Comparison of Tract-Length and FA Histograms to Evaluate Global Tractography

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Introduction

Due to the lack of ground truth in human imaging, it is difficult to evaluate the accuracy or relative quality of DTI tractography. The objective of this work was to develop methodology, based on tract-length and FA histograms, that could be used to evaluate whole-brain tractography with data acquired under different conditions for a given subject, for example 6 verses 25 gradient directions, quadrature verses 8-element phased array head coil, or acquisitions at 1.5T verses 3.0T.

Rationale

Assuming a streamline tractography approach where a seed voxel is connected to surrounding voxels in piecewise linear steps along the direction of the principal eigenvector under the assumption of a rank 2 tensor (3x3 components) model, the noise in the EPI data, or a relatively coarse sampling of the 3D space by six gradients, is expected to perturb the eigenvalues. Occasionally this would also cause a switching or missorting of the three eigenvalues **[1]**. Though perturbations may change the FA, a mere switching of eigenvalues would not change the FA. Thus FA maps may or may not be a sensitive indicator of the quality of tractography. The noise and sampling configuration also affect the estimate of the propagation angle between voxels, which is determined by the eigenvector associated with the largest eigenvalue. An inaccurate estimation of the propagation angle would cause tracts to be deflected along a wrong path, making them likely to terminate sooner than if they had continued along the correct path. Consequently, tract orientation estimation errors would be manifested in fewer long tracts independent of FA.

Method

Whole-brain single shot EPI DTI data were acquired from 6 healthy normal human volunteers on a 1.5 T GE EXCITE scanner at TR=8.3s, field-of-view 26cm, 128x128 matrix, 28 contiguous 4mm thick slices from 25 isotropic gradient directions with b=1000s/mm^2, one b=0 acquisition, and number of excitations (NEX)=1 for a total acquisition time of 3min 53s. Similarly, four sets of data were acquired from 6 non-colinear directions and combined with two b=0 acquisitions to equalize the time for 25 and 6-directions acquisitions. An 8-element phased array RF coil was used and compared to a quadrature head coil. Also, data were acquired by the same sequence on a GE 3.0T scanner for 2 subjects.

Results and Discussion

A typical result of the 25-direction tractography is presented in **Fig. 1** where all tracts lying on, or intersecting a specified slice are shown within a 3-D rendered brain. The differences in the tract-length histograms (25-directions minus the 6-directions lengths) are shown in **Fig. 2a** and corresponding differences in FA histogram are shown in **Fig. 2b**. The tract-length histograms clearly show that at equal acquisition time, there are more long tracts in the 25-direction acquisition than the 6-direction acquisition, suggesting better estimation of the tensor with 25 directions. The tract-count above a threshold could thus be used as a metric to evaluate tractography. **Fig. 2b** does not show any clear pattern. **Table 1** shows the number of tracts ≥ 10 cm and pixels with FA ≥ 0.2. The tract-length comparison shows greater counts in 5/6 subjects for 25 vs. 6 directions. Though the FA difference pattern appears to be reversed, the FA effect was small and inconsistent. The difference histograms comparing the two coils are presented in **Fig. 3**, clearly showing a higher tract-count for long tracts with the 8-element coil. This is consistent with the demonstrated higher sensitivity and higher signal-to-noise ratio for EPI acquisitions by the 8-element coil and provides an indirect validation of the tract-length histogram to evaluate tractography. The 3T to 1.5T comparison (**Fig. 4**) reveals the improvement in global tractography due to the higher SNR at 3T. This comparison, however, does not reveal the loss in specific tracts that may occur due to the increased susceptibility artifacts in the frontal regions at 3T. We conclude that tract-length histogram is a reliable metric to evaluate global DTI tractography.

Fig. 1

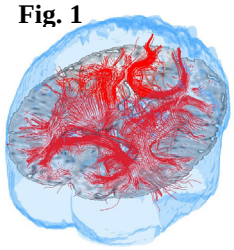
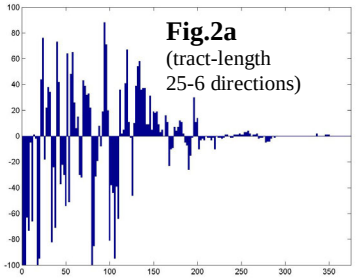
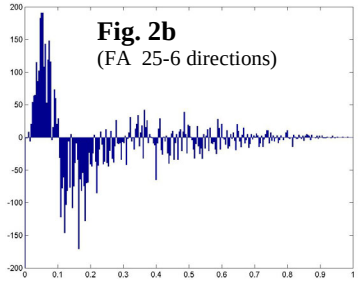
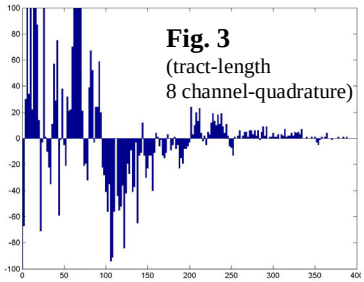


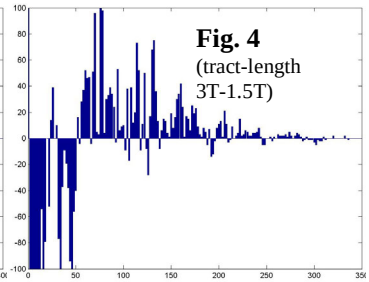
Table 1

	25		6	
Sub #	Length	FA	Length	FA
1	3638	29706	3152	30205
2	4293	33533	4143	34411
3	4124	35132	3768	36705
4	4347	31017	3969	31631
5	4762	35293	3962	43057
6	3789	47200	4182	49308









Reference: [1] Basser, et. al. *MRM* 44:625-632 (2000).