Diffusion kurtosis imaging reveals widespread white matter abnormalities in Alzheimer' s disease

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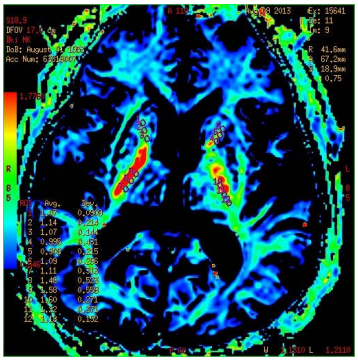

Fig 1. MK mapping of DKI for a male patient, 60 years old with 11 years' AD history. ROIs were symmetrically located bilateral internal capsule. The size of ROIs was smaller than the anatomical structure, and away from cerebrospinal fluid and blood vessels.

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

Purpose: Diffusion kurtosis imaging (DKI) is a method that can obtain the non-Gaussianity diffusion of water and supply more information than DTI. The purpose of this work is to initially exploit the clinical application value of DKI on white matter microstructure damage in Alzheimer's disease (AD).

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. Recent years, scholars worldwide began to study the integrity of microstructure of brain, mainly evaluation of the white matter and fiber bundle by DTI in AD patients[2]. Quantitate study of gray matter by DTI is difficult because the diffusion of water molecules in the gray matter is anisotropic. Diffusional kurtosis imaging (DKI) is a natural extension of DTI that enables the precise quantification of the diffusional kurtosis, a measure of diffusional non-Gaussianity[3]. 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. The purpose of this work is to initially exploit the value of DKI on quantitative and qualitative assessment in AD through the quantitative measurement and analysis of the brains of AD patients and healthy controls.

Methods: Twenty three AD patients and Twenty four age- and sex-matched healthy volunteers underwent MR DKI scanning on a 3.0T MRI system (GE Signa HDXT 3.0T MRI) using an eight channel phased-array brain coil. Both conventional MR and DKI sequences were obtained for all the subjects. The bilateral MK values, Ka values, Kr values, MD values, Da values, Dr values and FA values of the frontal WM, parietal WM, occipital WM, temporal WM, splenium of the corpus callosum, genu of the corpus callosum, trunk of the corpus callosum, anterior limb of the internal capsule, posterior limb of the internal capsule and external capsule, hemispherium cerebelli were measured, as illustrated in Fig.1. 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 in AD group significantly decreased in parietal WM, temporal WM, external capsule, occipital WM, anterior limb of the internal capsule and genu of the corpus callosum, trunk of the corpus callosum splenium of the corpus callosum, posterior limb of the internal capsule, hemispherium cerebelli; MD, Da and Dr value in AD group significantly increased in frontal lobe-WM, anterior limb of the internal capsule, trunk of the corpus callosum, hemispherium cerebelli, parietal WM, temporal WM, external capsule, splenium of the corpus callosum, posterior limb of the internal capsule, genu of the corpus callosum, occipital WM; FA value in AD group significantly decreased in frontal WM, parietal WM, occipital WM, temporal WM, trunk of the corpus callosum, genu of the corpus callosum, anterior limb of the internal capsule, external capsule (all $P<0.05$). The biggest area under ROC curve (AUC) value of 0.954 belongs to Dr value in the temporal WM. In all subjects, the MK values, Ka values Kr values and FA values showed the positive correlation with MMSE score in all ROI ($P<0.05$). Furthermore, the negative correlation was present between MD values, Da values, Dr values and MMSE score ($P<0.05$).

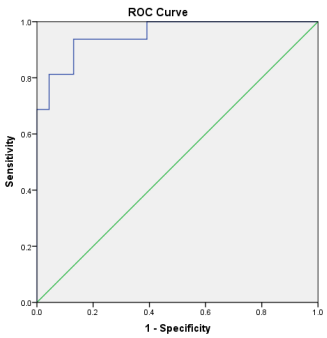

Fig 2a The AUC of Dr value in the temporal lobe-WM.

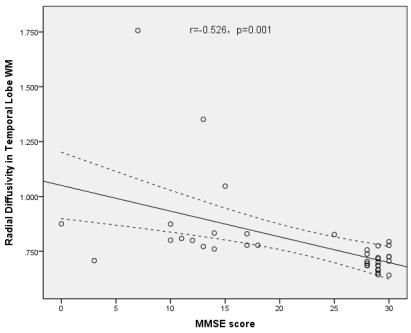

Fig 2b Correlations between regional parameters and MMSE score.

Discussion: It was found that the parameters between AD patients and healthy controls showed significant difference. The white matter of temporal and parietal lobe, trunk of corpus callosum, anterior limb of the internal capsule and external capsule showed more different parameters than other ROIs, followed with thalamus, the head of caudate nucleus, hippocampus and dentate nucleus. Dr values of white matter of temporal lobe is the best index in discriminating AD patients with healthy people among these parameters. Dr values of hippocampus and of white matter of frontal lobe, MD value of white matter of temporal lobe, Dr values of globus pallidus and white matter of temporal lobe are better indexes too. Correlation between parameters and MMSE score was found. MK values, Ka values, Kr values and FA values showed the positive correlation with MMSE score except negative correlation between Ka value and MMSE in substantia nigra, FA value and MMSE score in head of caudate nucleus. The negative correlation was present between MD values, Da values, Dr values and MMSE score in all regions.

Conclusion: The changes of DKI parameters indicate the axonal loss and myelin damage of AD. DKI parameters may be more accurate in the assessment of microstructure damage and mental status of AD patients. The Dr values in the temporal WM can be as the best individual biomarkers of differentiation AD to controls. DKI can quantitatively evaluate the white matter changes in AD patients.

References:[1] O'Brien JT, et al; BMC Med 2014; 12:218 [2] Bartzokis G, et al; Biol Psychiatry 2012; 72:1026-1034 [3] Falangola MF, et al; Magn Reson Imaging 2013;31:840-846