Enhancement of In Vivo T1 Contrast and Image Quality at Ultrahigh Magnetic Fields (4.7-17.6T) Utilizing Fasting Imaging Techniques

K. R. Padgett[1], S. J. Blackband[2,3], S. C. Grant[3,4]

[1]Radiology, University of Miami, Miami, Florida, United States, [2]Neuroscience, University of Florida, Gainesville, Florida, United States, [3]National High Magnetic Field Laboratory, Tallahassee, Florida, United States, [4]Chemical and Biomedical Engineering, Florida State University, Tallahassee, Florida, United States

Introduction:

The push to higher magnetic field strengths has necessitated a re-evaluation of standard MR protocols to account for changes in image contrast mechanisms. Because of its pervasive use in anatomical imaging, the degradation of T_1 contrast at high fields due to increases in tissue T_1s is particularly vexing (1). Previous work (2) has demonstrated that sufficient T_1 contrast may be obtained at ultrahigh magnetic fields through the use of optimized magnetization preparation (3-5). However, the duration required to achieve T_1 enhancement through magnetization preparation substantially increases the total scan acquisition time. Furthermore, T_1 preparation methods do little to rectify field homogeneity issues (B_0 or B_1) that frequently arise with i*n vivo* animal imaging efforts above 4 T (see Fig 2). In this study, fast imaging techniques (segmented k-space sampling and RARE encoding) are incorporated with magnetization preparation (adiabatic IR and MDEFT) to assess the potential tradeoffs between reduced acquisition times and T_1 contrast enhancement. Additionally, spin echo versions of these preparation methods (both standard and rapid imaging) are implemented for high field rodent imaging to overcome *in vivo* susceptibility artifacts, to assess potential benefits of magnetization preparation with regard to B_1 inhomogeneity and to evaluate quantitative measurements of *in vivo* contrast. To this end, experiments were performed on biologically representative T_1 phantoms and *in vivo* rodents at 4.7, 11.1 and 17.6 T.

Methods:

Fabrication of T_1 phantoms: To determine appropriate T_1 values, living C57BL6/J mice were scanned at the three field strengths using a SR multislice SE sequence in which the recovery time (TR) was incremented to sample longitudinal relaxation. White matter (WM) in the corpus callosum, gray matter (GM) in the cortex and CSF in the ventricles were segmented to provide a range of T_1 values, and phantoms spanning this range were created with copper sulfate-doped deionized water.

MR parameters: Phantoms were imaged using SR, IR and MDEFT T_1 contrast techniques employing standard GRE and SE imaging as well as k-space segmented GRE and RARE-encoded SE schemes (NEX=2; MTX=128x128; GRE: TE/TR=5/50ms; SE: TE/TR=6.4/50ms; Slice=2 or 0.5 mm; FOV=dependent on magnet). Adiabatic hyperbolic secant pulses were utilized for all preparation schemes. To assess contrast enhancement, the preparation time (τ) was incremented (0.05-5 s) for MDEFT acquisitions, the inversion time (TI; 0.05-5 s) was incremented for IR acquisitions, and the TR was incremented (0.05-5 s) for SR acquisitions. A speed up factor (η of four was employed for both the segmented GRE and RARE acquisitions.

Data analysis: Regions of Interest (ROIs) were placed in each of the sample containers. The mean signal from each ROI (x_{signal}) was recorded as a function of the total acquisition time (for MDEFT: *Tacq* = PE/η*(TR+2*τ)). The signal-to-noise ratio (SNR) was determined by: $SNR = x_{signal} \Big/ \left(\sigma_{noise} * \sqrt{T_{acq}}\right)$, where σ_{noise} is the standard deviation of a noise ROI. The contrast-to-noise ratio (CNR) was calculated by taking the absolute difference of the SNR of different ROIs. CNR curves that represent phantom-equivalent WM, GM and CSF T_1 values are presented below as a function of τ Contrast comparisons were made between GRE and SE images, between rapid and standard imaging, and between the different preparation methods.

