Effect of Voxel Size on DTI Fractional Anisotropy

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Introduction: Diffusion tensor imaging (DTI) has demonstrated a broad array of clinical applications due its sensitivity to anisotropic structure in, e.g., white matter and muscle[1]. A scalar, fractional anisotropy (FA), contrasts the principal eigen values of diffusivity and, thus, is limited by sensitivity to diffusion *and* to noise[2]. According to this reasoning, it does not follow that FA is invariant across a range of voxel sizes, magnet fields, and experimental design. Signal to noise ratio always varies with voxel size, but the exact relation is not straightforward. The current study attempts to find the dependence of FA on voxel size while keeping all other parameters constant.

Materials and Methods: Five healthy volunteers (age range = 29-48 yrs; 35.4 ± 7.86 M±SD) were imaged on a Siemens Sonata 1.5 T scanner. Single shot spin-echo planar DTI was acquired in six directions using TR/TE = 5800/97, b values of 0 and 1000 sec/mm^2, NEX = 10. Using a within-subjects design, 7 different voxel sizes covering the same brain volume. Voxel dimensions were (in mm): [2x2x2], [2x2x3], [2x2x4], [3x2x4], [4x2x4], [4x4x4], [4x4x8]. Corresponding DTI FA maps were generated using DTI studio (http://www.mri.kennedykrieger.org) software with a background noise suppression threshold of 50 units.

Computation of white-matter only FA:

Normalization: Each subject's FA map was spatially normalized to an in-house FA template using affine only matching in SPM2.

Tissue class segmentation: Automated segmentation (SPM2) of subjects' normalized FA map produced tissue-class probability maps (WM/GM/CSF). The binarized WM mask was then multiplied by the subject's normalized FA map to create a WM-only FA map for each voxel size.

FA x voxel volume: Subject FA mean was plotted vs. voxel volume. Group averaged results were also plotted on same plot.

Results: An exponential function was observed between voxel size and FA (see Figure 1). This relationship was remarkably consistent across the five subjects. Smaller voxels produced higher FA, particularly for 8-32 mm^3. The variation of FA with resolution was large relative to inter-subject variability A logarithmic transformation produced expected linearity (see Figure 2).

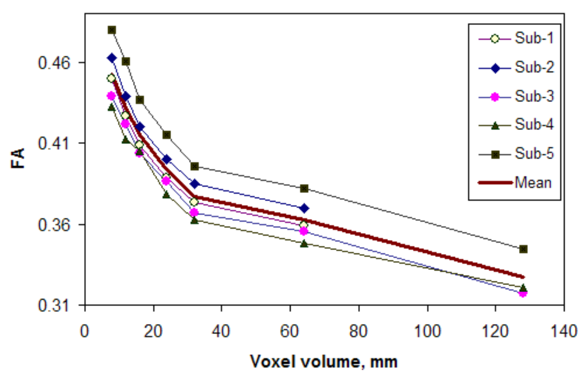

Figure 1. Relationship of voxel volume with FA in 5 healthy subjects. We can see that FA inceases with the decrease of voxel volume.

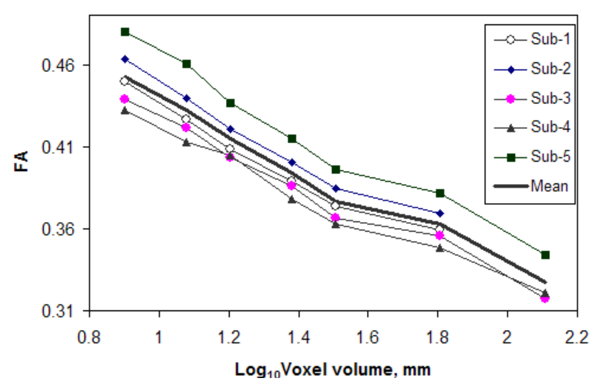

Figure 2. Relationship of voxel volume (logarithm) with FA in 5 healthy subjects. We can see the linear relationship between logarithm of voxel volume and FA values.

Conclusion: Voxel size significantly affects FA with smaller voxels giving higher fractional anisotropy values. This effect is strongest at highest resolutions of imaging and is an important source of variance in FA in comparison with FA differences between healthy individuals. These findings suggest that valid interpretation of FA differences in cross-sectional and longitudinal studies requires identical imaging resolutions and experimental designs.

References:

1. Benson et al 2007;Global White Matter Analysis of Diffusion Tensor Images Is Predictive of Injury Severity in Traumatic Brain Injury; *Journal of Neurotrauma*. Mar 2007, Vol. 24, No. 3: 446-459
2. Schmithorst,et al.2001; Correlation of white matter diffusivity and anisotropy with age during childhood and adolescence: A cross sectional DTI MRI study. *Radiology* 2002;222:212-218