The Voxel-Based Comparison of Fractional Anisotropy and Mean Diffusivity between the Elderly and Young Using TBSS

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Introduction

It is hypothesized that white matter (WM) degenerates with age. Age related decreases in fractional anisotropy (FA) and increases in mean diffusivity (MD) were observed across the entire WM skeleton as well as in specific WM tracts [1]. It is essential to compute the FA in a voxel-based manner for a population to obtain the detailed information about general characteristics of the degeneration. The general scenario of image registration is to 'normalize' the source images to a template image in order to minimize certain cost functions and do the voxel-by-voxel comparison. Here, we use Tract-Based Spatial Statistics (TBSS), a non-linear registration technique, to normalize diffusion tensor imaging (DTI) datasets to avoid poor registration to template during normalization that is commonly observed in voxel-based morphometry [2]. We applied TBSS to FA and MD images to examine the differences in white matter integrity between the healthy elderly and young participants.

Methods

A total of 40 healthy male Japanese participants were examined using DTI images. There were twenty right-handed elderly participants that aged 50-74 years old (mean=66.85, SD=5.23) and twenty right-handed young participants that aged 20-34 years old (mean=22.2, SD=3.16). Images were acquired on a 3T MRI system with a 12-channel head coil. DTI was performed using a twice-refocused balanced echo diffusion echo planar imaging (EPI) sequence; TR/TE = 7700/93 ms, field of view (FOV) = 200 x 200 mm2, image matrix size = 100 x 100, and slice thickness = 2 mm. Thirty diffusion directions with the maximum diffusion sensitivity bmax = 1000 s/mm2 were repeated twice. Following brain extraction, motion correction, and generation of DTI parametric maps using the tools provided in FSL (http://www.fmrib.ox.ac.uk/fsl), the voxel-wise statistical analysis of DTI parameter maps was conducted with TBSS [2]. Direct registration of individual FA volumes to the FMRIB58 template was applied, and the mean FA image and mean FA skeleton were created. After registration, nonparametric permutation testing was performed using Randomize. Voxel-wise cross-subject statistical analysis was conducted with group comparison (controls>patients and patients>controls). Multiple comparison correction was conducted with Threshold-Free Cluster Enhancement (TFCE) in Randomize [3].

Results

Widespread decreases of FA and increases of mean diffusivity were found in elderly versus young participants. At $p<0.001$, the corpus callosum, putamen, posterior corona radiata and superior corona radiata showed the greatest reduction in FA (Fig.1a). Superior longitudinal fasciculus, internal capsula and posterior thalamic radiation also showed significant reduction in FA at $p<0.05$ (Fig. 1b). We also demonstrate that MD in the anterior corona radiata, posterior corona radiata, superior corona radiata and capsule are significantly higher in elderly participants at $p<0.001$(Fig. 2a). Finally, the anterior thalamic radiation, posterior thalamic radiation, superior longitudinal fasciculus and fornix showed significantly increased in MD at $p<0.05$ (Fig. 2b).

Conclusion

The efficient registration by the TBSS successfully demonstrated the differences in FA values between healthy young and elderly groups. FA and MD shared the most significant difference in corona radiata. The present study found that FA values were lower in older than in younger adults ($p < 0.01$) in numerous WM regions, which are consistent with previous research [4]. In addition, the increased FA in the putamen found in the elderly group is consistent with a previous observation of the FA with aging [5]. In conclusion, our findings demonstrate the effectiveness of TBSS as a population-wise measure of the white matter change on a voxel-by-voxel basis.

Fig. 1a Fig. 1b

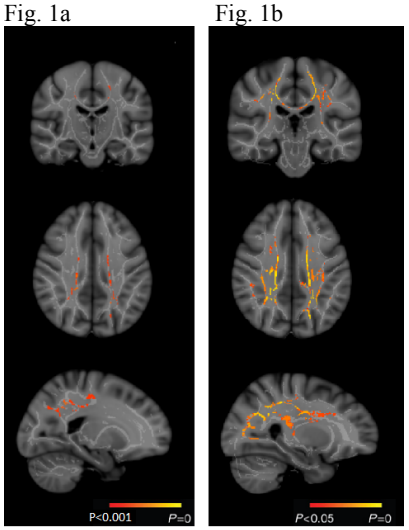

Figure 1: decreases in FA (young > elderly participants), at the threshold of $p < 0.001$ (Fig. 1a) and $p<0.05$ (Fig. 1b).

Fig. 2a Fig. 2b

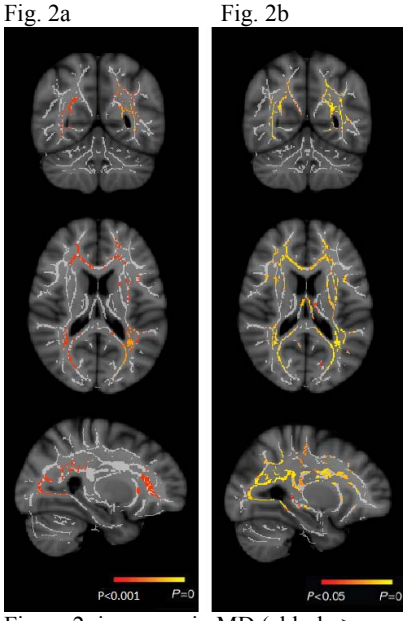

Figure 2: increases in MD (elderly > young participants), at the threshold of $p < 0.001$ (Fig. 2a) and $p<0.05$ (Fig. 2b).

References

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