Effect of reference template selection in diffusion tensor based voxel-wise analysis

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Introduction

Diffusion tensor based voxel-wise analysis (DT-VBA) has been increasingly used to investigate subtle differences in brain white matter microstructure among various types of patient groups and groups of control subjects.[1-2] The method provides an inference of inter-group differences in white matter integrity on a voxel-wise basis in a standardized space. Spatial normalization is an important preprocessing step in DT-VBA analysis and is used to reduce inter-subject anatomical variability by registering each image volume to a standard space.[3-5] Varieties of reference template and processing procedures exist in the implementation of DT-VBA.[6] It is still not clear which image processing procedure may produce more plausible or more accurate results. The purpose of this study is to systematically evaluate the effects and accuracy of varying reference template and image preprocessing procedure of the DT-VBA.

Methods

Twelve normal right-handed male participants (mean age = 22.3±2.4 y/o) were recruited in the study. All MR scans were performed on a 1.5T MR system (Excite II; GE Medical Systems, Milwaukee, Wis., USA) at the Veterans General Hospital Taipei. Whole brain diffusion-weighted images were acquired using a single shot diffusion spin-echo EPI sequence with TR/TE = 17000/68.9 ms, the voxel size = 2 × 2 × 2.2 mm^3. T1 images were also acquired with TR/TE = 8.54/1.84 ms, the voxel size = 1 × 1 × 1.5 mm^3. The diffusion-weighting gradients were applied in 13 non-collinear directions with b-value = 900 s/mm^2 and NEX = 6. All FA images were calculated from each DTI dataset by the in-house program. Subsequent preprocessing procedure of the DT-VBA including FA image registration and normalization were performed on SPM2 (Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK). Three methods were progressed as follows. Method 1: the T1 template available in SPM2 was used to proceed in the following steps: (i) to perform a coregistration between each subject's non-diffusion-weighted (Null) image and the T1 image, applying the same transformations to the FA maps; (ii) performed a normalization of the T1 image to a customized T1 template, applying the same deformation parameters to the FA maps. Method 2: the EPI template available in SPM2 was used to proceed in the following steps: (i) to perform a normalization of the Null image to a customized EPI template; (ii) to apply the same transformations to the FA maps, which was inherent the same as Null image. Methods 3: with the template option set to FA, was directly performed a normalization of the FA image to a customized FA template. In order to realize the effect of different DT-VBA procedures, the final step in all Methods was to apply the inverse transformations to ROIs in a standardized space. ROIs were defined on the same axial slice of standardized FA image for each normalization protocol. One was on the genu of corpus callosum, and other two were defined on both hemispherical internal capsules respectively. (Figure1.) The similarity of FA values in standardized space and those in native space were examined by using non-parametric correlation method.

Results

Results of template effect normalization in DT-VBA preprocessing illustrated that cerebral dimensions of standardized brains from the T1 and the EPI template were all larger than those for the FA template, which was the most marked for the Z (inferior-superior) dimension. (Figure 2) As shown in Figure 2, the anterior commissure (AC) in standard space was about 4~6 mm below the line at X=0, Z=0, and the anterior commissure (AC) and posterior commissure (PC) were not aligned horizontally. The results reflected in Figure 3, for evaluating the similarity of FA values between standardized and native space, indicated that the non-parametric correlation coefficients of FA values in DT-VBA normalization process using the FA template (Method 3, the average coefficient of correlation <R>=0.972) all turned out to be higher than those using the T1 (Method1,<R>=0.932) and the EPI (Method 2,<R>=0.930) templates, which may suggest a slightly higher similarity before and after spatial normalization.

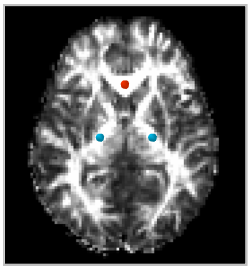

Figure 1. *ROIs (r = 3mm) were located on the genu of corpus callosum(ROI(1),red), and on both hemispherical internal capsules respectively (ROI(2)(3),blue).*

Conclusions

The results of this study demonstrated that while doing the DT-VBA procedure, the FA template for normalization could present AC on a correct origin of the standardized space coordinates. By using the FA template, the similarity of FA values in standardized space and those in native space were having higher correlation. These results may due to the FA template possess the same image modality with the FA image. Consequently, this may result in improving the accuracy and power of statistical analysis in DT-VBA researches. Furthermore, image normalization using the FA template could not only provide fewer steps of image processing, but also reduce the erroneous bias occurred from algorithm implementation.

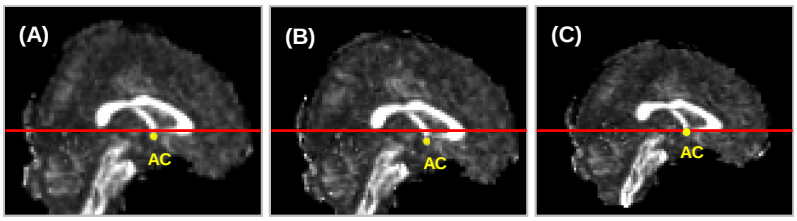

Figure 2. *Normalized FA images, using T1 template (A), EPI template (B), and the FA template (C). The AC were 4 mm (A) and 6 mm (B) below the line at X = 0, Z = 0 respectively.*

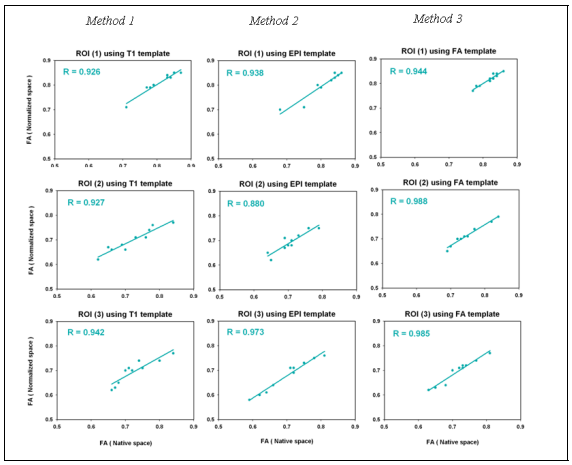

Figure 3. *The results of non-parametric correlation analysis. With the results, using the FA template for normalization suggested a slightly higher precision for spatial normalization.*

Reference

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Acknowledgements

This study was supported in part by National Science Council grant NSC 97-2752-H-010-004 –PAE.