TO ROTATE B OR NOT TO ROTATE B? THE IMPORTANCE OF REORIENTING THE B-MATRIX DURING MOTION CORRECTION OF DT-MRI DATA

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Introduction

To robustly estimate Diffusion Tensor MRI (DT-MRI) measures, such as the Fractional Anisotropy (FA), it has recently been shown that the acquisition of a higher number of Diffusion-Weighted (DW) gradient directions is needed, preferably combined with cardiac gating to reduce pulsation artifacts [1, 2]. Consequently, acquisition times are longer, increasing the adverse effect of subject motion. Previous research has indicated that correcting for these motion artifacts (and potential geometrical distortions induced by eddy currents) improves the accuracy of, for instance, the estimated FA [3, 4]. However, it remains questionable whether reorienting the B-matrix, which preserves the orientational diffusion information while correcting for subject motion, can further improve the estimation of the diffusion tensor, even in data collected for normal willing healthy volunteers. In this work, we investigated the effect of such a B-matrix reorientation on the diffusion tensor, in particular the FA and the First Eigenvector (FE), and looked at the consequences for fiber tractography (FT).

Methods

Acquisition: A DT-MRI data set was acquired on a 3T system with the following parameters: b-value = 1200 s/mm^2 along 60 gradient directions (6 non-DW images); FOV = 23cm; 96×96 acquisition matrix; 2.4 mm slice thickness. We used parallel imaging with an ASSET acceleration factor of 2.

Data processing: The tensor model was estimated using the Levenberg-Marquardt non-linear regression method [5]. An affine co-registration technique based on mutual information was used to realign the (non-)DW images to the first non-DW image [6]. The goodness-of-fit (GoF) – here calculated non-parametrically for each voxel as the normalized median absolute value of the DW residual with respect to the tensor model – is used to indicate the quality of the diffusion tensor fit (lower GoF values reflect a better model fit), representing an indirect measure to assess the quality of the motion/distortion correction procedure [4]. Finally, a standard deterministic streamline fiber tractography approach was used to show the fiber pathway differences between rotating and *not* rotating the B-matrix [7].

