Advances of Diffusional MR Imaging of the Brain

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Diffusional magnetic resonance imaging (dMRI) provides indispensable clinical information and is routinely performed in most of all brain MRI study. The dMRI can also uniquely visualize the white matter tracts and is recently highlighted to explore structural connectivity of the brain. Diffusion tensor imaging (DTI) and diffusion tensor tractography are representatives of dMRI. Quantitative analysis of DTI and more sophisticated application of advanced diffusion MRI newly revealed disease–specific subtle abnormalities in corresponding areas of the brain in many neurological/psychiatric disorders. The dMRI is a promising technique to visualize new aspect of the brain, which no one has never seen before.

Key words: magnetic resonance imaging (MRI), diffusion weighted image (DWI), diffusion tensor imaging (DTI), non-Gaussian diffusion MRI, diffusional MRI (dMRI)

Advances of brain MRI started from structural information and acquisition techniques in the 1980s and recent targets are functional information and post processing. Diffusional magnetic resonance imaging (dMRI) is the best highlighted technique, including cutting edge acquisition and post processing techniques as well as structural and functional information. It is especially unique about evaluation of the cerebral white matter. dMRI is playing an important role in worldwide big scientific projects such as “Human Connectome Project” (USA) and “KAKUSHIN NOU: Brain/MINDS” (Japan) to clarify the connectivity of the brain.

Diffusion tensor imaging (DTI), representative of the dMRI, can visualize the white matter tracts in vivo, which has never seen before. In the brain, diffusion of water molecules (Brownian motion) is anisotropic due to white matter fibers. When the white matter fibers are densely packed, water molecules move mainly along (parallel to) the fibers and we can trace the tract by analyzing the water diffusion direction.

Dense and thick bundles such as the corticospinal tracts, the cingulate, the uncinate and the fornix are clearly visualized (Figure-1). Region of interest (ROI) analysis and tract specific analysis (TSA) are developed to quantify the tract integrity measuring parameters within the tract.

Whole brain statistical analysis can be implicated in DTI data, such as the statistical parametric map (SPM) and tract–based spatial statistics (TBSS). Using these methods, we can explore regional brain abnormalities without the hypothesis of locations. Numerous reports in neurological/psychiatric disorders had been reported. Non–Gaussian diffusion analysis is recently highlighted to analyze precise microstructures by using multi–shell (b-value) and multi–motion probing...
gradient (MPG) (>30 axis) MR acquisition). We can estimate intra and extra cellular diffusion that reflex the microstructures. Diffusional kurtosis imaging (DKI) is a simple and robust technique to analyze non-Gaussianity. The most recent technique is neurite orientation dispersion and density imaging (NODDI). NODDI is a promising non-Gaussian diffusion analysis to estimate neurite (dendrite and axon) direction, dispersion and density. Translational research of dMRI comparing with transparent brain with two-photon microscopy has been started to bridge microscopic network findings to human living brain (Figure-2).

In summary, by using dMRI, we can estimate microstructural changes and connectivity of the human living brain.

References