Diffusion Tensor Magnetic Resonance Imaging (DTI) of Abnormalities in the Thigh Muscles of Polymyositis Patients

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Introduction: Polymyositis (PM) is an inflammatory muscle disease, which is characterized by severe proximal weakness, fatigue, elevation of serum levels of muscle enzymes, abnormal EMG, and muscle biopsy. MRI demonstrates heterogeneous pathology in PM patients, ranging from unaffected muscles to severe inflammation, fat infiltration, and more serious fat replacement. Using diffusion-weighted imaging (DWI), we previously examined the fluid motion within the muscle as proposed by Le Bihan et al (1,2). In this investigation, the newer technique of diffusion tensor imaging (DTI) was employed. Fluid motion was defined at a molecular level in terms of apparent diffusion coefficients (ADC), eigenvalues (λ_1, λ_2, λ_3), fractional anisotropy (FA), and fiber tractography (3,4). Fluid motion and fiber structure are important factors for transport of metabolites and oxygen required for muscle contraction.

Methods: In order to identify unaffected, inflamed, and fat-infiltrated muscles, the thighs of 2 PM patients were examined on the basis of T1- and T2-weighted images, STIR images, and T1 and T2 relaxation times (Figure 1). Patient No. 1 showed focal inflammation in the vastus lateralis (VL) and adductor magnus (AD). Patient No. 2 with chronic disease demonstrated fat infiltration in the vastus lateralis (VL), intermedius (VI), and medialis (VM), and also in the adductor (AD). Both patients had 3 unaffected muscles, namely the biceps femoris (BI), semitendinosus (ST), and semimembranosus (SM), which showed normal imaging characteristics. For DTI images, a diffusion weighted spin-echo echo-planar imaging (EPI) pulse sequence along the X, Y, Z, XY, XZ, and ZY directions was used to examine 15 transaxial slices that were 0.5 cm thick with no interslice gaps. Apparent diffusion coefficients (ADC), eigenvalues (λ_1, λ_2, λ_3), fractional anisotropy (FA), and fiber tractography were determined with the Philips diffusion registration tool (PRIDE).

Results: For Patient No. 1, inflamed muscles had significantly higher ADC values than 3 unaffected muscles with no inflammation (1.75 ± 0.03 vs $1.57 \pm 0.02 \times 10^{-3}$ mm^2/s, $P = 0.03$). In Patient No. 2, fat-infiltrated muscles showed lower ADC values than the unaffected hamstring muscles (1.37 ± 0.08 vs $1.61 \pm 0.04 \times 10^{-3}$ mm^2/s, $P = 0.05$). λ_1, which has been reported to be directionally parallel to the long axis of muscle fibers, was greater for inflamed muscles compared to unaffected muscles and smaller in fat-infiltrated muscles. Unaffected PM muscles were not statistically different from normal control muscles. With selected regions of interest (ROI), tractography showed that fiber lengths in diseased muscles were less uniform and significantly shorter than those in unaffected muscles (13.9 ± 2.0 vs 42.8 ± 3.1 mm, $P = 0.002$).

Conclusions: DTI provides information for muscle characterization of water movement at a molecular level. ADC values indicate increased motion in the inflamed muscles and decreased movement in fat-infiltrated muscles. λ_1 values demonstrate anisotropy in the Z direction of muscle fibers in all PM muscles. Fiber tracking indicates fragmentation of fibers in the presence of fat infiltration as well as inflammation. With appropriate selection of small ROIs, spatial progression of abnormalities within a given muscle can be ascertained. DTI has the potential for evaluation of diffusion of energy-rich substrates and oxygen within diseased muscles and elucidation of the pathophysiology of myositis patients.

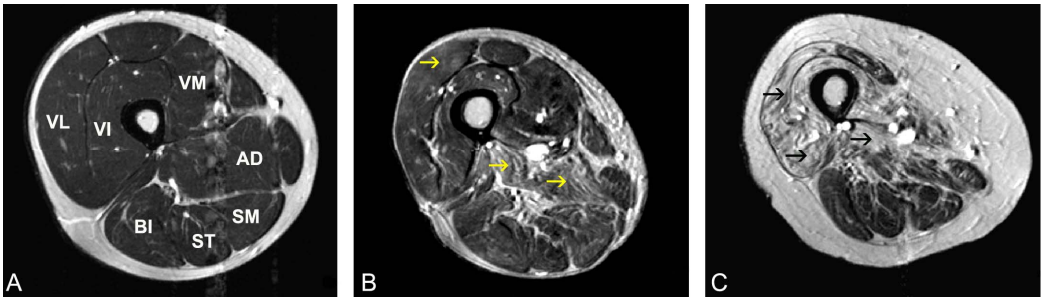

Figure 1. T2-weighted images of the thigh of (A) normal control, (B) PM patient with inflammation (arrows), and (C) PM patient with fat infiltration (arrows).

References: 1. Le Bihan D, et al. Radiology 1986:161:401-407; 2. Qi J, et al. J Magn Reson Imaging 2008:27:212-217; 3. Le Bihan D, et al. J Magn Reson Imaging 2001:13:534-546; 4. Damon B, et al. J Applied Physiol 2007:103: 673-681