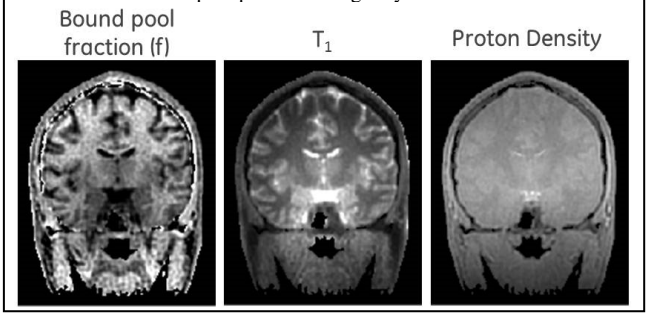
Rapid, motion robust, and quiet quantitative magnetization transfer (qMT) imaging using a zero echo time (ZTE) acquisition

James H Holmes[1], Alexey Samsonov[2], Pouria Mossahebi[3], Diego Hernando[2], Aaron S Field[2,4], and Kevin M Johnson[5]

[1]*Global MR Applications and Workflow, GE Healthcare, Madison, WI, United States,* [2]*Radiology, University of Wisconsin-Madison, Madison, WI, United States,* [3]*Department of Medicine, University of Wisconsin-Madison, Madison, WI, United States,* [4]*Biomedical Engineering, University of Wisconsin-Madison, Madison, WI, United States,* [5]*Medical Physics, University of Wisconsin-Madison, Madison, WI, United States*

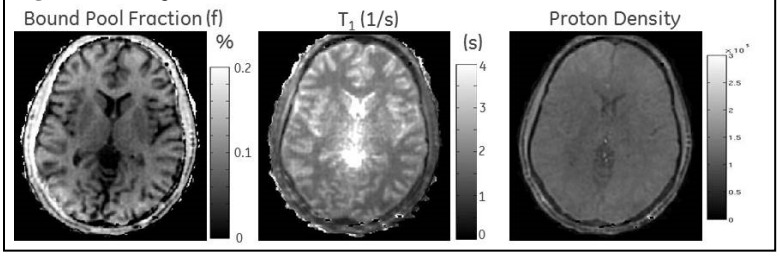
PURPOSE: Quantitative magnetization transfer (qMT) methods have shown significant promise to improve monitoring of neurodevelopment and neurodegenerative changes in the brain [1]. However, these methods remain very challenging to implement in a clinical setting due to long acquisitions times and the resulting likelihood of increased patient motion. Conventional methods rely on the acquisition of numerous imaging measurements however recent work using the modified cross relaxation imaging (mCRI) method [2,3] have demonstrated the ability to estimate a subset of tissue parameters based on fitting to 3 imaging measurements and a B1 map. However, even with this simplification, the conventional image acquisition methods still result in very long scan times. For robust clinical utility, significant reduction in scan time and motion robustness are needed including reducing both to motion related artifacts and motion of patients due to anxiety. We propose combining an intermittent MT preparation with a zero echo time (ZTE) acquisition to provide rapid and silent quantitative imaging with improved robustness to motion. The protocol can be further augmented with a B1 mapping the Actual Flip angle Imaging (AFI method) [4] for greater quantitative accuracy.

Figure 1. Qualitative results from a normal volunteer generated in just over 3 min from the quiet protocol using only ZTE.



