# Quality Assessment of DTI-based Muscle Fiber Tracking

**A. M. Heemskerk[1], T. K. Sinha[1], K. J. Wilson[1], Z. Ding[1,2], and B. M. Damon[1]**

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

**Introduction**

DTI-based fiber tracking in skeletal muscle offers exciting possibilities to reconstruct muscle architecture (1-3). In addition, the consistent alignment of fibers within the muscle also enables an assessment of the quality of fiber tracking. For example, all fibers within the bipennate Tibialis Anterior (TA) muscle run from origin (either the tibia or the superficial fascia of the anterior compartment) to point of insertion (the central aponeurosis). Therefore, all reconstructed fibers that do not follow this pattern might be considered inaccurate. In previous work it was shown that we are able to track fibers starting on either side of the aponeurosis toward their respective origins (1). In this work we propose a method to determine the quality of individual muscle fiber tracts based on the location at which the fibers terminate, the fiber path, the fiber length, and similarity to the neighboring fibers.

**Quality Assessment Procedure**

The fiber tracking procedure uses a mesh definition of the aponeurosis as the seed surface for fiber tracking, the formation of a mask to define the muscle boundaries and provide a stop criterion for fiber tracking, and the generation of up to 20,000 fiber tracts in the superfical and deep compartments of the muscle according to a streamlining algorithm. The quality assessment consists of the following steps.

1) Determine the total number of fibers that have been tracked and that are surrounded by at least 2 tracked fibers (FT=100%).

2) Exclude fiber tracts that have less than 6 tracked steps (~5 mm; $FT_{short}$).

3) Exclude fibers that are tracked to the wrong side of the aponeursosis ($FT_{neg}$). To exclude these, two additional masks were formed based on the position of the superficial part of the aponeurosis or the deep part of the aponeurosis (see Fig1). If a point along the tracked fiber falls within the mask of the other compartment, the whole fiber is excluded.

4) Exclude fibers that differ by more than 2 standard deviations in length from their 8 neighboring fibers ($FT_{length}$).

5) Include fibers that stop within 2 pixels from the muscle border ($FT_{good}$). Near the muscle border fibers might stop because of the mask, but they also might stop just before reaching the mask because high curvature or low FA related to the proximity of the border. Therefore, we define all fibers that stop within 2 pixels from the border as fully traced fibers (Fig 1).

6) Exclude the remaining fiber tracts, which we consider to have stopped prematurely for reasons such as high curvature between successive points or low FA ($FT_{pre}=100-FT_{short}-FT_{neg}-FT_{length}-FT_{good}$).

**Methods**

Subjects: Anatomical and DTI datasets were obtained from 8 healthy subjects (4 male).

MRI: Data were obtained with a Philips 3T scanner using a double flexible surface coil covering the length of the TA muscle. For anatomical reference a proton density weighted scan was obtained: FOV=196x196 $mm^2$, matrix size=256x256, slices thickness=6 cm, 55 slices, TR=4152 s, TE=11 ms. DTI data were acquired in 5 continuous stacks with a total of 55 slices, using an EPI sequence with FOV=192x192 $mm^2$, matrix size=96x64 with 128x128 reconstructed matrix, 4 excitations, TR=3300 ms, TE=48 ms, b=500 $s/mm^2$.

Image processing: Image registration was performed of 1) the diffusion weighted images to the b=0 image, 2) the DTI stack to the adjacent stack; and 3) DTI set to the anatomical image set. From the anatomical images, the borders of the TA were traced and the positions of both the superficial and deep aspects of the central aponeurosis were digitized. A 3D mesh reconstruction of the aponeurosis was defined with 200 rows × 100 column density and the points of intersection were used as seed points for fiber tracking. Fiber tracking was performed by following the direction of greatest diffusion from the seed points along each of the TA's aponeurosis. Fiber tracking occurred in the direction of $\varepsilon_1$ and terminated at the muscle border, if FA<0.1, or if successive points had a curvature of >45°.

