Assessing Test-Retest Reliability of Quantitative Tractography Based on Diffusion Spectrum Imaging

Durai Arasan[1], Wang Zhan[1], and Luiz Pessoa[1]
[1]*University of Maryland, College Park, MD, United States*

Introduction: Compared with diffusion tensor imaging (DTI) techniques, the diffusion spectrum imaging (DSI) has demonstrated its superiority in characterizing complex diffusion patterns related to multiple fiber structures within a single imaging voxel [1]. Quantitative tractography measurements, e.g. fiber counts, have been increasingly used as a tool for assessing the axonal connectivity in living human brains [2]. However, the test-retest reliability of the tractography remains unclear for DSI-based techniques since the reported assessments so far were generally based on DTI [3]. The lack of reliability assessments has led to the difficulty of comparing DSI tractography with other tractography techniques for neuroscientific applications, and the difficulty in optimizing tractography parameters for more reliable results [4, 5]. We addressed this issue by investigating the test-retest reliability for a set of tracts in a group of healthy subjects, with multiple independent DSI scans for each of them.

Methods: Four healthy volunteers (age=26.25 ± 2.5 years, 2 females) were scanned using a Siemens Trio 3T system equipped with a 32-channel RF coil. For each subject, four independent imaging sessions were performed in two different days with an interval less than 4 weeks. Each MRI session included a whole brain DSI (Siemens sequence, TR/TE = 9500/154 ms, FOV= 231 mm, 50 slices with isotropic 2.4 mm voxel) with 515 diffusion encodings at 5 b-values up to 7000 s/mm^2 [5]. A standard MPRAGE scan (1x1x1 mm resolution) was also included for structural validation purpose. DSI Studio [6] was used for the DSI data processing, diffusion reconstruction, fiber tracking, and generating tractography measurements for fiber counts, tract length, tract volume, and track quantitative anisotropy (QA) [5]. The tracks were selected according to [3]. A single seeding region (100,000 seeds) and two-ROI constrains similar to [4] were implemented to obtain the tracks bilaterally. We estimated the test-retest reliability by calculating the coefficient of variation (CV) and the intraclass correlation coefficient (ICC) [7] of the tractography measurements using a two-way random ANOVA with absolute agreement.

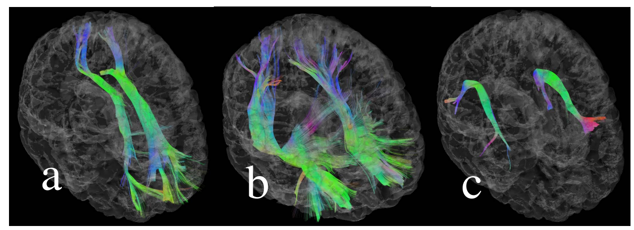

Fig.1: DSI tracts: a. cingulate bundles (Cing), b. interior fronto-occipital fasciculus (IFO), and c. arcuate fasciculus (Arc).

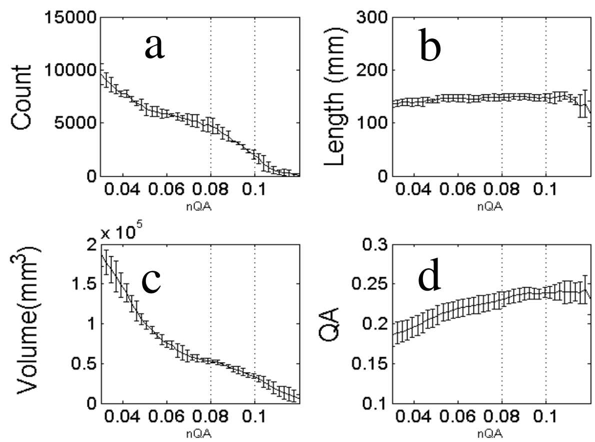

Fig.2: Tractography measurements of a right IFO tract as a function of nQA threshold. a. fiber counts, b. track length, c. track volume, d. track QA. Two vertical lines indicate the optimal nQA range.

Results: Cingulate (Cing), inferior fronto-occipital fasciculus (IFO) and arcuate fasciculus (Arc) bundles are used here to illustrate the results. Figure 1 shows the 3D tractography images of Cing and IFO bundles from a single DSI dataset. In Figure 2, a right IFO track is used to demonstrate the within-subject mean and standard deviation of the tractography measurements, including tract fiber counts, length, volume, and QA, as the function of the normalized QA (nQA) threshold of the tracking algorithm. An optimized nQA threshold can be observed ranging from 0.08 to 0.10 with minimized variations and relative insensitivity against threshold selection. Table 1 shows the test-retest reliability results for selected tractography measurements using all DSI datasets, where the ICC values, especially for the fiber counts, are greater than the corresponding DTI results previously reported (ICC less than 0.8 [3, 8]).

	Fiber Counts			Track Length		
	ICC	CV	p	ICC	CV	p
Cing_L	>0.99	3.05	<0.001	0.98	5.10	<0.001
Cing_R	>0.99	2.36	<0.001	0.88	5.15	<0.001
IFO_L	>0.99	1.19	<0.001	0.81	8.60	0.02
IFO_R	>0.99	3.94	<0.001	0.92	5.62	<0.001
Arc_L	>0.99	4.56	<0.001	0.92	7.30	<0.001
Arc_R	>0.99	6.13	<0.001	0.93	11.6	<0.001

Table 1: ICC, CV, and p values estimated for DSI tractography

Discussions and Conclusion: Following similar procedures as previous DTI-based assessments, our study revealed greater test-retest reliability for DSI-based tractography. This result provides direct evidence supporting DSI-based tractography for high-quality neuroscientific applications, even at the cost of longer imaging time. It is noted that DSI-based fiber counts show particularly high reliability, suggesting the advantage of DSI tractography in measuring structural connectivity. The present test-retest reliability measurements also may help in optimizing parameters for the tractography techniques.

References: [1] Wedeen, et al., MRM, 2005; 54:1377-1386. [2] Greenberg, et al., J. Neurosci. 2013; 32:2773-2782. [3] Wang et al., NeuroImage, 2012; 60:1127-1138. [4] Wakana, et al., NeuroImage, 2007; 36:630-644. [5] Yeh, et al., IEEE Trans. Med. Imag. 2010, 29:1626-1635. [6] http://dsi-studio.labsolver.org/ [7] www.mathworks.com/matlabcentral/fileexchange/22099 [8] Danielian et al., NeuroImage 2010; 49:1572-1580.