In-vivo calf muscle fiber tractography: rest and stress conditions.

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Introduction:

The lower extremity is a structurally complex muscular organ with unique functional versatility. It is comprised of a network of interwoven muscle fibers that, in concert, produce the variations in shape and position necessary for locomotion. Accordingly, the three-dimensional analysis of leg muscle architecture is indispensable to an understanding of its function. However, such analysis has not been possible till now since techniques for non-invasive determination of fiber organization at each spatial location in the tissue were not available. Diffusion tensor imaging (DTI) studies of muscle have been performed in-vitro on striated muscle and fiber directions obtained from DTI have been shown to conform to those obtained by histological examination. The focus of this work is to investigate the feasibility of muscle fiber tracking in-vivo to monitor changes from the rest state to a stress state (e.g., when subject is performing plantor flexion). DTI in the calf muscle poses additional problems compare to brain tissue: one arising from the lower T2 of muscle and the other from significant amount of fat in the extremities.

Method:

For this study, data from ten healthy adult volunteers were acquired using a 3.0 T scanner (Magnetom Trio®, Siemens Medical Solutions, Erlangen, Germany) with an extremity coil. Diffusion weighted mages in the axial and sagittal views were acquired from the mid-calf region on a Siemens, 3T Trio, with the leg in a relaxed state, using an extremity coil. Image acquisition parameters were: TE/TR/FOV:Matrix::69/3300/200x165/128x128. A 'b' value of 600 s/mm2 (in contrast to 1000 s/mm2) was used since higher b-values resulted in a very low SNR for the diffusion weighted images. The choice of low b-values also allowed minimum TE times of 67 ms. Further reductions in total readout time per slice were achieved by using a rectangular field of view as well a 5/8 Fourier acquisition along the phase encode direction. Fat saturation was performed either with a non-slice selective fat saturation pulse or with a short inversion recovery sequence. Of the two methods, the STIR sequence was more effective in fat suppression although a SNR decrease was also seen in muscle compared to the fat saturation method. The diffusion weighted images were processed off-line using software written by us in IDL to generate the diffusion tensor at each voxel, this was diagonalized to obtain the eigenvalues and corresponding eigenvectors (Fig. 1 and 2). . Fiber tracking (Fig. 3)was performed by using the free software dTV for MR-DTI analysis developed by Image Computing and Analysis Laboratory, Department of Radiology, The University of Tokyo Hospital, Japan. The software *dTV* is available via following URL: http://www.ut-radiology.umin.jp/people/masutani/dTV.htm"

Results:

Results are summarized in the three figures and the figure legends.

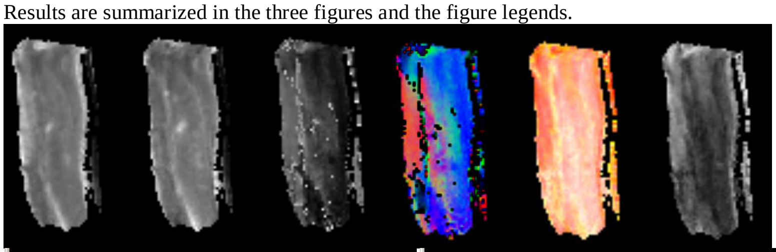

Figure 1 Rest. The images are in order (left to right): image of the primary eigenvalue, secondary eigenvalue, angle made with the SI axis, color map of the projection of the leading eigenvector (blue:SI, red:LR, green:AP), color map of the anisotropy type, and fractional anisotropy.

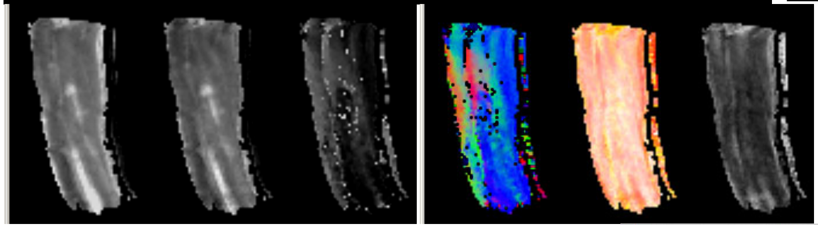

Figure 2 Stress. The same legend holds for the stress state images (plantor-flexed) below. Note the change in the eigenvector direction in the anterior muscle compartments from strong LR to AP direction.

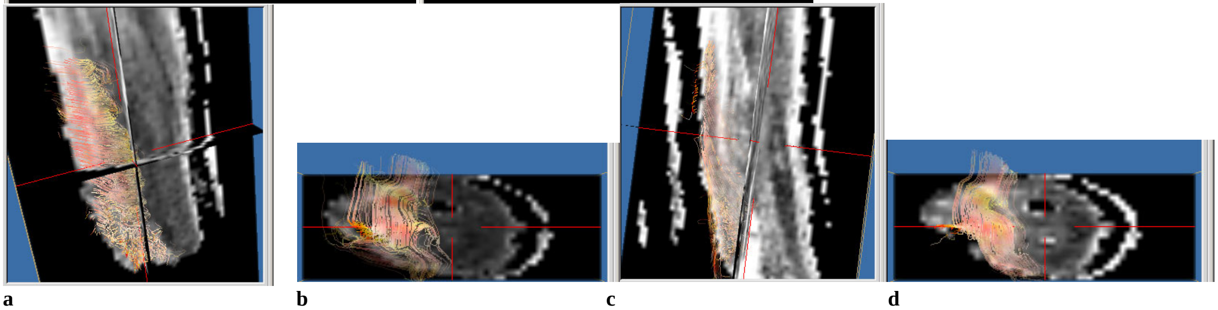

Figure 3: Fibers tracked from the anterior region are shown in the sagittal and axial projections of the 3D volume and confirm the change in fiber direction. Images taken at rest are shown in (a,b) and plantor-flexed in (c,d). The sagittal image shows at rest (left), fibers coming out of the plane in the LR direction (corresponding to the red in the color map image of Fig. 1). In the stress state (c, d), the in-plane (AP component) corresponding to green in Fig. 2 can be visualized.

Conclusions:

We have demonstrated the feasibility of in-vivo muscle fiber tracking using diffusion tensor data acquired at 3T. Changes in fiber orientation as a function of muscle activity such as plantor flexion can be monitored. This methodology can be used to study muscle structure function relationships in normal and diseased states.