

Probabilistic tractography algorithms for tracking the optic radiation (OR): Are they ready for the Neurosurgeon?

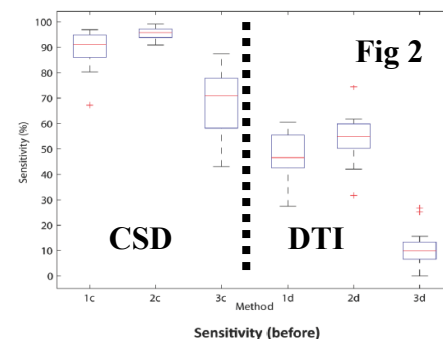
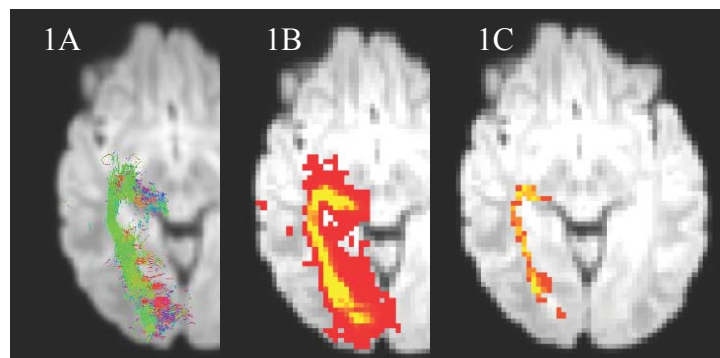
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Purpose and Background: The aim of this research was to investigate whether diffusion weighted MRI (DWI) data acquired within a clinical neuroradiology MRI protocol could be used to accurately and robustly visualize the optic radiation (OR). The hypothesis was that DWI data (collected in <5 min) would be sufficient to allow constrained spherical deconvolution (CSD) probabilistic tractography [1] and/or traditional diffusion tensor (DTI) probabilistic tractography algorithms [2] to accurately track the OR. In addition, it was hypothesized that CSD algorithms would offer improved performance over DTI algorithms because of their ability to account for crossing and kissing fibers. The OR is a very important white matter structure that has proven to be problematic to track using DWI tractography algorithms. If OR tractography is proven feasible and eventually validated in the clinical environment it could open up numerous clinical applications ranging from improved neurosurgical planning of tumor and temporal lobe resections, to acting as a biomarker of OR axonal integrity in patients with optic neuritis or chiasmal compression. However, to date there is a paucity of necessary comparative studies on such difficult white matter structures; thus restricting the clinical translation of diffusion tractography.

Methods: Twenty patients receiving magnetic resonance imaging (MRI) scans of the brain underwent DTI scanning in addition to their normal neurological scans on a Siemens TRIO 3T MRI scanner. Diffusion sensitizing gradients were applied in 30 non-collinear directions with a maximum b-value of 3000 s/mm² (and one b=0 image). Tractography was performed using a combination of two different models of diffusion (DTI and CSD) and three different methods of generating tractography seed regions of interest (ROIs). MRtrix was used to perform the CSD algorithms and FSL was used to perform the DTI algorithms. Tractography was limited to the contralateral hemisphere from any mass affecting disease. Patients with significant midline shift were excluded from the study. The six resulting OR tractography techniques were evaluated and compared, both visually and quantitatively. All OR tracks were converted to track probability images and registered to the OR from FSL's white matter atlas using FLIRT [4]. Then ROC curve analysis (MATLAB®) was used to calculate the Youden index as an estimate of tract accuracy. In addition, the distances between Meyers loop (MLA), and the temporal (TP) and occipital (OP) poles were measured and compared to those measured in dissection studies [3].

Results: Five out of six methods were able to reconstruct the entire OR in at least 19 out of the 20 subjects. Figure 1 shows an example of the OR tractography results. These tracks were acquired by seeding the Lateral Geniculate Nucleus to track white matter to V1 (Figure 2, algorithms 3c and 3d). As can be seen the CSD algorithm (1A and 1B) provides a much more complete visualization of the OR compared to the DTI algorithm (1C). The MLA-TP distances (34±6 mm) for this CSD algorithm were within error of the dissection results (27±4) method. However, this DTI algorithm's MLA-TP distances were significantly longer (38±6). This is confirmed by the ROC analysis where the Youden indices were significantly (p<0.05) greater for all the CSD methods (range: 0.53-0.61) compared to the DTI methods (range: 0.1 – 0.49). In figure 2, it can be seen that all the CSD methods (1c,2c,3c) showed significantly (p<0.05) higher sensitivities for predicting the atlas OR compared to their DTI counterparts (1d,2d,3d).



Conclusions: Tractography of the OR can be accomplished using data collected in clinically relevant timeframe with minimal disruption to a patient's normal clinical routine. A number of algorithms can be used to reconstruct the OR using CSD and DTI based tractography. By far the most robust and sensitive algorithm is to use CSD based probabilistic tractography, seeding from the lateral geniculate nucleus targeted to V1 of the visual cortex. While careful validation of these techniques is required, these results show that these tractography algorithms are capable of being translated to the clinical environment.

References: [1] Tournier et al, Neuroimage, 2007; [2] Berhrens et al., MRM 2003 ; [3] Ebeling et al., Acta neurochirurgica. 1988. [4] Jenkinson et al. Neuroimage 2002.