The impact of maximum turning angle in different deterministic tractography algorithms applied in pediatric populations

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Introduction: Diffusion weighted imaging (DWI) is a noninvasive method to study white matter integrity that has become routinely used in clinical practice. Analysis of fiber tractography extracted from DWI images has been largely used to evaluate the integrity and anatomy of the white matter, to locate specific tracts and to map connectivity. This can be of great help when trying to characterize specific diseases and when mapping eloquent white matter tracts are decisive in surgical planning.

Different ways of acquiring and post processing diffusion weighted images often make comparisons between studies in different laboratories and institutions challenging. Modification in only a single parameter of the post-processing algorithm can result in considerable quantitative and qualitative changes in the final product, even when the acquisition parameters are similar. Moreover, routinely one single set of parameters of post-processing reconstruction is chosen to study all of the white matter tracts in the brain, without considering that tracts with distinct morphology may benefit from different parameters. Because there is no consensus on how to post-process diffusion data for clinical studies and research [1], we sought to demonstrate the impact of the choice of maximum turning angle along commissural, association and projection tracts in four different deterministic tractography reconstruction algorithms in a pediatric population.

Methods: The Informatics for Integrating Biology and the Bedside (i2b2, available at http://www.i2b2.org) software suite enables the repurposing of healthcare data for clinical research [2]. It allows users to perform IRB approved queries online and returns all relevant demographic data, medical records, and image accession numbers for patients who match the specified search criteria. Using a prototype of the Medical Imaging Informatics Bench to Bedside (mi2b2) software plug-in allowed us to retrieve clinical images from our hospital's PACS. After obtaining IRB approval, we identified data from patients with 3 Tesla Siemens MRI scans collected between birth to 6 years of age during the interval of 2007-2011 that had 12 or 60 non-collinear direction diffusion weighted images, b-values of 700 and 1000, suitable for tractography reconstruction.

Thirty-two scans met the inclusion criteria. Twenty-two of those were performed with 12 non-collinear directions (7 normal and 15 abnormal scans) and 10 with 60 directions (3 normal scans and 7 abnormals). Abnormal scans included hypoxic-ischemic injury, metabolic disorder, hydrocephalus, tuberous sclerosis, polymicrogyria, focal cortical dysplasia and low grade glioma. The diffusion data was reconstructed on Diffusion Toolkit (http://trackvis.org/dtk/) using the diffusion tensor model and four deterministic tractography algorithms: Fiber Assignment by Continuous Tracking (FACT), interpolated streamline (IS), second-order *Runge*-Kutta (RK2) and tensorline (TL) and three different turning angle thresholds: 30, 45 and 80 degrees.(3,4) In order to better demonstrate the difference between solutions we manually dissected the corpus callosum (CC), corticospinal tract (CST) and inferior fronto-occipital fasciculus (IFOF) by drawing regions of interest on FA color maps using TrackVis.

Results: FACT - Using the FACT algorithm, the 45-degree angle threshold could regularly better depict tracts, while the lower angle thresholds were not able to demonstrate termination of the fibers reaching the cortex and the higher angle ones introduced false continuity to the fibers.

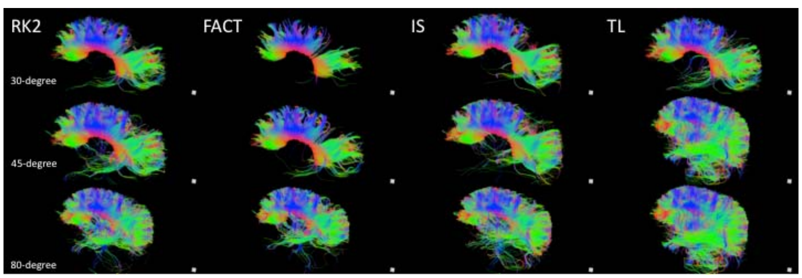

Fig. 1: 19-month-old with history of seizures   normal MRI of the brain. RK2, FACT and IS reconstruction algorithms: even though 45-degree angle introduce some noise, it was possible to retrieve more parieto-occipital fibers when compared to 30-degree angle reconstruction. TL algorithm   45-degree angle threshold introduced unacceptable amount of spurious tracts. 80-degree introduced too much noise in all the solutions.

RK2 - Using RK2, the 45-degree angle threshold was consistently the most successful when studying the CC and IFOF. This was also the best angle threshold most of the times when dissecting the CST, however, we found that an increase to 80 degrees would be of benefit for some subjects, mainly when trying to retrieve the projections to the lateral cortex.

IS - In the case of the IS algorithm, the 45-degree angle threshold was the best to demonstrate the IFOF anatomy and, in most of the cases, was the best angle for the CC and CST. An 80-degree angle threshold better demonstrated the fibers projecting to the lateral perirolandic area for the CST and better demonstrated the termination of the fibers reaching the cortex for the CC at the expense of introducing spurious fibers and anomalous continuation with adjacent tracts.

TL – All the different fiber bundles were consistently better reconstructed using a 30-degree angle threshold for the tensorline, larger angle thresholds dramatically increasing the number of spurious tracts. No significant difference in the optimal angle threshold was observed when comparing 12 and 60-direction DTI and normal versus abnormal scans.

Conclusion: Our preliminary results suggest that optimal angle threshold for pediatric tractography reconstruction may change when using different deterministic post-processing algorithms and may vary when analyzing different fiber bundles. Knowledge of these differences is important when using tractography for clinical management.

References:

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