Diffusion complexity of gray nucleus in Alzheimer' s disease: an initial diffusion kurtosis imaging study

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Target Audience: Physicians and Researchers who interested in AD and diffusion kurtosis imaging

Purpose: To initially exploit diffusion complexity changes of gray nucleus in Alzheimer's disease (AD) by using diffusion kurtosis imaging (DKI).

Introduction: Alzheimer's Disease (AD) is the most common CNS degenerative disease in aged people and causes senile dementia[1]. Clinical features are progressing cognitive impairment and memory damage. Neuropathological features of AD are senior patch formed by β-amyloid protein deposition and neurofibrillary tangles. Eventually neuronal cell are lost, including gray matter (dendrites) and white matter (axon)[2]. Nowadays, the diagnosis of AD includes the confirmed AD, probable AD and possible AD. The "gold standard" of confirmed AD is the neuropathological results. The studies of the integrity of microstructure of brain by DTI in AD patients were prevalent, while gray matter structures of the AD patients have definite pathological changes, hard to be well investigated by DTI due to the isotropic feature of GM. DKI derives from DTI and can quantify the displacements between real diffusion of water molecules and the ideal state of Gauss distribution, characterize the degree of limitation and heterogeneity of water molecular diffusion, reflect the subtle changes of the complex structure of the brain parenchyma precisely[3].

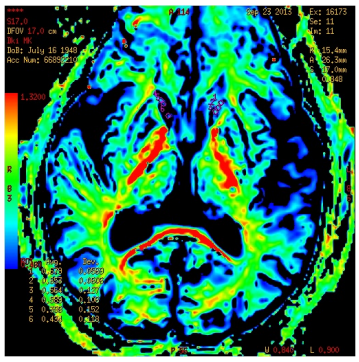

Fig 1. MK mapping of DKI for a male patient, 66 years old with 4 years' AD history. ROIs were symmetrically located head of caudate nucleus. The size of ROIs was smaller than the anatomical structure, and away from cerebrospinal fluid and blood vessels.

Methods: Twenty three cases of clinically confirmed AD and Twenty four age- and sex- matched healthy volunteers underwent MR DKI scanning on a 3.0 T MR imaging scanner (GE Signa HDxt, US). The DKI parameters, including fractional anisotropy(FA), mean kurtosis(MK), radial kurtosis(Kr), kurtosis anisotropy(Ka), axial diffusion ratio(Da), radial diffusion ratio(Dr)and medial diffusion ratio(MD), were measured on bilateral head of caudate nucleus, dentate nucleus, putamen, globus pallidus, red nucleus and substantia nigra in AD patients and controls. Two independent samples t-test was used to compare the mean values of parameters in all brain regions between the AD and healthy groups. Receiver operating characteristic (ROC) test were used to assess the ability of regional diffusion measures to discriminate differences between groups. The correlations between DKI parameters and MMSE score were tested using Pearson's correlation.

Results: Compared to the healthy group, the mean value of MK, Ka and Kr markedly increased in substantia nigra, MK value increased in head of caudate nucleus, and Ka value decreased in dentate nucleus ($P<0.05$).The MD, Da and Dr value significantly increased in head of caudate nucleus and dentate nucleus; MD and Da value increased in putamen; MD value increased in red nucleus; Da and Dr value increased in globus pallidus ($P<0.05$).FA value decreased in globus pallidus and substantia nigra; Whileas, FA value markedly increased in head of caudate nucleus, red nucleus and dentate nucleus($P<0.05$). The cutoff value of 0.798 was calculated for the Dr value in the globus pallidus with the best area under ROC curve (AUC) of 0.810. The Ka value showed the negative correlation with MMSE score in substantia nigra; The FA value exhibited the negative correlation with MMSE score in head of caudate nucleus; The MD value, Da value of head of caudate nucleus, putamen, dentate nucleus and Dr value of globus pallidus showed negative correlation with MMSE score; The FA value of red nucleus and substantia nigra have the positive correlation with MMSE score (all $P<0.05$) .

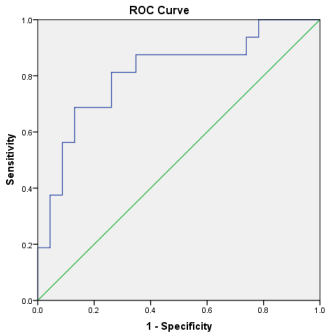

Fig 2 The ROC map of Dr value in the globus pallidus.

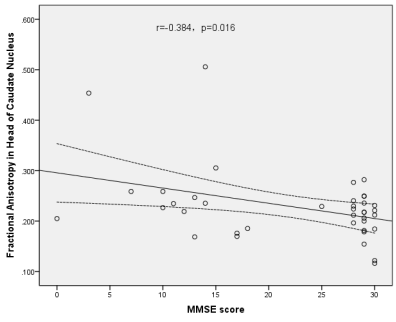

Fig 3 Correlations between FA value and MMSE score in the head of caudate nucleus.

Discussion: Neurofibrillary tangles is the pathological feature of AD. The changes of DKI parameters demonstrate this feature and show correlations with the mental state of AD. The results of our study showed different change trends of DKI parameters due to the difference of microstructure in different gray nucleus. Among the structures we measured, the globus pallidus shows the most complicated microstructural composition. Iron deposition in this gray nucleus is abundant and causes the non-Gauss distribution of water diffusion. Compared to globus pallidus, the head of caudate nucleus show relatively simple microstructure. In short, DKI can detect diffusion complexity of gray nucleus in AD patients.

Conclusion: DKI is useful for evaluating the structure change of gray nucleus in AD patients.

References: [1] O'Brien JT, et al; BMC Med 2014; 12:218 [2] Richard E, et al; BMJ Open 2013; 3: e002541 [3] Gong NJ, et al; Neurobiol Aging 2014; 35:2203-2216