

Combining Double Quantum Filtering and Magnetization Transfer with UTE to Obtain Images Based on Macromolecular Characteristics

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In recent years there has been interest in intramolecular dipolar interactions in macromolecules (MM) in tissues, such as brain, spinal cord, and rat-tail using NMR and MRI (1-4). It was suggested that these interactions could be probed by three successive steps: 1) exciting selectively the MM magnetization, 2) transferring the MM magnetization to the water, and 3) obtaining images based on the water signal. For brain (human and mouse) as well as spinal cord new contrast was observed, which was attributed to differences in the amount of myelin in white and grey matter (2). However, the time to echo (TE) used in these experiments was fairly long (>3ms) and it left unanswered the role of the water T_2 in creating this contrast. This issue was particularly acute for rat tail where tendons are an essential part and their T_2 is hundreds of μs long. In the current study, using ultra-short TE (UTE) methods, we demonstrate that the differences in the amount and possibly structure of the MM among the various compartments are the main source for the new contrast. In Fig. 1a and 1b we show gradient echo (GE) and UTE images of porcine spinal cord. As seen in these images, though the TEs are very different (1.6 and 0.2 ms, respectively) there is little difference in contrast between them. In both images the grey matter has higher intensity. On the other hand when UTE is combined with DQF-MT (90- $\tau/2$ -90- t_{DQ} -90- $\tau/2$ -90- t_{LM} -UTE, DQF-MT-UTE) (Fig. 2) white matter is significantly more intense than grey matter. Furthermore, setting $\tau/2 > 100\mu\text{s}$ no images could be obtained indicating that the source of the observed magnetization is the MM. This latter fact along with the lack of dependence of the images intensities on TE, indicating insensitivity to the water T_2 , lead us to the conclusion that the contrast in the DQF-MT experiment is the result of differences in the MM characteristics of the white and grey matter in the spinal cord. Similarly UTE images through a slice of rat tail disc shows very little contrast between the tendons, annulus fibrosus, nucleus pulposus and muscles (Fig. 3a). Combining these imaging results with spectroscopic measurements that yielded $T_2 > 300\mu\text{s}$ for water, we conclude that differences in its T_2 or amount play a small role in creating the contrast obtained via UTE MRI. On the other hand the DQF-MT-UTE yields striking contrast between the tendon, the annulus fibrosus, and muscles (Fig. 3b), which is attributed to differences in the MM characteristics of these compartments. We will continue to explore this promising new contrast mechanism to measure and map dipolar interactions in both neural and soft tissue MRI applications.

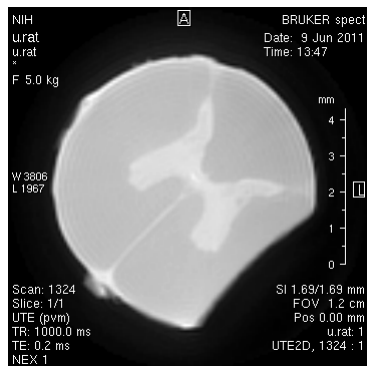
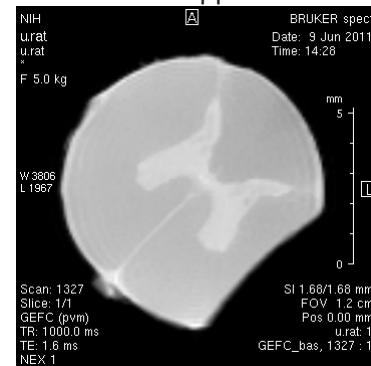


Fig. 1 (a) UTE, TE=0.2ms



(b) GE, TE=1.6ms

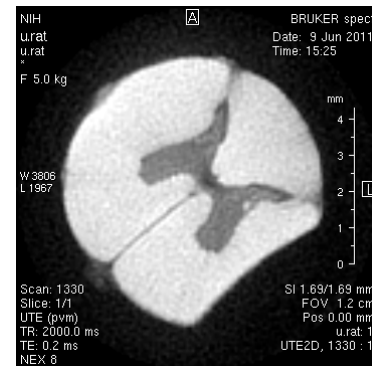


Fig. 2 DQF-MT + UTE, $\tau/2=10\mu\text{s}$, $t_{\text{LM}}=95\text{ms}$, TE=0.2ms.

T=Tendons, M=Muscles
 A=Annulus fibrosus
 N=Nucleus pulposus

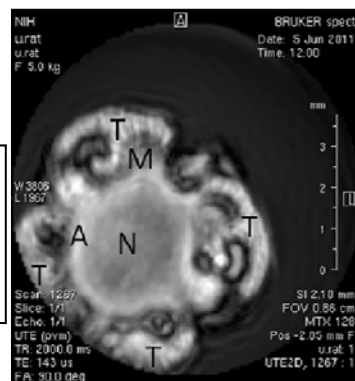
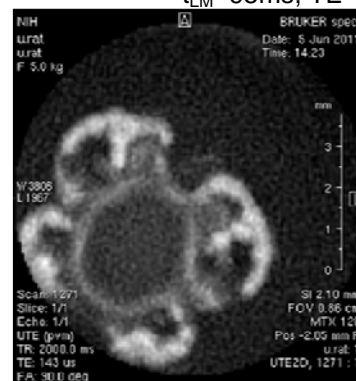


Fig. 3 (a) UTE, TE=0.143ms



(b) DQF-MT-UTE, $\tau/2=10\mu\text{s}$, $t_{\text{LM}}=50\text{ms}$, TE=0.143ms.