Measuring Tissue Microstructure with MRI: Pathological and Biological Applications of MRI Structural Measures

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In this presentation, we will review the application of MR measures of microstructure to representative tissues. These methods are typically applied in two contexts: 1) in basic research to address important biological questions not approachable by other means, and 2) in clinical research to provide diagnostic and prognostic information for human patients.

Bone: Osteoporosis is a major health problem in the elderly, and increases susceptibility to fractures, particularly of the hip, spine and wrist. One MR approach to evaluating trabecular bone involves measuring the effects of trabecular structure on R2* caused by differences in magnetic susceptibility between trabeculae and bone marrow. It has been hypothesized that the increased trabecular spacing associated with osteoporosis prolongs T2*. We will review correlations of T2* measurements with bone density and fracture status.

Lung: Emphysema is a pulmonary disorder in which lung tissue is gradually destroyed. In its early stages, emphysema is difficult to detect using conventional pulmonary function tests. One MR method that has been used to determine lung microstructure is measurement of the diffusion of inhaled hyperpolarized ^{3}He. With this approach, the lung is modeled as a network of cylindrical airways covered with alveoli. Based on diffusion measurements, it is possible to calculate acinar duct radii, lumen radii, and the depth of the alveolar sleeve. The MR approach yields higher sensitivity than conventional approaches in identifying the early changes of emphysema in smokers. It is also adaptable to the study of animals as small as mice.

Heart: The myocardium consists of an array of crossing helical layers. This structure is altered in response to myocardial ischemia and heart failure. Using diffusion tractography approaches, it is possible to determine this structure non-invasively, though their application to the beating (moving) heart *in vivo* remains technically challenging. Nevertheless, changes in the structure of myocardium in aging and disease are readily observed in *ex vivo* tissue specimens. In addition, species differences in myocardial organization have been identified. This information is complementary to that available through other imaging modalities.

Tumor: Diffusion MRI has been applied to a variety of cancers. Whereas change in tumor volume is often used clinically as an indicator of therapeutic response, response can be assessed earlier after therapy with diffusion MRI. For most tumors and treatment strategies, an increase in ADC values following therapy – corresponding to a reduction in tumor cell density – is associated with a favorable therapeutic response. In addition, high pretreatment ADC values are associated with better outcome in some tumors.

Brain development: Whereas diffusion anisotropy values in adult brain are high in white matter and low in grey matter, the converse is true in the brains of premature infants. As development progresses, grey matter anisotropy values fall and white matter values increase. Using this approach, differential rates of brain development are detectable. For example, changes in diffusion anisotropy values take place earlier in developing motor cortex (and underlying white matter) than in prefrontal cortex.