Depiction of Multiple Sclerosis Lesions with Zero Echo Time (ZTE) Imaging at 7T

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Target Audience: MR physicists and engineers, neuroradiologists, neuroscientists

Purpose: To compare zero echo time (ZTE) to conventional T1 weighted fast gradient echo at 7T in multiple sclerosis patients. ZTE imaging is expected to provide greater sensitivity to myelin-bound water and myelin itself due to its vastly shorter echo time than conventional methods. Lesion detection, however, relies on providing clear depiction of surrounding normal grey and white matter with high sensitivity. Conventional fast gradient echo imaging at 7T suffers from contrast loss due to greater B1 inhomogeneity and longer T1 relaxation times than lower field strengths. This project was designed to investigate improved depiction of cortical and subcortical MS lesions using ZTE while retaining the grey-white contrast needed to facilitate cortical segmentation.

Methods: A zero echo time (ZTE) sequence based on a 3D radial acquisition[1] was implemented for a 7T human research system (GE MR950, 7T23 software, Waukesha WI). Optimizations included redesign of the inversion pulse, replacement of the fat suppression pulse, and optimization of the scan timing parameters (number of spokes per segment, inversion preparation delay, and post-segment recovery delay). Images were acquired from volunteer patients, previously diagnosed with MS, with informed consent under a protocol approved by the Committee on Human Research. During the same session, inversion recovery (IR) prepared fast 3D gradient echo images were also acquired with the same RF coil (Nova 2 ch CP transmitter and 32 channel receiver, Wilmington MA) using the following parameters: TE 2.26 ms, TR 6.15 ms, TI 600 ms, 8 degree flip, 5 minute scan time. IR prepared ZTE images were also acquired with effective TE 24 μs, 12 μs nominal RF pulse width, 62 kHz receiver bandwidth, 384 spokes per segment, 1 second post segment delay. Images were then transferred offline for further analysis.

Results and Discussion: Images from a representative MS patient are shown in Figures 1, 3, and 5 (BRAVO) and 2, 4, and 6 (ZTE), showing discrete MS lesions and surrounding brain tissue. No receiver bias field correction has been applied to either set of images. Of particular note are the visibility of the skull and related structures, as well as the foam padding supporting the head and some components of the RF coil. Some diffuse signal is present in the background as well as some star artifacts from the interpolation kernel. Otherwise the contrast between grey and white matter is far more consistent across the brain than BRAVO. Figures 7 and 8 show corresponding sections of posterior cortex showing the loss of grey-white contrast in BRAVO (presumably due to B1 inhomogeneity) which is retained in ZTE. Figures 9-14 show corresponding sections from coronal resampling of the volume data. To date five MS patients have been scanned with both protocols in the same session.

Conclusion: The silent sequence as adapted for 7T – matching the inversion pulse to the available B1, increasing the fat suppression pulse bandwidth, and optimizing the sequence timing -- provided improved grey-white contrast uniformity over the whole brain in equivalent scan time compared to IR prepared 3D fast gradient echo and allowed improved visualization of MS lesions and the surrounding tissue. Further this implementation allows the use of array receiver coils, providing high sensitivity over the whole brain, extending previous implementations which required special hardware modifications[2].

References: 1. Madio D and Lowe I MRM 34:525-9 1995 2. Weiger M, Brunner D, Dietrich B, Muller C, and Pruessmann K MRM 70:328-32 2013