Examination of Pathologic Changes in White Matter by Diffusion Tensor Imaging

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Diffusion tensor imaging (DTI) is an important tool used to examine changes in white matter structural integrity in both development and disease (Mori et al., 2006; Wozniak & Lim, 2006; Jito et al., 2008; Beardsley et al., 2005). The method is a recently developed technique based on magnetic resonance imaging (MRI), and is proving useful in human studies and animal models, both *in vivo* and in fixed tissue. MRI signals are derived from the motion of hydrogen (proton) nuclei in a magnetic field; in tissue, these signals arise primarily from the protons in water. DTI extends the resolution and contrast of conventional MRI by acquiring a series of images with multiple imaging parameters. If the diffusion of water molecules is restricted in one direction, this is referred to as anisotropic diffusion, and differences in diffusion compared to random diffusion are termed fractional anisotropy. This property has been applied to examine the organization of white matter in brain, based on the premise that water is expected to move more easily along myelinated axons rather than in a direction perpendicular to them. Thus, DTI detects the presence of oriented (as opposed to random) structures, with the more highly oriented, well-organized myelinated axons having higher fractional anisotropy (FA) values. While myelination or levels of myelin contribute to these measurements, differences may also indicate changes in water content, axonal packing, astrocytic hypertrophy or abnormalities in tract organization (Spadoni et al., 2007; Harsan et al., 2007).

MRI and DTI studies in humans have shown anomalies in white matter that may in part reflect abnormal myelination. For example, DTI showed lower fractional anisotropy and decreased white matter density in the lateral splenium of the corpus callosum in individuals with fetal alcohol syndrome compared to controls, consistent with disorganized fiber tracts in the

region of the optic radiation and crossing visual association fibers, and with a significantly correlated reduction in visual–motor integration (Sowell et al., 2008). DTI is widely used to diagnose and follow the course of multiple sclerosis, and is an important parameter included in assessment of efficacy of therapies to slow disease progression, i.e., demyelination and axon degeneration (Fox, 2008). The application of DTI to follow changes in Alzheimer's and other neurodegenerative diseases is under investigation (Stebbins & Murphy, 2009), and the method has proved useful in assessing changes following stroke or brain injury in both humans and animal models (Jiang et al., 2010).

The white-matter connectivity of the brain can be imaged by using color-coded orientation maps representing the principal directions of the diffusion tensor in various brain regions (i.e., tractography). The image represents an axial section of an adult human brain near the mid-point of the corpus callosum and basal ganglia (contributed by L. Hermoye to Wikipedia).

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