Test-retest reliability of tract-specific diffusion measures

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Introduction:

Alterations of white matter (WM) have been observed in several neurological diseases (1,2). Longitudinal investigation of these changes is crucial for a better understanding of their role in patterns of disease progression. Tractography based on diffusion magnetic resonance imaging (dMRI) allows non-invasive 3D in-vivo dissection of WM tracts and the extraction of diffusion measures characterizing WM microstructure. Anatomically-constrained high angular resolution diffusion imaging (HARDI)-based tractography has been introduced in recent years to overcome the challenges posed by WM areas with complex architectures (e.g. crossing fibers) and has been increasingly used in studies on WM changes in neurological diseases (3). However, the reproducibility of this technique has not yet been adequately assessed. The aim of this study was to determine the reproducibility of dMRI measures extracted along major WM tracts reconstructed using anatomically-constrained HARDI-based tractography in two sequential scans.

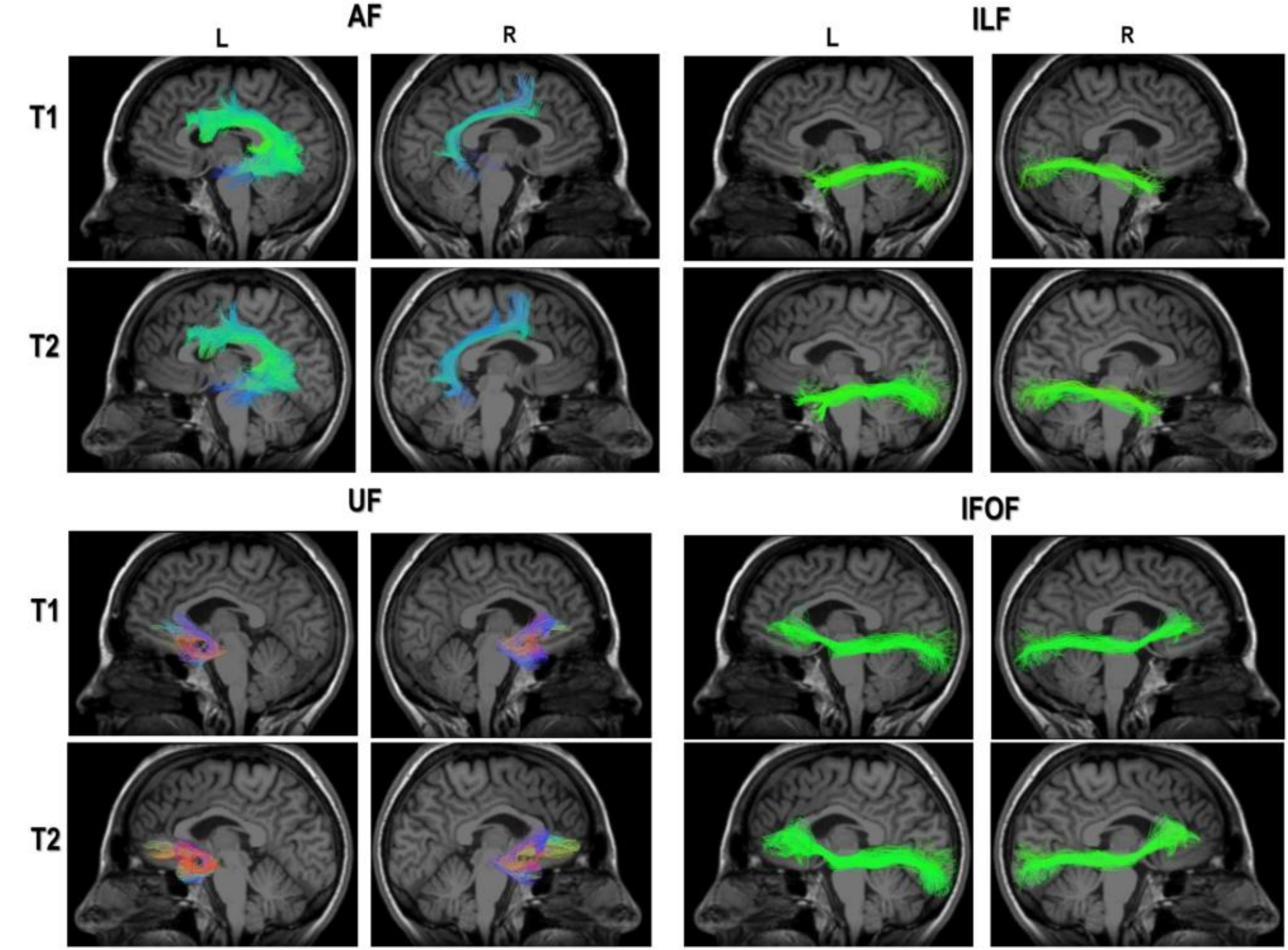
Methods:

Participants. Ten right-handed cognitively-unimpaired participants (age: M = 61.8 ± 6.08; education: M = 15.7, ± 3.59; 7 women) were scanned twice, one week apart.

