model. Dixon data were processed using an iterative approach [5]. All data were registered to Dixon second echo images or water fraction maps. For the control subject, to determine the parameters of each muscle, regions-of-interest (ROIs) were drawn along the muscle boundaries and pixels affected by partial volume effects and flow artifacts were excluded.

Results Example T_{1w} images, fat fraction, T_2, and apparent diffusion coefficient (ADC) maps are shown in Figure 1. To ensure that data were obtained from voxels primarily composed of muscle tissue, we used a water signal fraction threshold of ≥0.5 in the Dixon data to mask out fat-dominated voxels in the T_2 and ADC maps. Substantial fat infiltration and replacement were identified in the patient, as shown in the T_{1w} image. Fat infiltration and replacement were further quantified in the fat fraction map. For the healthy control, the fat fractions of all muscles are between 0.04 – 0.11. However, for the patient, an average fat infiltration of 0.78 was observed in most muscles except gracilis (GR) and sartorius (SA), with fat fractions of 0.64 and 0.49, respectively. The fat infiltration can also be identified from elevated T_2 values as shown in the T_2 map. For most muscles in the patient, the ADC values were higher except in the GR muscle, which may indicate muscle inflammation. As an example, the T_2/ADC values of the rectus femoris muscle in the patient and control were 60 ms / 2.3×10^{-3} mm^2/s, and 29 ms / 1.9×10^{-3} mm^2/s respectively. Quantitative analyses also indicate that more healthy muscle fibers are present in the GR muscle of the patient.

Discussion: Dixon fat/water imaging, multi-echo T_2 and DT-MRI methods have been used for the first time in a PM patient to identify fat infiltration and inflammation. Future work includes the optimization of the multi-echo sequence for fully refocusing of all components, performing multi-exponential analysis with the multi-echo data, and performing fiber tracking to obtain muscle fiber structural parameters.

Figure 1, Example T_{1w} image, Fat fraction, T_2, and ADC maps in the patient and the control. T_2 and ADC are masked with water fraction > 0.5.

References: [1] Park JH et al, *Radiology*, 177:473 (1990); [2] Park JH et al, *Arthritis & Rheumatism*, 38:68 (1995); [3] Qi J et al, *JMRI*, 27:212 (2008); [4] Damon BM et al, *MRM*, 48:97(2002); [5] Berglund et al, *MRM*, 63:1659 (2010). 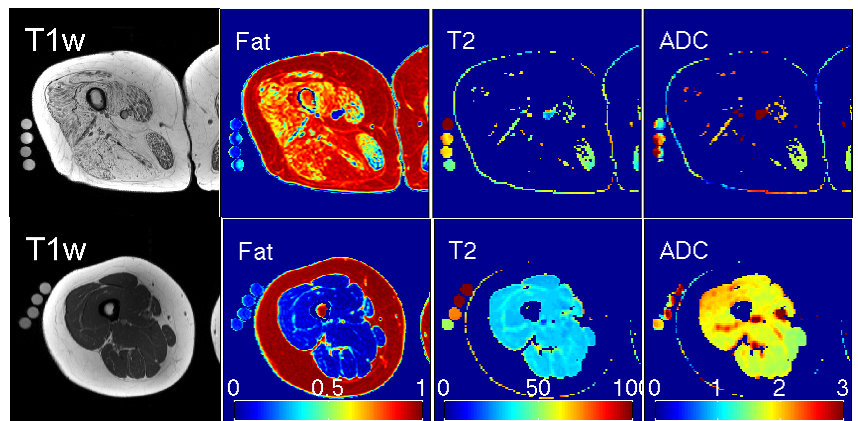[6] Poon CS et al, *JMRI* 2:541(1992)