Diffusion Tensor MR Imaging: Analysis of Anisotropy Metrics in the Aging Brain

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Introduction:

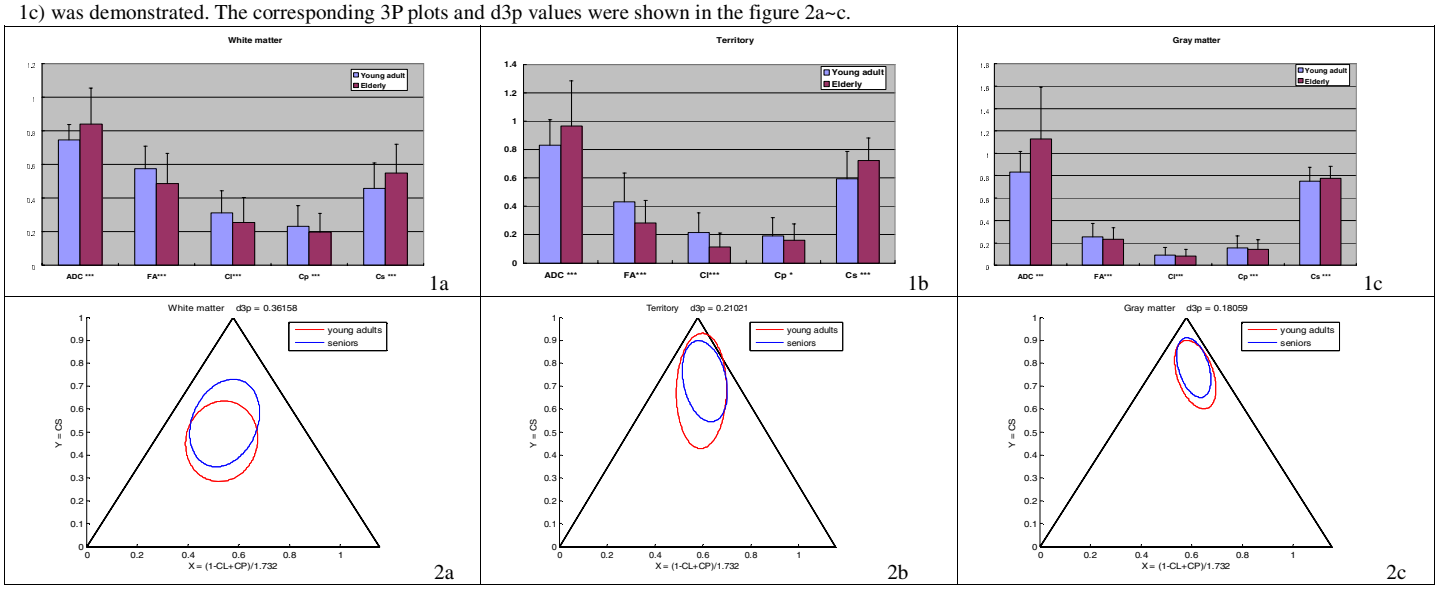
Diffusion tensor imaging technique has been applied to the evaluation of the cerebral diffusion anisotropy. Some researches have approached the diffusion anisotropy of the aging brain using apparent diffusion anisotropy (ADC) and fractional anisotropy (FA) [1, 2]. Other researchers argued that these methods could lead to confusion in interpretation of diffusion behavior of the brain. They provided a new method, three-phase (3P) plot, for representing the diffusion tensor shape [3]. This graphical technique is based on a barycentric coordinate system, which weights the tensor shape by a combination of linear (Cl), planar (Cp) and spherical coefficients (Cs) representing linear, cylindrical, and spherical shapes. The purpose of this study is to elucidate the geographic difference of the diffusion anisotropy of the cerebral gray and white matter using this new graphic technique as well as a bivariate distance measurement (d3p) in the aging brain.

Materials and Methods:

Six young adults (M:F=3:3; age=27.17 ± 4.58 years) and 14 seniors (M:F=8:6, age=68.64 ± 8.31 years) were enrolled in this study. All MR examinations were performed using a 1.5T MR system (Siemens Vision; Erlangen, Germany) with a single-channel circularly polarized head coil. Axial MR images were acquired using a spin-echo echo-planar imaging sequence. The diffusion-sensitizing gradients were applied along six directions: (+x)–(+y), (+x)–(-y), (+y)–(+z), (+y)–(-z), (+z)–(+x), and (+z)–(-x), with the diffusion weighting factor b = 500 s/mm^2, plus one reference image with b = 0 s/mm^2. Spatial misregistrations due to eddy current effects were removed by using a twice-refocused spin echo technique with bipolar gradient waveforms. Imaging parameters were as follows: TR/TE/NEX = 5000/100/2, FOV= 24 cm, section thickness = 5 mm (no intersection gap), and matrix size = 128 × 128. Total imaging time was one minute and 10 seconds, with 16 sections acquired. The diffusion tensor was calculated on a voxel-by-voxel basis by using the known relationship with the b matrix. Trace apparent diffusion coefficient (tADC), fractional anisotropy (FA) and three geometric parameters (Cl, Cp, and Cs) were derived from the three eigenvalues. The geometric parameters, which represent the three basic geometric shapes (linear, planar, and spherical) were further analyzed to generate three-phase (3P) plots under a barycentric coordinate system. Based on the knowledge of human brain anatomy on T2-weighted images and FA maps, the brain tissue was classified into three groups; i.e. white matter (including posterior limb of internal capsule, subcortical white matter and corona radiate), territorial (including superficial gray matter and subcortical white matter), and gray matter (including caudate nucleus, globus pallidus and superficial gray matter) under manual segmentation. Statistical analysis was performed with Student t-test for the comparison between the young adults and senior groups.

Results:

Comparison of the ADC, FA, Cl, Cp and Cs between the young adults and seniors with respect to the white matter (Fig. 1a), territory (Fig. 1b) and gray matter (Fig. 1c) was demonstrated. The corresponding 3P plots and d3p values were shown in the figure 2a~c.



Discussion:

The results showed significant age-related decline in FA and significant age-related increase in ADC no matter in the white matter, territory or even gray matter. This result is in consistent with prior researches [1, 2]. Moreover, our results further reveal significant age-related decline in Cl and Cp and significant age-related increase in Cs in all cerebral structures. It discloses the facts that the aging process not only causes degeneration the white matter but also the gray matter and that the degeneration has shifted the geometric distribution of the brain tissue from linear and cylindrical to spherical shapes.

Reference:

1. Abea O. Neurobiology of Aging 2002; 23: 433–441
2. Salata DH. Neurobiology of Aging 2005; 26: 1215–1227.
3. Alexander AL. Magn Reson Med 2000; 44:283–291