Results

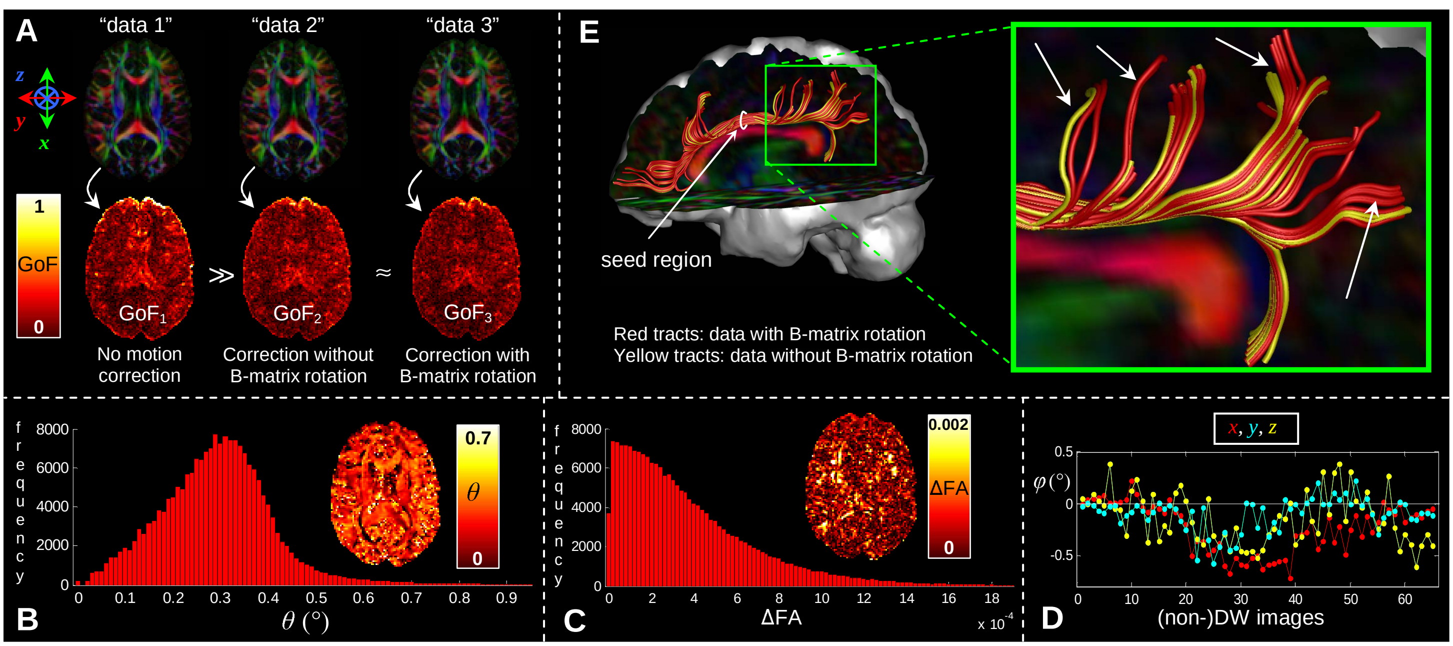
In Fig. A, the FA and GoF are shown for the motion-uncorrected data ("data 1", GoF_1) and for the motion-corrected data: without ("data 2", GoF_2) and with ("data 3", GoF_3) B-matrix rotation. In particular, notice the difference in the region of the ventricles (GoF_1 vs. GoF_2 and GoF_3). Fig. B displays the histogram of the angle between the voxelwise estimates of the FE of "data 2" and the FE of "data 3". Similarly, the absolute difference in FA (ΔFA) between "data 2" and "data 3" is shown in Fig. C. The rotation angle φ for each axis (x, y, z of coordinate system in Fig. A), as obtained from the motion correction procedure, is plotted for each DW image in Fig. D. Finally, fiber tract pathways of the left cingulum – using "data 2" (yellow) and "data 3" (red) are shown in Fig. E.

Discussion

It is important to note that in this example, the acquired DT-MRI data set was considered as a 'normal/typical' data set with no 'visually detectable' motion artifacts, which can be confirmed by the small rotation angles shown in Fig. D, which were roughly within a 1° range. Although GoF_1 was significantly higher than GoF_2 and GoF_3, no statistically significant difference was found between GoF_2 and GoF_3 (paired-sample Wilcoxon signed rank test). However, as shown in Figs. B and C, rotating the B-matrix clearly affects the direction of the FE and changes the FA values. These differences may appear negligible, their effect is far from negligible when accumulated over long distances in tractography, which is clearly visible in Fig. E, as indicated by the arrows.

Conclusion

Our results demonstrate that for correcting DW motion artifacts, the B-matrix should be rotated – even for 'normal' data sets, especially when fiber tractography will be applied. It is important to note that the data in this study were collected from highly motivated individuals who understood the need to remain still during data acquisition. In real world (clinical) scenarios, the importance of reorienting the B-matrix during motion correction to avoid bias, is even more paramount.



References

[1] D.K. Jones, MRM 51, p. 807-815, 2004; [2] C. Pierpaoli *et al*, Proc ISMRM 2003, p. 70; [3] J.-F. Mangin *et al*, Medical Image Analysis 6, 191-198, 2002; [4] G.K. Rohde *et al*, MRM 51, 103-114, 2004; [5] D. Marquardt, SIAM Journal Applied Math 11, p. 431-441, 1963; [6] Maes F. *et al*, IEEE Trans Med Imaging 16, p. 187-198, 1997; [7] P.J. Basser *et al*, MRM 44, p. 625-632, 2000