CRAZED signal dependence on correlation distance and sample orientation in rat sciatic nerve

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Introduction: Conventional magnetic resonance imaging is typically limited to resolutions of 100’s of microns in small animals and to millimeters in humans. No single conventional magnetic resonance method probes both the micron and millimeter distance scales or an intermediate scale (< 50–300 µm) between diffusion measures and direct imaging. The CRAZED [1] pulse sequence has a structural sensitivity determined by applied gradients. Specifically, the correlation distance $d_c = \pi/\gamma GT$ dictates the distance scale of the signal sensitivity to magnetization variations (see Figure 1). In this work, we address the issues of CRAZED signal dependence on sample orientation and the gradient induced correlation distance in sciatic nerve and cylindrical phantoms with the goal of determining what size information can be obtained unambiguously from the CRAZED signal.

Methods: Two samples were measured: a cylindrical doped water sample and ex vivo rat sciatic nerve. A spectroscopic CRAZED sequence was implemented with $d_c = [4002 1199 359.7 107.9 32.3 9.786]$ µm. Both samples were rotated over a 90° arc in 10° steps. Histology and electron microscopy were performed to assess the underlying structures of the sciatic nerve and to determine the extent of degeneration during the CRAZED measurements. The measurements on the water sample signal were also numerically simulated.

Results: Figure 2 illustrates the histology results, indicating micro-anatomical structures at roughly the 10 µm and 300-400 µm scales, and that these structures are preserved during the measurement. Figure 3 plots the most important CRAZED results: that the signal dependence on sample orientation and gradient direction for a nerve when $d_c = 10$ µm and 360 µm matches the simulations of a cylinder when $d_c = $ the cylinder diameter.

Discussion: The results for the sciatic nerve have characteristics indicative of cylinders at both the ten and hundreds of micrometers distance scales, reflecting both axon and the tibial/peroneal fascicle structures that compose the nerve. These results support the view that CRAZED methods are able to probe a range of distance scales not available in other magnetic resonance methods.

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