Application of geometric indices of diffusion tensor imaging on ischemic cerebral infarction: comparison of two definitions

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Introduction: Diffusion tensor imaging technique has been used to evaluate diffusion anisotropy in the brain. Fractional anisotropy (FA) is the most popular index to describe the anisotropic diffusion of brain tissue. Other than FA, some indices regarding the tensor geometric such as linear (CL), planar (CP) and spherical (CS) coefficients [1,2] characterize the geometric shape of diffusion tensor. Two different definitions of geometric diffusion coefficients have been proposed, but so far there is no study quantitatively comparing their sensitivities on brain diseases. Therefore, the purpose of this study is to compare these two geometric index definitions on normal subjects in diffusion tensor imaging and estimate their sensitivity on detecting brain stroke.

Materials and Methods: Diffusion tensor images were acquired from six normal subjects (M:F=3:3; age=27.17 ± 4.58 years) and one stroke patient at a 1.5T MR system (Siemens Vision; Erlangen, Germany) using a spin-echo echo-planar imaging sequence with the following parameters: TR/TE/NEX = 5000/100/2, FOV= 24 cm, section thickness = 5 mm (no intersection gap), matrix size = 128 × 128, b-value = 707 s/mm2 along six non-collinear directions. Afterwards, tensor calculation was conducted to obtain three eigenvalues (λ1, λ2 and λ3) as well as fractional anisotropy (FA). Further, two sets of geometric indices were also calculated according to the following two definitions:

Definition-1: $$C_L = \frac{\lambda_1 - \lambda_2}{\lambda_1 + \lambda_2 + \lambda_3}, C_P = \frac{2(\lambda_2 - \lambda_3)}{\lambda_1 + \lambda_2 + \lambda_3}, C_S = \frac{3\lambda_3}{\lambda_1 + \lambda_2 + \lambda_3}$$

Definition-2: $$C_L = \frac{\lambda_1 - \lambda_2}{\lambda_1}, C_P = \frac{\lambda_2 - \lambda_3}{\lambda_1}, C_S = \frac{\lambda_3}{\lambda_1}$$

In these two definitions, all of metrics fall in the range 0~1, and sum of them equal to identity (CL + CP+ CS= 1). After all of data were calculated, total of 30 slices, containing 105029 pixels, of six normal subjects were included to compare histograms of two geometric definitions. For sensitivity comparison of two geometric definitions, following detectability index was used to measure their detectability on stroke lesion.

$$d = \left| \frac{m_{normal} - m_{stroke}}{\sqrt{\sigma^2_{normal} + \sigma^2_{stroke}}} \right|$$

where m and σ^2 are the means and variances of geometric indices of two definitions.

Results: Figure 1 shows the barycentric coordinate of three geometric indices in RGB colors, where red, green and blue represents spherical, planar and linear coefficients, respectively. After mapping RGB colors of two definitions to tensor image, we could obtain two different color maps of brain, as shown in Figs. 2(b) (definition-1) and 2(c) (definition-2). For global comparison, histograms of three geometric indices of two definitions as well as FA were plotted in Fig. 3, showing that three geometric indices of definition-2 exhibit wider distribution which therefore has better sensitivity on detecting geometric changes of DTI in brain tissue. For detectability comparison on stroke lesion, Fig. 4 shows the braycentric isocontours of normal and stroke regions, as pointed by white arrows in Fig. 5. The calculated detectability indices of definition-1 and definition-2 are 1.849 and 2.063, respectively, meaning that definition-2 has better sensitivity on detecting stroke lesions.

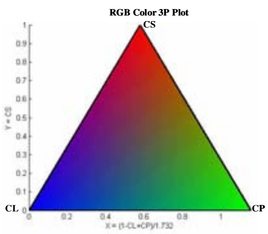

Figure 1. Illustration of the barycentric coordinate of RGB colors for CL,CP and CS.

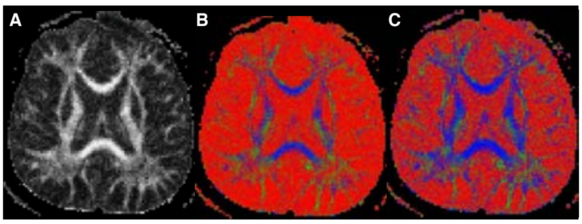

Figure 2. Representation of FA (a), barycentric geometric RGB map of definition-1 (b) and definition-2 (c) on a normal subject.

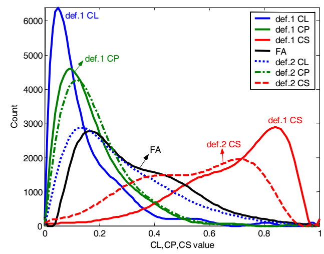

Figure 3. The histogram of FA, and three geometric indices of two definitions.

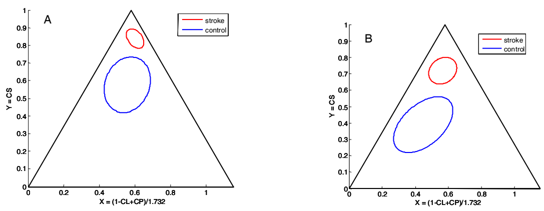

Figure 4. Isocontour locations of normal (blue) and stroke (red) regions in barycentric coordinate.

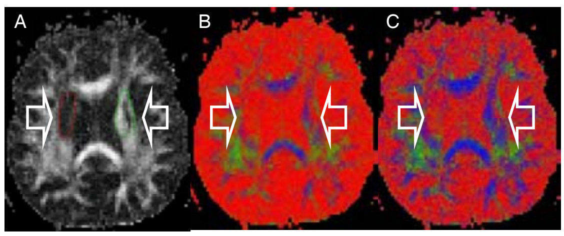

Figure 5. Representation of FA (a), barycentric geometric RGB map of definition-1 (b) and definition-2 (c) on a stroke patient.

Discussions and conclusions: Our preliminary results demonstrated that geometric indices provide more information for understanding the complexity of white matter tissues. From the histogram comparison of two definitions on normal subjects and detectability comparison on one stroke patient, we found that geometric indices of definition-2 are more sensitive in detecting brain abnormalities and would be useful in clinical applications.

References:

[1] Westin CF et al, ISMRM 1997: 1742. [2] Westin CF et al, MICCAI 1999: 441-452. [3] Basser PJ, et al. *Magn Reson Med* 1998;39:928-934. [4] Alexander AL. Magn Reson Med 2000; 44:283–291.