

Characterization of age-related changes in human brain using diffusion kurtosis imaging

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Introduction: Diffusion kurtosis imaging (DKI) is a novel technique to characterize a non-Gaussian diffusion property in biological tissues [1-5]. DKI has shown great promises to better characterize microstructural changes both in grey and white matter (GM/WM) in rodent [1, 2] and human prefrontal cortex [3, 4] while conventional diffusion tensor imaging (DTI) is limited to WM [3]. Recently, Veraart et al. reported that diffusivity measures by DKI provided more accurate estimation compared to conventional DTI [5]. In this study, we aimed to characterize age-related changes in a deep GM region using DKI at 3 Tesla clinical MRI system.

Methods: Twenty seven healthy volunteers (scoring ≥ 26 on the Mini Mental State Examination (MMSE)) were studied after signed, informed consent and divided into two groups: young (7 male, 6 females; rang = 21~38 yrs, mean age = $26.5 \pm$ standard deviation (SD) = 4.9) and middle-aged (6 male, 8 females; rang = 44~59 yrs, mean age = 52.9 ± 5.0). All scans were performed on a Philips 3T MRI Achieva scanner (Philips Healthcare, Best, The Netherlands) with a body coil excitation and an 8-channel SENSE head coil for reception. Four averaged minimally weighted (b_0) and 2 averaged 32 gradient directions with two b values (1000 and 2000 s/mm^2) were acquired using single-shot EPI sequence with following parameters: TR/TE = $2000/69$ ms, nominal resolution = $2.55 \times 2.55 \times 3 \text{ mm}^3$, reconstruction resolution = $2 \times 2 \times 3 \text{ mm}^3$, 44 axial slices with no interslice gap to cover the whole brain, SENSE factor = 2, 3/4 partial Fourier encoding, total scan time = 19 min. 39 s. For anatomical reference, T1-weighted images were acquired using 3D-MPRAGE sequence with the following parameters: TR/TE = $7.0/3.2$ ms, TI = 800 ms, nominal/reconstruction resolution = $1 \times 1 \times 1 \text{ mm}^3$, 167 slices, scan duration 10 min. 41 s. Diffusion-weighted images were first co-registered to b_0 followed by spatial Gaussian smoothing with full-width-half-maximum of 2.5 mm using Automated image registration (AIR5) [6]. DTI- and DKI-derived maps were calculated using Diffusional Kurtosis Estimator (DKE) [7] running in MATLAB (Mathworks, Natick, MA, USA). Region of interest (ROI) was manually drawn in putamen using ImageJ (National Institutes of Health, Bethesda, MD, USA) and then transferred to all DTI- and DKI-derived maps for quantification. Independent samples T test and Spearman-rho analysis were performed to test group difference and the correlation between each metric and age, respectively, using SPSS (Chicago, IL, USA).

Results and Discussion: Table 1 shows that mean DTI- and DKI-derived metrics in putamen were significantly different between young and middle-aged groups. The increase of DTI-derived metrics agrees well with former DTI study on putamen [8]. Fig. 1 illustrates significant correlation between each metric and age, suggesting DKI may detect microstructural changes due to aging in putamen.

Conclusion: In the present study, we have demonstrated that age-related changes in brain can be quantitatively assessed using DKI. Further study with larger sample size may help better understanding the age-related changes in various neural tissues.

References: [1] Cheung MM et al., Neuroimage, 2009. [2] Wu EX et al., NMR Biomed, 2010. [3] Falangola MF et al., J Magn Reson Imaging, 2008. [4] Helpern JA et al., JMRI, 2011. [5] Veraart et al., Magn Reson Med, 2010. [6] Woods RP et al., J Comput Assist Tomogr, 1998. [7] Tabesh A et al., MRM, 2010. [8] Pfefferbaum A et al., Neurobiology of Aging, 2010.

	Young	Middle-aged	<i>p</i>
FA	0.12 ± 0.01	0.14 ± 0.01	<0.001
MD [†]	0.74 ± 0.02	0.77 ± 0.03	<0.05
$\lambda_{\parallel}^{\dagger}$	0.84 ± 0.03	0.88 ± 0.03	<0.05
$\lambda_{\perp}^{\dagger}$	0.70 ± 0.01	0.71 ± 0.03	0.085
MK	0.70 ± 0.03	0.76 ± 0.05	<0.05
K_{\parallel}	0.81 ± 0.06	0.87 ± 0.07	<0.05
K_{\perp}	0.64 ± 0.05	0.70 ± 0.05	<0.05

Table 1. Mean DTI- and DKI-derived metrics of putamen in young and middle-aged groups and *p* values of independent samples T test between the two groups. [†]: mm^2/ms , others: dimensionless.

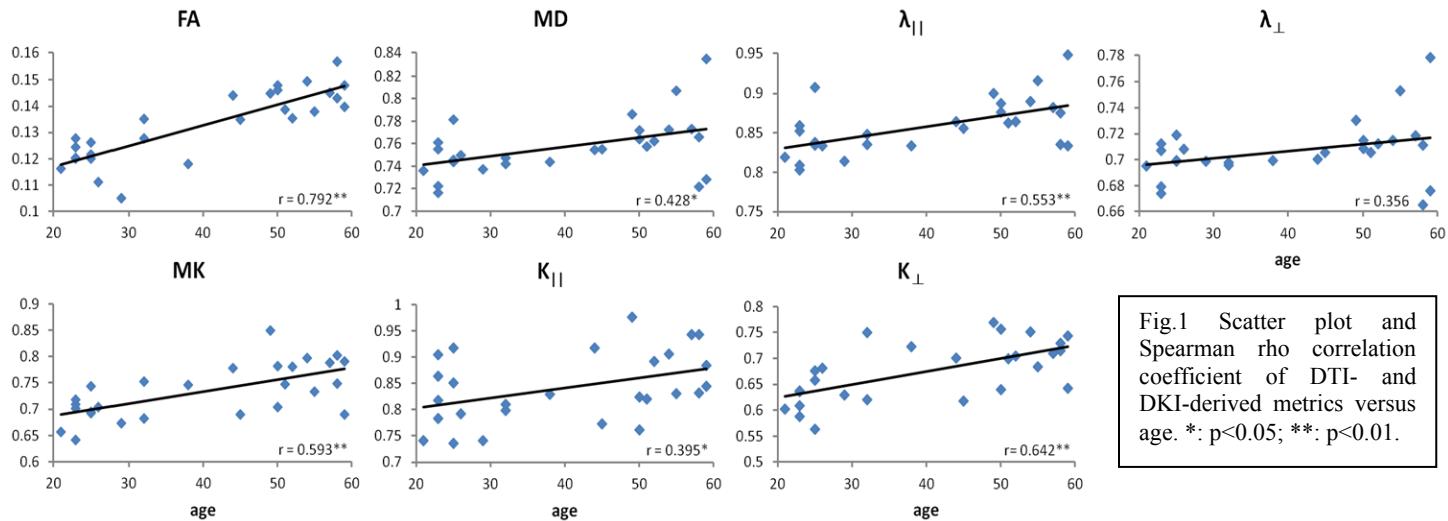


Fig.1 Scatter plot and Spearman rho correlation coefficient of DTI- and DKI-derived metrics versus age. *: $p < 0.05$; **: $p < 0.01$.