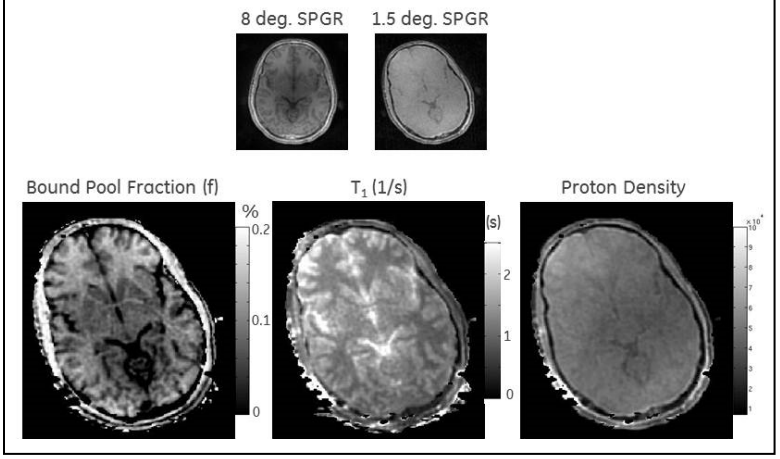
METHODS: Five healthy volunteers were imaged on a 3T clinical MRI (MR750w, GE Healthcare, Waukesha, WI) using 8-channel receive array head coils (Invivo Corporation, Orlando, FL). SPGR and MT weighted imaging was performed using a time efficient and very quiet ZTE acquisition [5,6]. MT preparation was achieved utilizing a 30ms, 3000° hamming windowed sinc RF pulse played at 3kHz off-resonance. The MT weighted image was acquired using the MT preparation pulse excited every 64 radial-out projections with an imaging flip angle of 1.5°. ZTE imaging was performed at 1.5° and 8° to achieve sufficient T1 weighting. Acquisition parameters included 1.8 mm isotropic acquired voxel size, 26 cm FOV and ±17 kHz BW. To correct for B1 variations, a Cartesian based AFI dataset was acquired. Quantitative mCRI modeling was performed using a modified 3 parameter fit to determine the qMT parameters: R_1, proton density (PD) and bound pool fraction (f) [3]. Five normal volunteers were imaged using the rapid protocol. Phantom experiments were also performed to evaluate the performance across a range of normal R_1 values.

Figure 2. Fitted qMT results with B1 correction from a normal volunteer.



RESULTS: Derived qMT parametric images in a normal volunteer demonstrate the ability to rapidly determine PD, T_1 ($1/R_1$), and f with a total imaging time of 3:10 min:sec for the SPGR and MT ZTE images. Single coronal slices are shown through the full isotropic 3D volume showing good distinction between gray and white matter (Fig. 1). Quantitative results following B1 correction using the AFI acquisition are consistent with those reported in the literature [7] (Fig. 2). An example of motion is shown in Fig. 3 and although motion is evident between the ~1 min. imaging SPGR acquisition, the volumes were co-registered prior to mCRI fitting to generate qMT images. The radial sampling scheme provided additional motion robustness for any movement within a given imaging volume. Acoustic noise of the acquisition was very quiet at less than 3 dB above ambient noise.

Figure 3. Volunteer with significant motion evident when comparing the 2 SPGR datasets. However following motion correction, the qMT maps for f, T_1 and PD could still be recovered.



CONCLUSION: In this work we demonstrate the potential to generate qMT images using a fast, quiet, and motion robust radial acquisition scheme in just over 3 min. This approach can help to address many of the challenges currently facing clinical adoption of qMT techniques for neurodevelopmental (i.e. pediatric) and neurodegenerative applications. Further improvements were shown with B1 correction using a conventional AFI acquisition and future work will include modifying the AFI sequence to allow a full completely quiet protocol. Although the work shown here focuses on a very rapid protocol, the method provides flexibility to increase spatial resolution or SNR. Each imaging volume can be acquired in ~1 min leaving the opportunity to acquire more MT or SPGR points to improve robustness and versatility of the qMT modeling.

REFERENCES:[1] Davies et al. Mult. Scler. 2004. [2] Yarnykh VL. MRM 2012. [3] Mossahebi P et al. MRM 2013. [4] Yarnykh VL. et al. MRM 2007. [5] Hafner MRM, 1994. [6] Madio et al. MRM 1995. [7] Underhill H.R. et al. NeuroImage 2009.

ACKNOWLEDGEMENTS: Funding from NIH5R01NS066982 and GE Healthcare