

The change of tissue microenvironment elucidated: the combined FA and Trace defined a circle in a normal aging study

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Introduction

Recent progresses in the investigation of brain structure and function have confirmed a noticeable age-related change even in the absence of neurological diseases as a decrease in the Fractional Anisotropy^{1,2} and the increase of trace³. To integrate the information contained in separated indices, a simple relationship between FA, trace and the amplitude of the diffusion tensor was noticed. It defined a circle in the plane of FA and trace, which explained such changes in DTI as a shift of balance in the water diffusion in tissues microstructures.

Methods and Materials

The amplitude of DTI, D:D, is defined as $\sqrt{\lambda_1^2 + \lambda_2^2 + \lambda_3^2}$. Eq. 1 described a relationship between FA, trace and D:D as a circle of radius $\sqrt{3}/2$. Because both FA and trace are positive, the circle is limited to an arc in the first domain. In a coordinate system of FA and the normalized trace, $trace/\sqrt{D:D}$, each point in the circle can be uniquely decided by the angle between its radius and the axes of FA, as in Eq. 2. The angle described the change of mean diffusion per unit anisotropy.

$$FA^2 + \left(\frac{trace}{\sqrt{2 * D : D}}\right)^2 = \frac{3}{2} \quad [1] \quad \tan(\theta) = \frac{trace}{FA * \sqrt{2 * D : D}} \quad [2]$$

DTI from 12 subjects, aged from 20 to 62, were measured using a 1.5 T MR scanner(Vision Magnetom Siemens, Erlangen). The subjects were divided into two age groups, each of six subjects. The young group is aged from 20 to 25 and the elder group is aged from 46 to 62. DTI were acquired in six non-collinear directions using a SE-EPI sequence with the following parameters: FOV/TE/ flip angle/matrix size/b factor =192 mm/60 ms/90°/64*64/886 s/mm².The total acquisition time is approximately 15 minutes for 25 averages. One non-diffusion weighting image was acquired. Region Of Interest (ROI) was selected from the genu of the corpus callosum from each subject.

Result & Discussion

Fig.1 plotted for pixels in each age group in a coordinate system of FA and the normalized trace. The red pixels were from the elder group with FA of 0.85±0.10, which is significantly lower than the black pixels from the young group, FA of 0.87±0.08. The black solid arc described the circle defined in Fig. 1. The angle defined in Eq. 2 were calculated from each pixel. Figure 2 plotted the angle versus the amplitude of the diffusion tensor. The circle in Fig. 2 covered 95 % of the pixels within each age group.

Figure 1 showed that the decrease in FA is accompanied by an increase in the normalized trace. Figure 2 showed the effect of normal aging as an increase of the angle in Fig. 2 and an increase in the amplitude of the diffusion tensor. The elder group has an average angle of 47.25±6.63 degree, compared with 44.38±5.12 in the young group, a distinct reduction of diffusion anisotropy pre unit diffusivity. The averaged amplitude of the diffusion tensor is 1.95±0.37 ×10⁻³ mm²/s in the elder group, significantly increased compared to 1.78±0.23 ×10⁻³ mm²/s in the young. Figure 2 showed the distribution covered a larger area in the aged group. The result of increased diffusivity and decreased anisotropy is consistent with the observations from the normal aging studies. The distribution of pixels explained the change of microstructure elucidated by FA and trace during the normal aging process.

Reference

1. Pfefferbaum et al. MRM 44:259-268(2000)
2. Madden et al. NeuroImage 21:1174-1181(2004)
3. O'Sullivan et al. Neurology 57:632-638(2001)

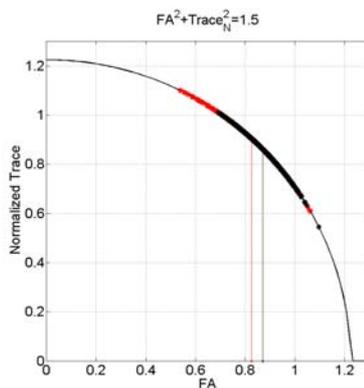


Fig. 1

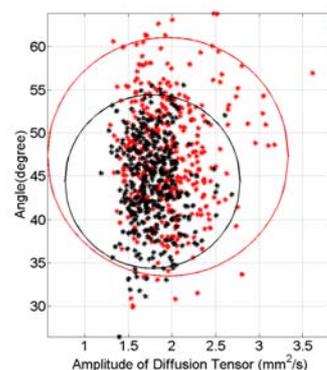


Fig. 2