Fat Fraction Bias Correction using T_1 estimates and Flip Angle Mapping

Issac Y. Yang[1], Yifan Cui[2], Curtis N. Wiens[2], Trevor P. Wade[1], Charles A. McKenzie[1, 2]
[1]Medical Biophysics, University of Western Ontario, London, Ontario, Canada; [2]Physics and Astronomy, University of Western Ontario, London, Ontario, Canada

Introduction: T_1 independent, T_2* corrected chemical shift based fat-water separation with accurate spectral modeling of fat (Quantitative IDEAL) has been employed clinically for a non-invasive approach of quantifying fat in the liver, muscle and vertebral bone marrow [1]. However, due to the difference between T_1 of fat and water, the measured fat fractions (FF) may be biased [2]. Current T_1 bias mitigation methods require acquiring images at low flip angles (FA), thus trading off precision (from reduced signal to noise ratio (SNR)) for improved accuracy [2]. Previous work has shown that T_1 bias can be reduced by using estimated T_1 values to generate correction factors, allowing higher FA to be used and increasing SNR with little loss of accuracy [3,4]. However, this technique requires accurate knowledge of the FA used When the true FA is unknown the accuracy of the correction is reduced [5]. In this study, we aim to combine rapid 3D FA mapping and *a priori* T_1 values on quantifying L4 vertebrae marrow FF, the only region of a healthy person with comparable FF to liver steatosis. to demonstrate the technique's performance for *in vivo* imaging.

Methods: The L4 vertebrae of 5 healthy volunteers were scanned at 3.0T (Discovery MR 750, GE Healthcare, Waukesha, WI) using Quantitative IDEAL (TR=7.3ms, ETL=2, TE=[1, 1,5, 2.1, 2.6, 3.1, 3.7] ms, N_x=192, N_y=144, FOV=28cm x 19.6cm, 24 slices at thickness=8mm, FA=2° and 8°).True fat fractions were determined using STEAM spectroscopy (TR=3.5s, TE=11ms and 30ms, with voxel size 20mm x 20mm x 20mm) after correction for T_2 decay. A FA map was acquired using a double angle Look-Locker sequence with parameters of N_x=32, N_y=22, FOV=28cm x 19.6cm, and 24 slices of thickness=8mm. FF images were generated after performing T1 correction using literature T_1 values (T_{1f}=382ms, T_{1w}=586ms) [6]. SNR maps are generated using a generalized pseudo-replica technique [7]. Validation of bias correction was performed by comparing the fat fraction values from the corrected fat fraction map to the STEAM acquired FF. SNR performance was assessed by comparing fat and water SNR, as well as standard deviations of FF image ROIs of the high FA acquisition to the low FA acquisition.

FIGURE 1: Fat fraction map of a volunteer before (left) and after (right) correcting for T_1 bias. The L4 FF was reduced from 34% to 30% (true FF=31%)

Results: The true FA at L4 ranged from 6.1^o to 6.6^o for volunteers 2-4 with little spatial variation. Volunteer 1 had FA=7.8^o at the L4 vertebrae. Figure 1 shows the FF map of a volunteer acquired at FA=8°, before and after correction. Figure 2 plots the FF bias from various acquisitions and corrections from all volunteers. T_1 correction alone brought the measured FF to within 2% of the true FF, and showed superior accuracy on 3 of the volunteers, and minor accuracy improvement on volunteer 1 compared to the FF acquired at FA=2. FF measurement was brought 1% closer to the true value in volunteer 3 when FA was measured. FF SNR from ROIs show an average reduction of 1.8% FF in FF standard deviation when FA=8° and corrections were used. SNR mapping showed the FA=8° acquisitions have 2-4 times increased SNR in fat or water signals compared to the FA=2° acquisitions.

FIGURE 2: Comparison between FF bias acquired at FA=2°, FA=8° before correction, after T_1 correction only and after T_1 correction using measured FA. T_1 correction alone has better accuracy than the low FA FF; using FA map

Discussion: Figure 2 demonstrates that correcting T_1 bias of a high FA acquisition improves accuracy. The accuracy can be improved further if the true FA was measured. ROI measurements showed slight improvements in precision with FA=8° acquisitions, but the SNR maps show at least doubling in SNR of fat and water signals, suggesting the precision improvements in FF is masked by biological variability of FF between voxels. The flip angle map is acquired on a separate breath hold, so it does not affect the acquisition time of Quantitative IDEAL. Previous experiments have shown that the correction will have comparable accuracy to a low FA acquisition as long as the estimated T_1 is within 20% of the true T_1. Therefore, improved FF accuracy can be achieved even with a T_1 estimate differing substantially from the true value. Even though L4 IDEAL scans may not be performed using these particular acquisitions, the low flip angle is used when imaging areas such as the liver, where the greater T_1 difference between fat and water (T_{1f}=382, T_{1w}=809ms [6]) results in greater bias, as well as being more susceptible to FA errors when correcting for T_1 bias. Our current work acts as a proof of concept for the application of this technique on *in-vivo* acquisitions, and future work will involve validation of this technique's performance on liver fat quantification.

Conclusion: T_1 corrections with flip angle mapping can be used to reduce the FF bias of a high FA acquisition and be more accurate than a low FA acquisition, while maintaining the superior performance in SNR.

References: 1. Yu et al. JMRI, 2007; 26: 1153-61 2. Liu et al. MRM, 2007 58:354-64. 3. Yang et al. Proc ISMRM 2011:2710. 4. Karimpanos et al, MRM , 2011:1312-26. 5. Wade et al. Proc ISMRM 2010: 2837. 6. de Bazelaire et al, Radiology, 2004 230:652-59.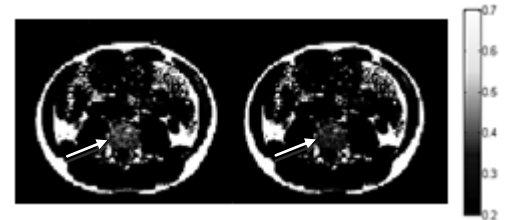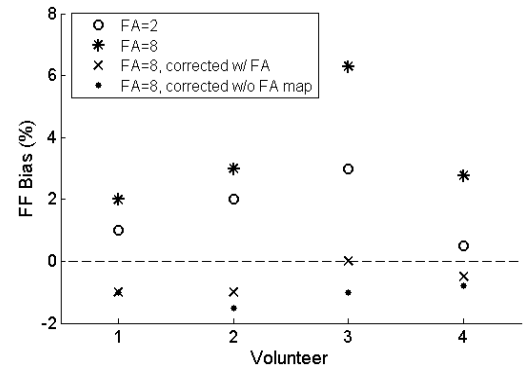 7. Wiens et al. MRM, 2011: 1192-97