**Results and Discussion**

The quality assessment showed a high percentage of good fibers (>78%) for the superficial compartment and a reasonable percentage (>51%) for the deep compartment. This lower percentage is partly caused by a larger number of short fibers, which are mainly located distally. The distribution of the quality assessment along the aponeurosis (Fig 2) shows that inaccurate fibers are mainly grouped. Partly this is expected as the underlying basis might be similar (e.g. $FT_{short}$ distally where fibers terminate because of mask or $FT_{neg}$ can result from spatially dependent artifacts such as eddy currents). Interestingly, the aponeurosis has a high curvature approximately at the location of $FT_{pre}$ in Fig 2A. Although there is a difference in the quality assessment between the different subjects there does not appear to be an obvious relation with subject characteristics like length, volume, cross sectional area or body mass index.

**Conclusion**

As judged by this quality assessment algorithm, most muscle fiber tracts are traced correctly. This enables further studies towards accurately quantifying muscle architectural parameters, assessing the quality of new fiber tracking algorithms, or using DTI-based muscle fiber tracking data in mechanical models of muscle.

**References**

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3) Heemskerk AM et al CMIR 2007 3(3): 152-160

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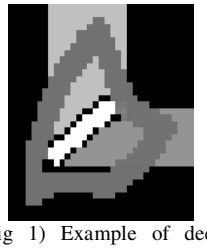

Fig 1) Example of deep and superficial (medium and light gray, respectively) masks based on aponeurosis (white). The near border mask (dark grey).

Table 1) Percentages of good and inaccurate fibers

| | superficial aspect aponeurosis | | | | | | deep aspect aponeurosis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| subjects | $FT_{good}$ | $FT_{short}$ | $FT_{neg}$ | $FT_{length}$ | $FT_{pre}$ | | $FT_{good}$ | $FT_{short}$ | $FT_{neg}$ | $FT_{length}$ | $FT_{pre}$ |
| 1 | 88.6 | 1.5 | 4.3 | 0.9 | 4.7 | | 77.4 | 17.6 | 0.0 | 0.6 | 4.5 |
| 2 | 93.1 | 6.3 | 0.0 | 0.3 | 0.2 | | 71.0 | 22.1 | 0.6 | 0.2 | 6.1 |
| 3 | 78.2 | 9.9 | 0.3 | 0.4 | 11.3 | | 64.8 | 28.9 | 2.6 | 0.5 | 3.2 |
| 4 | 90.0 | 5.7 | 1.4 | 0.9 | 2.0 | | 73.3 | 16.3 | 9.2 | 1.1 | 0.2 |
| 5 | 82.4 | 1.1 | 0.1 | 0.7 | 15.7 | | 79.3 | 10.4 | 0.2 | 0.4 | 9.7 |
| 6 | 93.7 | 1.1 | 4.3 | 0.4 | 0.5 | | 52.9 | 14.1 | 32.9 | 0.1 | 0.0 |
| 7 | 98.8 | 0.7 | 0.0 | 0.5 | 0.0 | | 60.5 | 10.8 | 28.5 | 0.3 | 0.0 |
| 8 | 82.9 | 6.7 | 1.9 | 0.5 | 8.0 | | 51.2 | 20.2 | 25.1 | 0.3 | 3.2 |
| mean | 88.5 | 4.1 | 1.5 | 0.6 | 5.3 | | 66.3 | 17.6 | 12.4 | 0.4 | 3.4 |

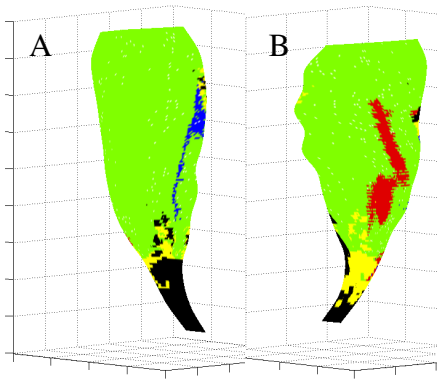


Fig 2) Distribution of quality assignment along the aponeurosis for subject 4. $FT_{good}$: green; $FT_{short}$: yellow; $FT_{neg}$: red; $FT_{length}$: white; $FT_{pre}$: blue; not traced: black. Superficial (A), deep (B) compartment.