Rodent experiments: Animals were anesthetized using 5%isoflurane/O_2. SR, IR and MDEFT images were acquired over a range of acquisition times, with and without rapid imaging techniques, to highlight particular neuroanatomical features by virtue of T_1 contrast.

Results & Discussion:

As shown in Fig. 1, there is very little alteration in contrast profiles of between standard and rapid imaging techniques with regard to MDEFT preparation. Optimal contrast is achieved at the same preparation time for both rapid and conventional imaging, while only segmented GRE acquisitions display a reduced CNR that is likely due to a reduced overall SNR. *In vivo* images (Fig 2) display the significant benefits of T_1 magnetization preparation and fast SE-based imaging.

These results demonstrate that fast imaging methods can be employed to improve image quality without significantly sacrificing T_1 contrast and that magnetization-prepared, fast SE imaging provides significant susceptibility correction *in vivo* while maintaining T_1-related CNR profiles.

Acknowledgements & Refeences:

Funding for this study was provided by the National Institutes of Health (R01-NF36992, P41-RR16105) We also like to acknowledge the NHMFL & the Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) facility at the UF McKnight Brain Institute for additional support.

1. Fischer HW, et al. Magn Reson Med 1990. 16:317-334. 2. Padgett ISAT, et al. ISMRM 2005 3. Lee, et al. Magn Reson Med. 1995. 34: 308-312.
4. Ugurbil K, et al. Magn Reson Quart. 1993. 9: 2 59-277. 5. Deichmann R., et al. NeuroImage. 2004. 21: 757-767.

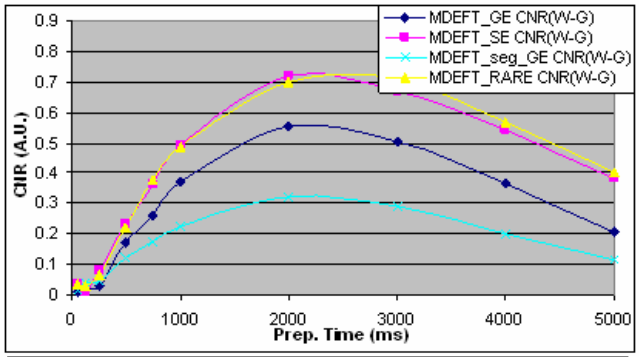

Figure 1: 17.6- T biologically representative T_1 phantom CNR curves demonstrate the contrast performance of MDEFT preparation with respect to WM (T_1=1.97 s) and GM (T_1=2.59 s). All imaging techniques display the same contrast trends as a function of the preparation time, as well as identical τ times. Unlike SE images, segmented GRE acquisitions display reduced CNRs compared to standard GRE acquisitions resulting from lower overall SNR values.

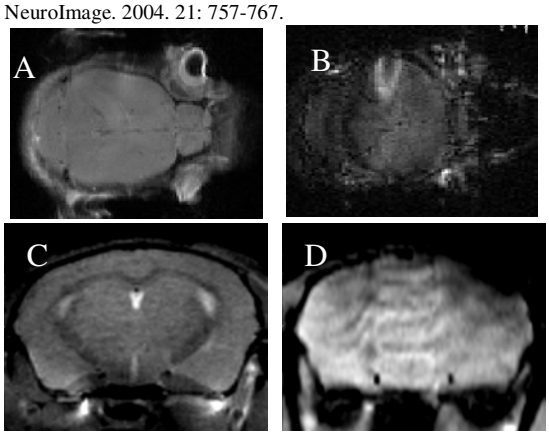

Figure 2: *in vivo* mouse imaging at 11.1 and 17.6 T
A & B: 11.1-T images acquired with standard SR SE (A) & GRE (B) acquisitions display little T_1 contrast and overwhelming susceptibility artifacts
C: 17.6-T mouse images demonstrate that T_1 contrast can highlight cortical grey and major white matter tracts as well as cell layers within the hippocampus using MDEFT_RARE SE imaging (τ= 2 s; η= 4).
D: 17.6-T MDEFT_GRE images demonstrate the negating effect of susceptibility artifacts on T_1 contrast.