B0 inhomogeneity correction of T2* from fat-water MRI: application to a diet-induced obesity mouse model at 15.2T

Henry H. Ong[1,2], Corey D. Webb[3], Marnie L. Gruen[3], Alyssa H. Hasty[3], John C. Gore[1,2], and E. Brian Welch[1,2]

[1]*Vanderbilt University Institute of Imaging Science, Nashville, TN, United States,* [2]*Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States,* [3]*Molecular Physiology and Biophysics, Vanderbilt University School of Medicine, Nashville, TN, United States*

Introduction

In obesity, adipose tissue (AT) is known to undergo both cellular expansion and complex metabolic/endocrine changes in association with chronic inflammation[1]. Previously, we investigated the potential of T_2^* estimates from quantitative fat-water MRI (FWMRI) to be sensitive to AT inflammatory changes due to adipocyte iron overload in an established diet-induced obesity mouse model at 15.2T[2,3]. Preliminary results indicated the presence of large background B_0 variations (50-250 Hz/mm), which could adversely affect T_2^* mapping. In this work, we implement a recently proposed B_0 variation correction for human FWMRI[4]. Through analysis of a subset of our previous data, we demonstrate the feasibility of the correction method for quantitative FWMRI mouse studies.

Methods

Male C57BL/6J wild type mice at 8 weeks of age were placed on low fat diet (LFD, 10% kcal from fat, N=3) or high fat diet (HFD; 60% kcal from fat, N=3). Food was purchased from Research Diets (New Brunswick, NJ, USA). Mice had free access to food and water.

MRI was performed on a 15.2T Bruker Biospec scanner. A 3D multi GRE image with slab excitation was acquired on each mouse using the following parameters: 128×128×32, FOV=32×32×48 mm^3, number of acquisitions=2, FA=5°, echoes =12, TE/ΔTE =1.2/0.78 ms, BW=500 kHz, and TR=50 ms.

All images were processed using a 3D fat-water separation algorithm[5]. Employing a 9 peak model of the lipid signal[6], the algorithm outputs a water image, a fat image, a single component T_2^* map, and an off-resonance (ΔB_0) map. The water and fat images can then be combined to produce a fat signal fraction (FSF) map.

Correction of B_0 variation is accomplished by including its effect within the standard T_2^*-corrected fat-water signal model[4]. The resulting signal model is simply the fat-water signal multiplied by a modulation term, which must be numerically calculated for 3D MRI. Water, fat, T_2^*, and ΔB_0 maps from the initial fat-water separation are used to calculate the modulation term at each voxel. Water, fat, T_2^*, and ΔB_0 values are re-estimated at each voxel using the corrected signal model including the modulation term with nonlinear least-squares fitting. Initial analysis showed significant modulation in x, y, and z dimensions, so B_0 variation correction was implemented in all three axes unlike in Ref. 4.

In this preliminary analysis, we analyzed a single slice encompassing the kidneys from HFD and LFD mice at 8 and 16 weeks after diet placement. Mean/stdev values of FSF, T_2^*, and ΔB_0 were recorded from ROIs within perirenal AT, kidney, and erector spinae muscle.

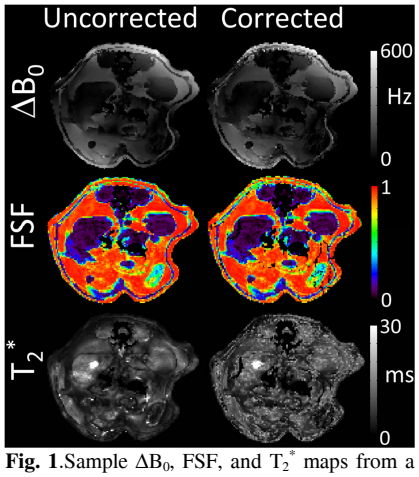

Fig. 1.Sample ΔB_0, FSF, and T_2^* maps from a 16wk HFD mouse before and after correction.

Results and Discussion

Fig. 1 shows sample ΔB_0, FSF, and T_2^* maps from a 16wk HFD mouse before and after B_0 variation correction. There is a high degree of similarity between the uncorrected/corrected ΔB_0 and FSF maps. The corrected T_2^* map exhibits less large-scale intensity variation suggesting that macroscopic B_0 variations are being compensated. However, the corrected T_2^* map also appears noisier. This may be the result of differences in data fitting approaches. The uncorrected maps all have spatial constraints to stabilize the solution, whereas the corrected maps are fit voxel-by-voxel.

