

A voxel-based analysis of SNR effect on diffusion tensor imaging

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Introduction:

Fractional anisotropy (FA) quantifies microstructural organization of various anatomical structures, especially the distinct differences between white and gray matter. The study of FA value differences between normal and clinical groups has been the primary focus of various brain research areas. However, the value of FA is very sensitive to low signal-to-noise ratio (SNR) in diffusion encoded measurements [1,2] in particular in gray matter [3,4]. Therefore, it is critical to investigate how the value of FA is influenced by SNR [5, 6]. However, there is no systematic study of the influence of SNR in DTI on the value of FA for the whole brain. In this study, voxel based morphometry (VBM) [7] is adopted for its unbiased approach and comprehensive assessment of differences throughout the brain results from different diffusion weighted SNR. The normalization for VBM is completed using recently available whole brain technique, DARTEL in SPM5 [8]. The group comparison of segmented grey matter (GM) and white matter (WM) from different encoding schemes is performed on the same healthy adult controls and the VBM results confirms that FA of GM is effected with lower SNR while FA of WM is more immune to SNR effects.

Methods:

Subjects: We included a total of 34 healthy adult controls (13 men & 21 women; age = 37.7 ± 11.2 years {mean ± SD}). The DTI data were acquired using a single-shot spin-echo diffusion sensitized EPI sequence with the well-balanced *Icosa21* encoding scheme, b=1000 sec mm⁻², T_R/T_E = 6100/84 msec. The *Icosa21* scheme has been shown to provide subsets of uniformly distributed icosahedral schemes to study SNR sensitivity [5]. The slice thickness was 3.0 mm with 44 contiguous axial slices covering the entire brain; FOV=24x24 cm². The number of b=0 images was 8; in addition each diffusion encoding was repeated twice and magnitude averaged.

Data Processing: The processing procedure is illustrated in Fig.1. Intra-session comparison is the key to the study of diffusion weighted SNR only effect in this work as the inter-session noise is avoided and relatively high constant SNR is isolated in comparison. This is realized by studying SNR sensitivity to different encoding schemes which are from one DTI scan session. An encoding scheme dataset with less number of directions can be generated by selecting encoding directions from a more uniformly distributed encoding scheme dataset. In this work, a well-balanced uniformly distributed encoding scheme *Icosa21* (group A) and a minimal encoding scheme *Icosa6* (group B) are selected for comparison. The encoding dataset of group B is generated from encoding dataset of group A as illustrated in Fig.1 (a), resulting that both datasets of group A and B share the same b₀ images which excludes the influence of constant SNR. Therefore, the comparison between group A and group B is an intra-session DWSNR comparison. As shown in Fig.1 (b), Intra-session SNR comparison is performed between FA from group A and B. First, FA in group A is computed for *Icosa21* while FA in group B is computed for *Icosa6*, respectively, for a total of 34 subjects. Then segmentation was completed for the resulting 68 FA maps (34 at low SNR *-Icosa6* and 34 at higher SNR *-Icosa21* subset) using the segmentation tools in SPM5. Both segmented FA maps of GM and WM were fed to DARTEL for normalization. DARTEL technique designed for whole brain MRI scan is selected for the purpose of FA value comparison over the whole brain area. The first step in DARTEL is to create a template iteratively based on the entire 68 data subsets. Then Jacobian scaled warped images are generated using a single velocity flow fields which parameterize the deformations to the template. The end result volumes are smoothed by a Gaussian filter with size of 8. Statistical analysis of FA values was performed with a two sided t-test. A p-value of less than 0.005 was considered significant. The VBM results is normalized to the template of the ICBM atlas [9] and displayed in Fig.2 using software MRICroN. The red area in Fig.2 corresponds to the area with p-value less than 0.005.

Results:

The VBM results are overlaid on the ICBM atlas in Fig.2. The p value for WM comparison in Fig.2 (a) indicates that WM is not affected by lowering SNR in DTI (total number of images NT=8+6*2 vs. 8+21*2). The p value for GM comparison in Fig.1 (b) indicates that GM (both subcortical and cortical) is sensitive to SNR change resulting from selecting different encoding schemes in DTI. The results in Fig.2 give detailed brain structural information related to DWSNR sensitivity. Based on the atlas structural information, there is significant difference due to lowering SNR in GM including basal ganglia (caudate, putamen), cortex and gray matter lobes etc.

Discussion:

This is the first report of VBM study of SNR impact on FA on the whole brain area. VBM approach gives detailed affected brain structural information resulting from lowering SNR in DTI. The approach of encoding scheme comparison gives insight on the choice of encoding scheme in DTI experiment design.

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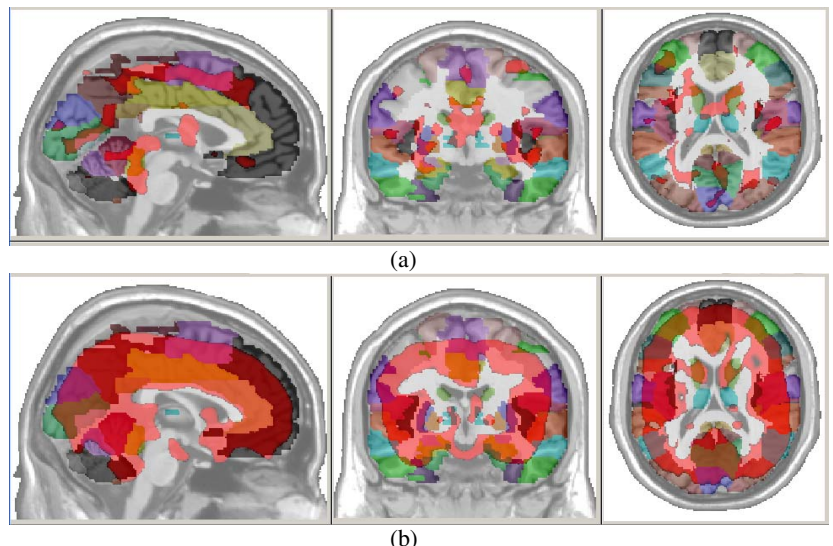
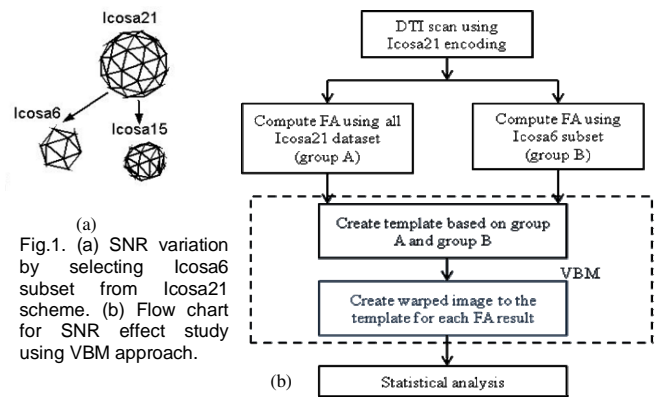


Fig 2. P values for white matter (a) and gray matter (b) are overlaid on ICBM atlas. The red area corresponds to p value less than 0.005.