Image acquisition. Images were obtained from a Skyra 3 Teslas MRI scanner, including one high resolution T1-weighted sequence and a diffusion weighted imaging (DWI) sequence (TR = 8051 ms, TE = 86 ms, FOV= 230 mm, 2 mm isotropic), with 64 independent directions (b=1,000 s/mm2), one T2-weighted image (b=0 s/mm2) in posterior-anterior acquisition and one in opposite phase.

dMRI data analysis. Analyses were conducted using the Toolkit for Analysis in Diffusion MRI (TOAD) (http://www.unf-montreal.ca/toad). DWI was noise-corrected using overcomplete local principal component analysis. DWI was upsampled to 1mm isotropic resolution. T1-weighted images were registered to the DWI using FSL (4). Fiber orientation distribution functions were estimated and a whole-brain tractogram was computed using MRtrix3 (5). The arcuate, inferior longitudinal, inferior fronto-occipital, and uncinate fasciculi (AF, ILF, IFOF, UF) were reconstructed using White Matter Query Language (6) (Figure 1). Outlier streamlines were then removed from each tract with a tract filtering algorithm (7). The following diffusion measures were extracted along each tract for each participant: fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), radial diffusivity (RD), number of fiber orientations (NUFO), and volume.

Statistical analysis. Intra-class correlation coefficient (ICC) analyses were run to assess the test-retest reliability of all measures in the four tracts, bilaterally. ICCs greater than .75 indicate excellent reliability, while ICCs between .60 and .74 indicate good reliability (8).


AF
L
R
ILF
L
R
T1
T2
UF
IFOF
T1
T2

·Figure 1. Reconstructed AF, ILF, IFOF, and UF (bilaterally) in a representative subject

Results:

All measures showed significantly good to excellent test-retest reliability (ICCs = .69 - .96; all ps < .05) in all four tracts, bilaterally (Table 1). FA and volume measures showed consistently excellent test-retest reliability (ICCs > .75) across all four WM tracts, bilaterally. AD, RD, MD, and NuFO showed good reliability in the left ILF (NuFO), right UF (NuFO and AD), and right AF (MD and RD) (ICC = .69 - .73), and excellent reliability in all other tracts.

		FA	AD	MD	RD	NUFO	VOLUME
AF							
	Left	0.86***	0.90***	0.91***	0.92***	0.79**	0.94***
	Right	0.87***	0.84**	0.70**	0.69*	0.86***	0.96***
ILF							
	Left	0.81**	0.94***	0.89***	0.81**	0.73**	0.83***
	Right	0.84**	0.80**	0.82**	0.86***	0.86**	0.85**
IFOF							
	Left	0.83**	0.87***	0.82**	0.80**	0.78**	0.83**
	Right	0.90***	0.93***	0.86***	0.86***	0.76**	0.91***
UF							
	Left	0.75**	0.89***	0.78**	0.76**	0.77**	0.85***
	Right	0.83***	0.70**	0.79**	0.87***	0.71*	0.84**

***$p < .001$; **$p < .01$; *$p < .05$

·Table 1. Intra-class correlation coefficient values for all measures in the four WM tracts (bilaterally)

Conclusions:

Our results demonstrate that diffusion measures of FA, AD, MD, RD, NuFO, and volume extracted using HARDI-tractography are reliable for the longitudinal study of the AF, ILF, IFOF, and UF tracts in healthy individuals. These findings are in line with other test-retest studies of diffusion metrics using different processing approaches (9,10). However, the reliability of this method for tracking WM changes in patients with neurological conditions needs to be further investigated, given the challenges posed for fiber reconstruction by large cerebral lesions or brain tumors. Nevertheless, our study shows that HARDI-based tractography is a promising technique for the longitudinal study of tract-specific WM structural properties.

Imaging Methods:

Diffusion MRI [1]

Modeling and Analysis Methods:

Diffusion MRI Modeling and Analysis [2]

Neuroanatomy:

White Matter Anatomy, Fiber Pathways and Connectivity

Keywords:

Neurological
Tractography
White Matter
WHITE MATTER IMAGING - DTI, HARDI, DSI, ETC

[1|2]Indicates the priority used for review

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Please indicate which methods were used in your research:

Diffusion MRI

For human MRI, what field strength scanner do you use?

3.0T

Which processing packages did you use for your study?

FSL
Other, Please list - Toolkit of Analysis in Diffusion imaging (TOAD); MRtrix

Provide references in author date format

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