DTI Reconstruction: K-space Average, Image-space Average, or No Average

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Introduction

Diffusion Tensor Imaging (DTI) is achieved by collecting a series of Diffusion Weighted Images (DWI) with different diffusion weighted vectors. For each DWI, it is usually acquired with multiple repetitions to boost the signal to noise ratio. Most of the MRI consoles saved the DWI after the K-space averaging automatically. Some other MRI consoles, such as the Siemens 3T human scanner, save each acquisition as an individual image. Instead of K-space averaging, one can perform image-space average. Alternatively, each acquisition can be treated as independent image and used to reconstruct DTI without doing signal averaging. To our understanding, there was no comparison of these approaches and to evaluate their performances on DTI reconstruction. In this study, we compared DTI maps of mouse brains in vivo using k-space average, image-space average, and no average approaches.

Theory

DTI reconstruction is based on

$$S = S_0 \exp(-b \cdot D) \qquad \text{[Eq. 1] (1)},$$

where S and S_0 are signal intensities with and without diffusion encoding respectively. *b* is a diffusion weighting vector, which contains diffusion encoding gradient directions. *D* is the diffusion tensor, a 3 x 3 symmetric matrix. Thus, there are 7 unknowns (S_0 and *D*). A minimum of 7 DWIs with independent *b* vectors are required to solve *D* from Eq. 1. Here we call the number of *b* vectors as DT, and DT should be larger than 7. The number of repetition for each DWI is usually called the number of average (NT). Before any averaging process, one should collect a number of NT x DT images in order to perform diffusion tensor reconstruction via Eq. 1. There are three ways of process these data: 1. to calculate the averaged DWI from the NT repetitions in K-space (K-space average approach), 2. to calculate the averaged DWI from the NT repetitions in image-space (image-space average approach), and 3. to use all images (NT x DT) into the calculation of Eq. 1 (no average approach).

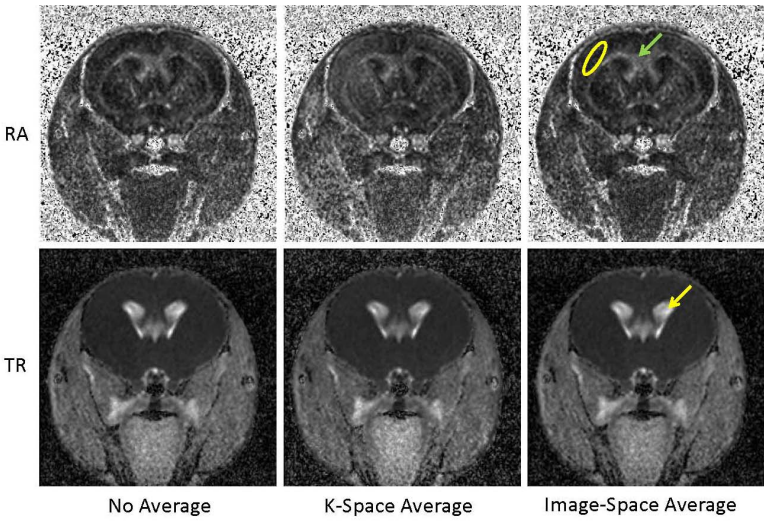

Fig. 1 One example of RA and TR maps reconstructed using no average, k-space average, and image-space average approaches.

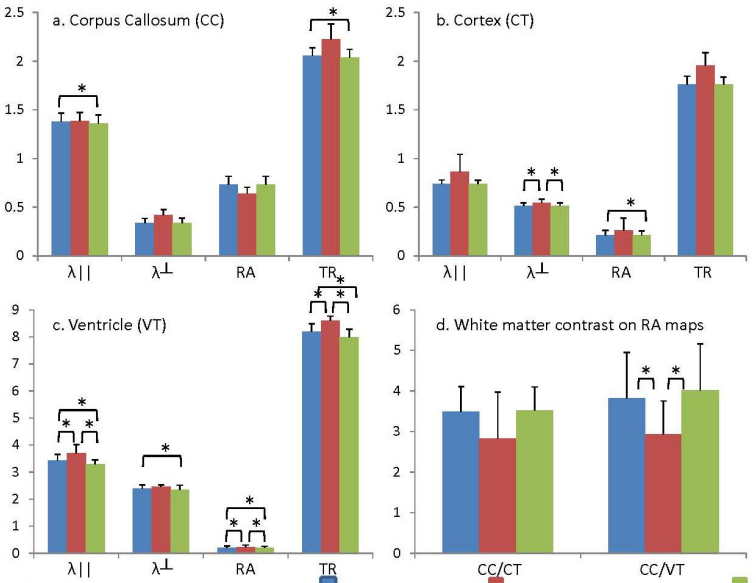

Fig. 2 ROI measurements of no average (), k-space average (), and image-space average ().

Materials and Methods

Five normal mice were anesthetized with a mixture of oxygen and isoflurane for imaging. Spin-echo DTI were collected using a Bruker 4.7T BioSpec small animal MRI instrument with TR 3 s, TE 29 ms, diffusion gradient pair (Δ) = 20 ms, diffusion gradient duration (δ) = 3 ms, DT of 7 including one b = 0 and six DWIs with 0.85 ms/μm^2, NT of 3, slice thickness 0.5 mm, field of view of 1.5 cm x 1.5 cm, and matrix 256 x 256. Relative anisotropy (RA), Trace of *D* (TR), axial diffusivity ($\lambda_{||}$), and radial diffusivity ($\lambda_{\perp}$) were generated using Matlab. Regions of interest were selected in corpus callosum (white matter, a green arrow in **Fig. 1**), cortex (gray matter, an oval in **Fig. 1**), and ventricle (a yellow arrow in **Fig. 1**).

Results

As shown in **Fig. 1**, k-space average provided the least contrast for presenting white matter on RA maps. White matter contrast of RA maps was significant improved by no-average or image-space average approaches (**Fig. 2d**). Based on paired T-test analysis, there are significant differences between three approaches summarized in **Fig. 2**.

Discussion and Conclusions

It was previously suggested that phase correction is sometimes needed in the process of complex numbers in MR spectrum and image (2). Without a proper phase correction, the phase drifting over time may affect the complex number averaging used in the k-space average approach for DTI reconstruction. However, it should be noted that the k-space average performed in this study did not apply phase cycling, which would have improved the accuracy of imaging over the image-space average and no average approaches. Further analysis is in process in our lab.

References (1) Basser PJ. NMR Biomed 8, 333-44 (1995) (2) Larry Bretthorst G. J Magn Reson. 191(2):184-92 (2008).

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