Resolution-Dependent Differences in Fiber Tracking and Quantification of the Visual Pathways

J. Klein[1], P. Erhard[2], and H. K. Hahn[1]
[1]Fraunhofer MEVIS, Bremen, Germany, [2]FB 2 (Chemistry) and Center of Advanced Imaging (CAI), Germany

Abstract: Fiber tracking and quantification of the visual pathways is still a challenging problem due distortions in the vicinity of the optic nerve, the small diameter of the bundle itself (at least in the frontal part), crossing fibers in the optic chiasm and the capsula interna, the high curvature in the Meyers loop, and the discontinuity in the corpus geniculatum laterale. In this work we examine how changes in the resolution of the DTI data sets influence the fiber tracking and quantification of the visual pathways, and show that an anisotropic resolution with a high coronal in-plane resolution should be preferred to an isotropic resolution with the same volume per voxel.

Introduction: For quantifying the optic nerve and the visual pathways, diffusion-weighted imaging in combination with diffusion tensor analysis can be used [1]. Until now, mainly ROI-based tools have been proposed [2,3] instead of tract-based quantification techniques, probably due to the difficulty and the non-reliability of fiber tracking of this special fiber bundle. Tract-based spatial statistics (TBSS) have been developed for quantifying the white matter of the whole brain [4], however, not for measuring a specific bundle. Special MR sequences have also been developed for the optic nerve [5], but not for the whole visual pathways. High-resolution DTI and tractography of the optic chiasm has been examined in [6].

Methods: DTI data sets were acquired in 30 gradient directions from a healthy volunteer on a 3T Siemens Allegra head-scanner. Four different image resolutions were chosen; see Tab. 1 for resolution and acquisition details. Neither the acquired DTI data nor the tensor field were smoothed, as we ultimately aimed to determine the differences in fiber tracking and quantification.
In order to reconstruct the visual pathways, we tracked them in three sections so that accumulation errors in the fiber tracking process can be restricted. For fiber tracking, we used a deflection-based algorithm [7]. For the frontal part (optic nerve), two seed ROIs on a coronal slice that cover the left and right optic nerve were chosen. For the second part (optic tract), a seed ROI on a coronal slice covering the optic chiasm was used. Finally, the last part (optic radiation) was tracked by selecting two ROIs on a coronal slice directly located to the pyramidal tracts which cover the optic radiation fibers. For all data sets, the same ROIs and the same density of the seed points were used (seed grid: $(0.1\text{mm})^3$).
The right and left bundles were separately measured and the results were averaged afterwards. For the quantification, the FA, ADC, AD (axial diffusivity), and the RD (radial diffusivity) were measured along the fiber tracts.

Results: The detailed results of the fiber tracking and the quantification can be found in Tab. 1. Best results were achieved using an anisotropic resolution of 1.4x1.4x3.5 where the highest number of fibers and the most plausible tracking results have been computed. Moreover, the anisotropy was higher and the ADC lower than all other measurement values obtained for the other data sets, indicating the highest directionality. The lowest quality was achieved if using a higher b-value of 1000 (lower signal) and only one number of excitation (NEX) at an isotropic resolution of 1.6mm^3 although the volume per voxel for this data set is the lowest one.

Conclusion: Our initial experiments have shown that for tracking and quantifying the visual pathways, a high coronal in-plane resolution, which better fits to the geometry of the visual pathways, leads to better results than using an isotropic resolution with the same volume per voxel. In clinical practice, it is impossible to optimize each DTI sequence for the clinical question, but we propose to adapt the resolution, if fiber tracking of the visual pathways should be performed.

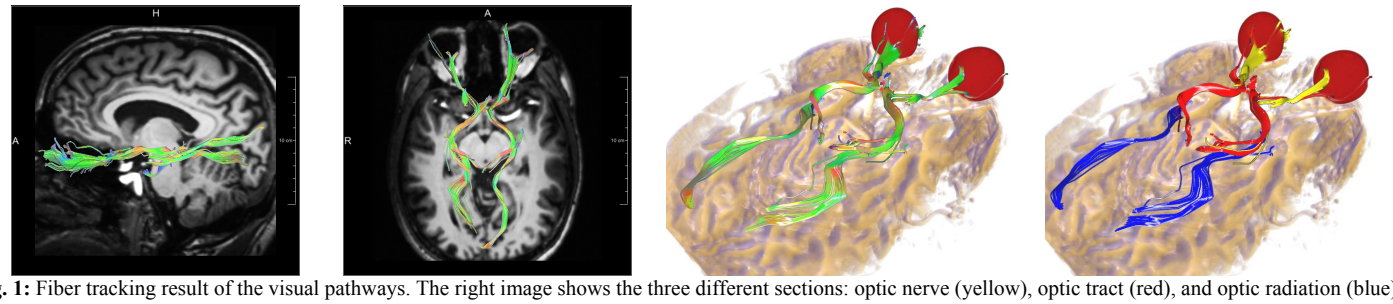

Fig. 1: Fiber tracking result of the visual pathways. The right image shows the three different sections: optic nerve (yellow), optic tract (red), and optic radiation (blue).

Resolution (mm^3) / orientation	Volume per voxel (mm^3)	b value	NEX	TR per slice / TE (ms)	Number of tracked fibers (%)	Optic nerve (FA, ADC, AD, RD)	Optic tract (FA, ADC, AD, RD)	Optic radiation (FA, ADC, AD, RD)
1.4 × 1.4 × 3.5 / coronal	6.86	500	2	140 / 80	100%	0.524, 0.000672, 0.00103, 0.000627	0.420, 0.000715, 0.000551, 0.000318	0.362, 0.000564, 0.000899, 0.000802
1.6 × 1.6 × 3.2 / coronal	8.192	500	2	126 / 80	64%	0.470, 0.000745, 0.000995, 0.000637	0.372, 0.000848, 0.000823, 0.000509	0.293, 0.000668, 0.000995, 0.000681
1.9 × 1.9 × 1.9 / axial	6.859	500	2	123 / 80	49%	0.429, 0.000775, 0.00111, 0.000734	0.379, 0.000730, 0.000842, 0.000475	0.278, 0.000946, 0.00112, 0.000881
1.6 × 1.6 × 1.6 / axial	4.096	1000	1	135 / 87	26%	0.372, 0.00149, 0.00177, 0.00139	0.246, 0.001800, 0.00215, 0.00162	0.287, 0.000939, 0.00119, 0.000812

Tab. 1: All data sets have been acquired at a 3T Siemens Allegra scanner, University of Bremen, Germany.

References [1] E. Pagani et al., Am J Neuroradiol, 28:411-420, 2007 [2] P. Staempi et al. Journal of Magnetic Resonance Imaging, 26(4), 2007 [3] S. Anand Trip et al., NeuroImage, 30(2):498 - 505, 2006, [4] S M Smith et al., Neuroimage, 31(4):1487-505, 2006, [5] S. Chabert et al., J MagnReson Imaging, 22(2):307-10, 2005, [6] A. Roebroeck et al., Neuroimage, 39(1): 157-168, 2008, [7] M.Schlüter et al., SPIE Medical Imaging, Vol. 5746, pp. 836-844, 2005