Next Generation Delta Relaxation Enhanced MRI with ±0.36T ΔB

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Introduction Molecular imaging lacks a modality that supports high resolution, sub-mm imaging (eg MRI-like resolution) while having high target specificity (eg PET-like target-to-background ratio). Delta relaxation-enhanced magnetic resonance (dreMR) imaging fills this void; dreMR uses insertable, resistive magnet technology that cycles the B_0 of an otherwise conventional MR scanner during imaging to produce contrast from the intended target only. dreMR has previously been demonstrated at maximum delta field (ΔB) values of ±0.15T [1,2]. Here, we present dreMR imaging at ΔB of ±0.36T, the highest achieved to date; our results demonstrate the advantages of achieving high ΔB.

Method We designed and built a next generation dreMR magnet capable of supplying ΔB = ±0.5T with a dual layer, solenoidal coil (Stelar s.r.l., Mede, Italy). The external dimensions are 17cm in diameter, 30cm in length, the weight is ~5kg, and the homogeneous field portion supports an imaging region of 28mm diameter. Other relevant coil properties are: R=0.5Ω, L=0.25mH, field efficiency 0.47T/300A, capable of producing ramp times of 1-2ms, while cooled by perfluoropolyether at a rate of >10kW. Solutions of dispersive (gadofosveset with 4.5% human serum albumin [HSA]) and non-dispersive (gadovosfaset without HSA) contrast agent in PBS at a range of concentrations from 0 to 200μM were prepared in 5mm NMR tubes and supported longitudinally in a Teflon holder for imaging experiments. The phantom, with cross section as shown in Fig 1, was placed in the imaging region of a dedicated birdcage quadrature receive/transmit RF coil. A Philips 1.5T scanner was used for the imaging experiments. T_1 mapping was performed to verify the quality of sample preparation prior to dreMR imaging. The dreMR magnet current is driven through filtered cables with a field controller, which is interfaced and synchronized via a digital output provided by the MRI system. To enable dreMR imaging, an inversion recovery, spin echo sequence (TR=10s, TE=11.6ms, TI=63 to 413ms, voxel dimension=0.45 x 0.45 x 3 mm, bandwidth=212Hz/pixel) was performed with dreMR field activated to augment or reduce the B_0 for a time period t_{on} during the relaxation period between the inversion and excitation pulses. By imaging at several values of t_{on} spanning the range of sample T_1's, we generated pairs of images acquired at ΔB up to ±0.36T. Images were ratiometrically scaled to account for unequal thermal equilibrium magnetization, M_0 (M_z at B_0±ΔB); dreMR images were computed as the difference between these scaled images (Fig2).

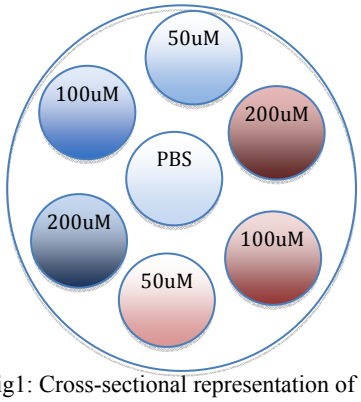

Fig1: Cross-sectional representation of dispersive (red) and non-dispersive (blue) samples arranged in phantom holder

Results & Discussion These experiments represent dreMR imaging with the highest ΔB achieved to date. The dreMR images in Fig 2 show strongly positive image intensities from the dispersive samples, with strongly suppressed image intensities from non-dispersive. Fig 3 shows that dispersive signal scales approximately linearly with ΔB from 0.12-0.36T, as predicted from the approximately linear $\Delta R_1/dB$ of HSA-bound gadofosveset over the range 0.6-2T [3], clearly signifying the benefits of achieving the largest ΔB possible for dreMR image quality.

Conclusion dreMR imaging was accomplished over a range of ΔB from 0.12 to 0.36T. The increase of dreMR signal with ΔB shows the advantage of attaining high ΔB in future dreMR setups. The phantom images are proof-of-concept of achieving high specificity, physiological signal-suppressed in vivo imaging at MR resolution.

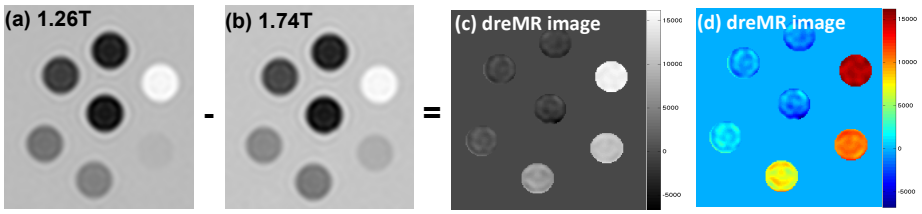

Fig2: Real component of IR T1W images (a,b) taken at ΔB = ±0.24T. Ratiometric scaling to account unequal saturated M_z prior to image subtraction produced dreMR images in greyscale (c) and colorized (d) presentation

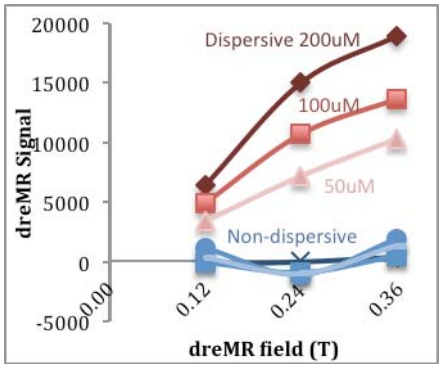

Fig3: ROI analysis of dreMR images show that dreMR signal of dispersive samples increases with ΔB while signal from non-dispersive samples representing physiological tissue is suppressed

References
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