EVALUATION OF THE BIEXPONENTIAL MODEL FOR THE DESCRIPTION OF DIFFUSION DATA ACQUIRED WITH MULTIPLE B-VALUES

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INTRODUCTION

Diffusion data of the brain are usually fitted to a single exponential (1EXP) model[1] assuming the existence of a single prevalent component in each voxel. To release this last constraint, under specific conditions of acquisition as multiple b-values, a bi-exponential (2EXP) model can be used. It is thought that the identification of the 2EXP model allows detecting two distinct compartments in a voxel, helping in the identification of a slow diffusion and a fast diffusion component[2, 3]. Aim of this work is to understand if the 2EXP model is better than the 1EXP in describing diffusion data in all brain areas or only in a critical portion of them, and if the 1EXP derived diffusion indexes can be compared to those obtainable with the 2EXP model.

METHODS

Dataset: Eight healthy volunteers (M/F = 3/5, age 28.8 ± 1.7 years) underwent a MRI exam with a 3T 32 channels Philips Achieva. DTI data consisted of 5 acquisitions with different b-values (500, 1000, 1500, 2000, 2500 mm/s^2) along 32 non-collinear directions.

Analysis: The 2EXP model $\boldsymbol{y} = fe^{-b\boldsymbol{D_1}} + (1-f)e^{-b\boldsymbol{D_2}}$, ($\boldsymbol{y}$ is the data vector, f the volume fraction of the first component, $\boldsymbol{D_1}$ and $\boldsymbol{D_2}$ the tensors of the two components) was identified with the nonlinear least squares estimator (Levenberg-Marquardt algorithm). The starting points for the parameters were obtained with a linear least-squares fit of the subsets of data composed by the data acquired at 500-1000 mm/ss^2 and 1500-2000-2500 mm/ss^2. FA_1, FA_2, MD_1 and MD_2 were obtained, as well as mFA= f FA_1 + (1- f)FA_2 and mMD= f MD_1+(1- f)MD_2. The 1EXP model was identified using the same nonlinear method, FA and MD were computed. Linear correlations among FA, FA_1, and mFA, and among MD, MD_1, and mMD were calculated in two manually-drawn ROIs, one where the f estimated values suggest the presence of two compartments (in the corpus callosum, cc-ROI) and one where f values are close to 0, suggesting the presence of a single compartment (in a mixed gray-white matter area, gw-ROI).

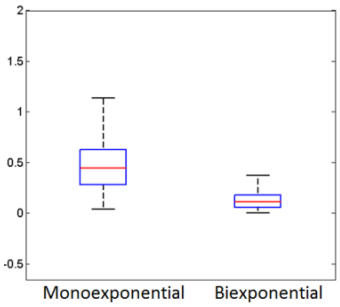

Fig. 1 – Boxplot representing mean WRSS calculated for the monoexpoential (left) and biexponential (right) model.

RESULTS

The weighted residual sum of squares (WRSS) is depicted in Figure 1. Considering the Fig. 1 as well as the goodness of the estimates (not shown), 2EXP shows to be superior in describing the data. In particular, f values and WRSS differences show that 2EXP has more impact in the considered part of corpus callosum. The correlation between FA_1 and FA was 0.43± 0.24 in the cc-ROI and 0.81 ± 0.16 in the gw-ROI. Correlation between mFA and FA was 0.92 ±0.04 and 0.91 ± 0.02 in the same ROIs. Correlation between MD_1 and MD was 0.10 ±0.19 in the cc-ROI and 0.29 ± 0.35 in the gw-ROI. Correlation between mMD and MD was -0.02 ± 0.05 and 0.09 ± 0.14 in the same ROIs.

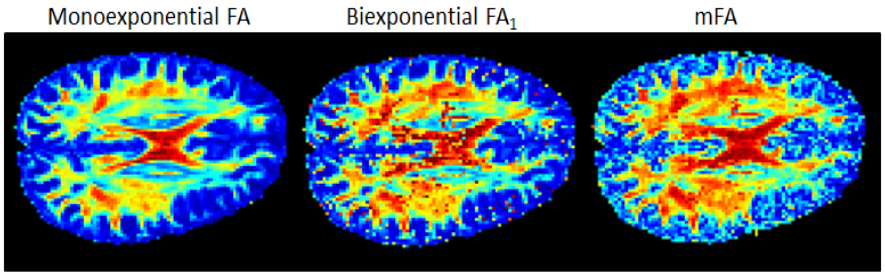

Fig. 2 – FA calculated with the monoexponential model (left), with the biexponential model (center) and mFA (right). It is to be noted that only FA_1 is represented for the biexponential model. FA_2 is not represented, because of its poor correlation with FA.

DISCUSSION AND CONCLUSION

2EXP model fits the data significantly better than 1EXP in all brain areas. The correlations between FA_1, mFA and FA show that FA is an index that merges information belonging to the 2 compartments, especially in ROIs where the f value supports the presence of 2 components, as the cc-ROI with f = 0.61 ± 0.21. In a ROI where the values of f suggest the presence of a single compartment, e.g. in the gw-ROI where f = 0.20 ± 0.08, FA_1 is more strongly related to FA. On the contrary, MD doesn't show relevant relation with MD_1 or mMD. Further study is necessary to obtain an acquisition scheme to make feasible the use of the 2EXP model in the clinical practice.

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