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

Poster No.: C-2549
Congress: ECR 2012
Type: Scientific Paper
Authors: K. de Macedo Rodrigues, E. P. Grant, R. Gollub, K. Krishnamoorthy, P. Caruso, L. Zollei; Boston, MA/US
Keywords: Pediatric, Neuroradiology brain, MR-Functional imaging, MR, Diagnostic procedure, Tissue characterisation
DOI: 10.1594/ecr2012/C-2549

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Purpose

Diffusion-weighted imaging (DWI) has become an important tool in clinical Pediatric Neuroradiology, enabling the characterization of normal brain, brain development as well as a range of pathologic conditions. Information about the diffusivity of water molecules in brain tissue can be used to build diffusion tensor maps, which can give a good representation of fiber bundle location and orientation. Based on the tensor model, different post-processing algorithms allow the reconstruction of white matter tracts. Despite of an increasing use of tractography in research and clinical settings, there is no consensus on how to select the finest reconstruction method. This makes 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, different outputs may lead to different clinical decisions. For this reason, we sought to demonstrate the impact of the choice of maximum turning angle between voxels in four different deterministic tractography reconstruction algorithms in a pediatric population.

Methods and Materials

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 (1). 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 MRI scans collected between birth to 6 years of age during the interval of 2008-2011 that had 12 or 60 non-collinear direction diffusion weighted images suitable for tractography reconstruction.

The diffusion data was reconstructed on Diffusion Toolkit 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 (2, 3).

In order to better demonstrate the difference between the resulting solutions we manually dissected the corpus callosum (CC) by drawing regions of interest on FA color maps on the mid sagittal plane using TrackVis (4). Visual analysis was used to access if the reconstruction output was close to what one would expect anatomically as well as to
evaluate for the presence of spurious fibers and anomalous continuation with adjacent tracts.

**Results**

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 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.

FACT - Using the FACT algorithm, a 45-degree angle threshold was consistently the most successful solution when studying the CC. The lower angle threshold was not able to demonstrate adequately the fibers of posterior aspect of the body of the CC as well as failed to demonstrate termination of the fibers reaching the cortex. When using the 80-degree turning angle threshold, introduction of spurious fibers and false continuity was observed (Fig 1).

RK2 - For RK2 algorithm, a 45-degree angle threshold was also required in order to better depict callosal fibers. Similar to what was observed for FACT, a 30-degree threshold failed to demonstrate part of the callosal fibers and a higher angle threshold introduced an undesirable number of spurious tracts and false continuations (Fig 2).

IS - When using the IS algorithm, most of the times a 30-degree angle threshold was the best to demonstrate CC anatomy with a minority of cases benefiting from the increase to 45-degree, with a better demonstration of fibers reaching the cortex at the expense of the introduction of stray fibers and anomalous continuation with adjacent tracts. The 80-degree angle threshold was considered to introduce an unacceptable number of false fibers (Fig 3).

TL - All the different fiber bundles were consistently better demonstrated using a 30-degree angle threshold for the tensorline, with larger angle thresholds dramatically increasing the number of spurious tracts (Fig 4).
No significant difference in the optimal angle threshold was observed when comparing 12 and 60-direction DTI scans or normal versus abnormal scans.

**Images for this section:**
**Fig. 1:** Fifteen-month-old with white matter signal abnormality concerning for mitochondrial disorder. FACT reconstruction shows poor depiction of callosal fibers when using 30-degree angle threshold, which was improved with a 45-degree threshold. With this angle it becomes possible to observe fibers projecting to the parietal and temporal areas. A higher angle introduced unacceptable amount of spurious tracts.
Fig. 2: Two year-old with tuberous sclerosis. RK-2 reconstruction demonstrates that a 45-degree turning angle is necessary in order to display fibers projecting to the occipito-parital cortex. An 80-degree constraint introduced innumerous false continuations to the callosal fibers.
**Fig. 3:** Three-year-old with facial hemangioma and normal brain MRI. IS reconstruction shows good depiction of the CC fibers with a 30-degree angle threshold. A 45-degree angle restriction shows more fibers projecting to the temporal lobe. This is however at expense of introducing false continuation with fornix as well as fibers projecting to the cerebellum brainstem and spinal cord.
Fig. 4: TL reconstruction was found to be the method more sensitive to increases in angle threshold. Good representation of the CC was achieved with a 30-degree angle. Higher angles were found to dramatically increase the amount of false continuation. The ROI located in the midsaggital plane in the topography of the CC allowed the reconstruction of most of the white matter tracts in the entire brain.
Conclusion

Our preliminary results suggest that optimal angle threshold for pediatric tractography reconstruction may change when using different deterministic post-processing algorithms. We could demonstrate that it is possible to obtain substantially different outputs when using different post-processing tractography reconstruction methods even when starting from the same DWI acquisition (Fig 5). This has to be taken into account when comparing studies from different laboratories and, particularly, when comparing follow-up examination of individuals in clinical circumstances, when this evaluation can be decisive for a change in management.

Images for this section:
Fig. 5: The same raw data and turning angle threshold was used to reconstruct the CC with the four different algorithms tested in this study to illustrate the dissimilarities in the final product.
References

1) Murphy, SN. Serving the enterprise and beyond with informatics for integrating biology and the bedside (i2b2)' Journal of the American Medical Informatics Association 17(2): 124-130 (2010).


4) Ruopeng Wang, Van J. Wedeen, TrackVis.org, Martinos Center for Biomedical Imaging, Massachusetts General Hospital.

Personal Information

Katyucia de Macedo Rodrigues, MD.
Research Fellow in Radiology
Children's Hospital Boston
300 Longwood Avenue
Boston, MA 02115
Tel: 857-218-5111
Fax: 617-730-4671
Katyucia.Rodrigues@childrens.harvard.edu