Reproducibility of DTI-based muscle fiber tracking

A. M. Heemskerk[1,2], T. K. Sinha[1,2], Z. Ding[1,2], C. P. Blyth[2], and B. M. Damon[1,2]

[1]Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States, [2]Institute of Imaging Sciences, Vanderbilt University, Nashville, TN, United States

Introduction

DTI-based fiber tracking is extensively used to reconstruct the trajectories of white matter tracks and in recent years also for skeletal muscle fibers [1-3]. The trajectory of the tracked fiber depends on the underlying anatomy, the noise and artifact characteristics of the data and the fiber-tracking algorithm. Although the tracked fibers resemble the known muscle architecture and have been used to quantify muscle architectural properties, little is know about the repeatability of either the architectural measures or the underlying diffusion measures. In the present study we investigated the reproducibility of DTI-based fibertracking, by means of repetitive measurements of diffusion-indices, and the calculated muscle architectural parameters (pennation angle (θ) and fiber length).

Methods

Subjects: DTI datasets were obtained from 5 healthy subjects (3 male), at two different days (D11, D21), in same position (D12, D22), and after complete repositioning (D2R).

MRI: Data were obtained with a Philips 3T scanner using a double flexible surface coil covering the length of the Tibialis Anterior (TA) muscle. For anatomical reference a T_1 weighted scan was obtained: FOV=192x192 mm^2, matrix size=256x256, slices thickness=3 cm, 112 slices, TR=0.5 s, TE=18.6 ms. DTI images were acquired in 5 continuous stacks with a total of 112 slices, using an EPI sequence with the same geometric parameters, 128x128 reconstructed matrix, 4 excitations, TR=5 s, TE=46 ms, b=500 s/mm^2, and 6 directions specified according to Jones et al. [4].

Fiber tracking: The diffusion weighted images were registered to the b=0 image using an affine transformation. Then the DTI dataset was rigidly registered to the anatomical image set. Tensor calculations were performed using the Philips PRIDE fibertracking tool. From the anatomical images, the borders of the TA were traced and the position of the central aponeurosis was digitized. A 3D mesh reconstruction of the aponeurosis was defined with 280 rows * 100 column density and the points of intersection were used as seed points for fibertracking. Fibertracking occurred in the direction of E_1 and terminated at the muscle borders, if FA<0.1, or if three successive points had a curvature of >45˚. The pennation angle was calculated as the angle between any point on the fiber tract and the plane tangent to the seed point from which that fiber tract emerges.

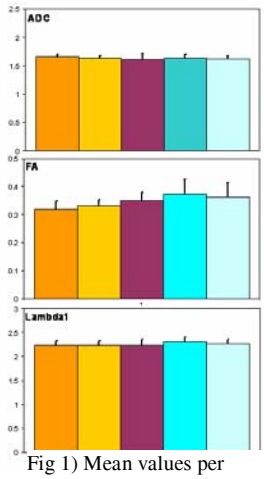

Fig 1) Mean values per measurement at maximal cross sectional area. From left to right: D11, D12, D2r, D21, D22

Results and Discussion

The difference in diffusion indices between measurements is small (Fig 1). An ANOVA showed no significant differences between measurements. Therefore, the DTI values are reproducible for all the repetitive measurements.

The left panel in Fig 2 shows the distributions of the pennation angle along the aponeurosis, the middle panel shows similar results for the measurement without repositioning. The difference in θ for these two datasets is depicted in Fig 2 and shows mainly a uniform distribution of small differences, with larger differences found at the edges of the aponeurosis. The mean pennation angle and fiber length for the different measurements showed a good comparison between scans (Fig 3). ANOVA showed no statistical differences in θ or fiber length for all the measurements. This indicates that the data processing is similar between scans.

The point-to-point differences (as shown in Fig 2) between different days and after repositioning on the same day are larger than without repositioning. This is most probably due to slight differences in the tracing of the aponeurosis between datasets, and may be corrected in the future using deformable registration routines.

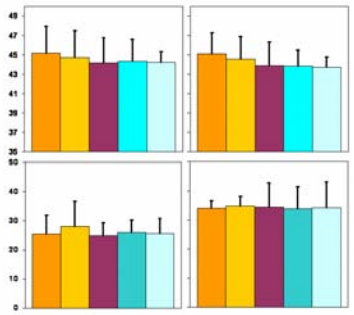

Fig 3) mean values of the pennation angle (upper row) and the fiberlength (bottom row) for superficial (left) and deep (right) compartment.

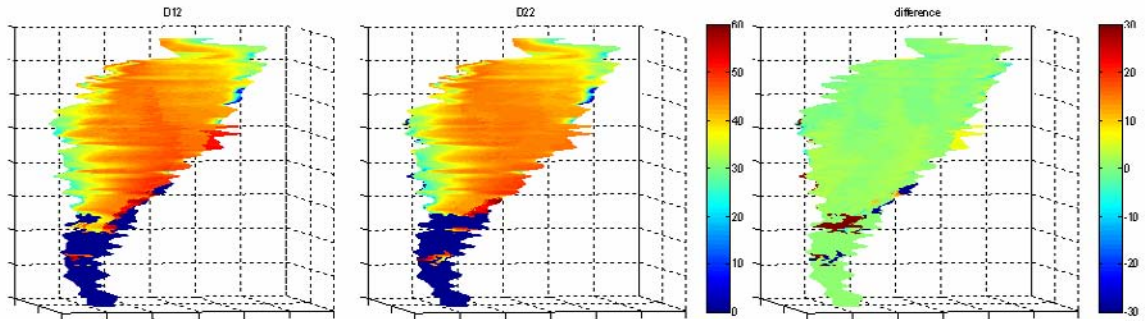

Fig 2) Distribution of pennation angle of the superficial compartment along the TA aponeurosis. D11 (left) and D12 (middle) show similar results as is indicated by the difference image (right). Colorbar indicates pennation angle in degrees.

Conclusion

The reproducibility of the data acquisition is good and comparison of fiber tracking based architectural measurements show similar results.

References

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