Table 1. Uncorrected and corrected FWMRI ROI parameter values

ROI	FSF		ΔB_0 (Hz)		T_2^* (ms)	
	Uncorrected	*Corrected*	*Uncorrected*	*Corrected*	*Uncorrected*	*Corrected*
HFD AT 8wk	**0.956 ± 0.006**	**0.952 ± 0.007**	**139 ± 37**	**144 ± 36**	**8.1 ± 0.7**	**30.9 ± 14.9**
LFD AT 8wk	**0.921 ± 0.013**	**0.908 ± 0.011**	*77.2 ± 51.2*	*78.3 ± 47.2*	**5.5 ± 1.0**	**21.4 ± 11.4**
HFD AT 16wk	**0.950 ± 0.010**	**0.944 ± 0.012**	*183 ± 83*	*183 ± 83*	**7.4 ± 0.9**	**23.6 ± 9.4**
LFD AT 16wk	*0.916 ± 0.015*	*0.901 ± 0.012*	*426 ± 59*	*439 ± 65*	**5.9 ± 0.9**	**24.7 ± 9.7**
HFD Kidney 8wk	*0.053 ± 0.013*	*0.051 ± 0.012*	*45.1 ± 17.2*	*46.9 ± 17.3*	**10.4 ± 1.6**	**20.7 ± 9.8**
LFD Kidney 8wk	*0.049 ± 0.008*	*0.044 ± 0.006*	*65.8 ± 45.8*	*66.3 ± 44.4*	**9.5 ± 1.4**	**13.5 ± 3.0**
HFD Kidney 16wk	*0.054 ± 0.011*	*0.053 ± 0.010*	*76.8 ± 34.5*	*78.7 ± 34.2*	**12.5 ± 1.9**	**31.3 ± 18.2**
LFD Kidney 16wk	*0.058 ± 0.006*	*0.057 ± 0.009*	**381 ± 150**	**384 ± 151**	*10.2 ± 4.8*	*28.0 ± 16.3*
HFD Muscle 8wk	*0.040 ± 0.006*	*0.042 ± 0.006*	*32.4 ± 17.0*	*32.7 ± 17.0*	**12.7 ± 2.4**	**23.1 ± 7.6**
LFD Muscle 8wk	*0.043 ± 0.006*	*0.043 ± 0.005*	*133 ± 78*	*134 ± 79*	**10.4 ± 2.5**	**21.0 ±6.5**
HFD Muscle 16wk	*0.052 ± 0.013*	*0.058 ± 0.007*	*104 ± 65*	*98 ± 64*	*12.2 ± 7.8*	*27. ± 17.9*
LFD Muscle 16wk	*0.055 ± 0.012*	*0.057 ± 0.017*	*372 ± 176*	*366 ± 159*	**11.7 ± 3.7**	**24.6 ± 14.0**

Bold and underlined data – $p < 0.05$, paired t-test (uncorrected vs corrected)

Table 1 shows uncorrected and corrected FSF, ΔB_0, and T_2^* ROI mean and stdev values. Bold values indicate a significant difference ($p < 0.05$) between uncorrected and corrected values using a paired t-test.

The correction method appears to systematically lower FSF in perirenal AT. No such bias was observed with ΔB_0. Any changes in FSF or ΔB values after correction were less than 5%.

Almost all of the T_2^* values showed significant increase (2-3×) after correction as expected, which suggests the correction method is working properly. These results are in agreement with Ref. 4: the correction primarily impacts T_2^* and not FSF or ΔB_0.

Conclusion

It is demonstrated that a recently proposed B_0 variation correction method for human FWMRI is feasible for in vivo mouse FWMRI at 15.2T. The correction method primarily affects T_2^* and not FSF or ΔB0 in agreement with previous reports.

References: **1**. Weisberg SP, et al, *J Clin Invest*, 112:1796 (2003). **2**. Orr JS, et al, *Diabetes*, 63:421 (2014). **3**. Ong HH, et al, *Proc Intl Soc Mag Reson Med*, 22: 2146 (2014). **4**. Hernando D, et al, *MRM*, 68:830 (2012). **5**. Berglund J, et al, *MRM*, **67**:1684 (2012). **6**. Hamilton G, et al, *NMR Biomed*, 24:784 (2011).

Acknowledgements: NIH T32 EB001628 and R21DK095456.