Clinical Comparison of Single-R_2* and Dual-R_2* Correction for Accurate Fat Quantification in the Liver

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Introduction: Accurate fat quantification using chemical shift-encoded techniques (based on separating the signals originating from fat and water) requires correction for R_2* (=1/T_2*) decay[1]. Independent estimation of R_2* for fat and water ("dual-R_2*") should theoretically model the underlying physics more closely and has been shown to be more accurate in phantom studies[2,3]. However, the phantoms used in these studies had large fat particle size that does not accurately mimic intracellular vacuoles of fat. The use of physiologically sized fat particles dramatically changes the relative R_2* values of water and fat[4]. Further, dual-R_2* correction has poor noise performance (Fig. 1) and higher mathematical complexity than using a common R_2* value for fat and water ("single-R_2*")[2]. The purpose of this work is to determine whether single-R_2* or dual-R_2* correction is more accurate for measurement of fat fraction (FF) in a clinical setting.

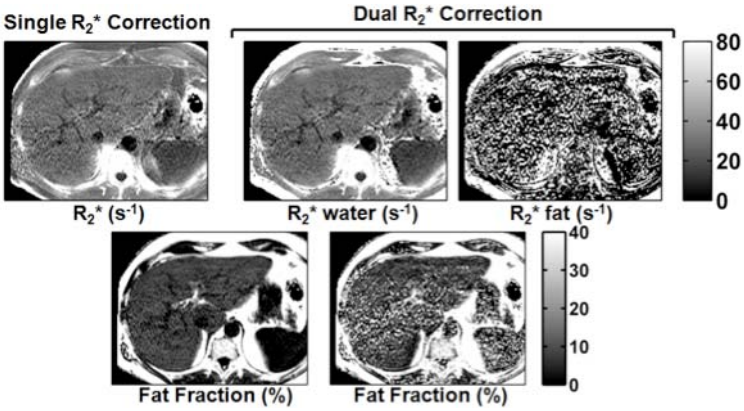

Figure 1. Dual-R_2* correction is associated with worse noise performance than single-R_2* correction. Axial R_2* maps show noticeably more noise using dual-R_2* vs. single-R_2* correction. Similarly, FF maps estimated using single-R_2* correction show higher noise performance than those obtained using dual-R_2* correction.

Methods: After obtaining IRB approval and informed consent, we performed liver scans on 97 patients. Chemical shift-encoded imaging and MRS on these patients was performed at 1.5T (SignaHDx, GE Healthcare, Waukesha, WI). Multi-echo 3D SPGR acquisition was performed, with TE_1=1.3 ms, ΔTE=2.0 ms, TR=13.7 ms, 6 echoes/TR, flip angle=5°, and matrix=256×128. We identified 20 patients with fatty liver (FF>10%, based on MRS), whose data were used for this study (dual-R_2* correction is unstable and has minimal impact at low FF). FF was measured from the imaging data by post-processing both single-R_2* and dual-R_2* models, performed with magnitude fitting to avoid the effects of eddy currents[5]. We compared the accuracy of FF measurement using single-R_2* and dual-R_2* methods, using MRS as the reference. To assess the need for dual-R_2*, we measured the difference in R_2* values of fat and water. Values of R_2* were obtained from Lorentzian fits to the water and main methylene peaks, from the MRS data. These results were used to calculate the bias associated with assuming single-R_2* rather than dual-R_2*. In the simulation, chemical shift-encoded signals were generated using a dual-R_2* model as the 'truth', and subsequently fitted using a single-R_2* model over FF ranging from 0-100%. The resulting 'simulated FF' was subtracted from the true FF in order to obtain a measure of bias.

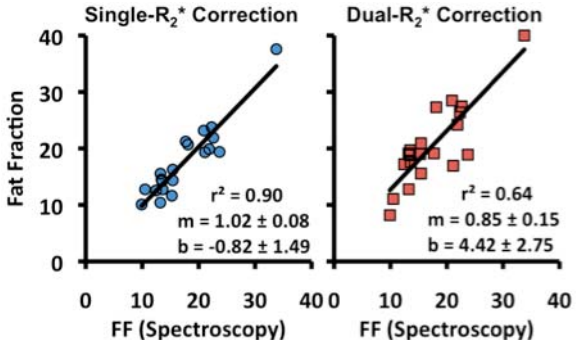

Figure 2. Single-R_2* correction shows better agreement with spectroscopy than dual-R_2* correction for quantification of fat fraction. FF estimated using single-R_2* and dual-R_2* models are plotted against FF co-localized and measured with spectroscopy. Linear regression was performed, and the slope (m), intercept (b), and r^2 of the fit are shown. The slope and intercept are displayed as the average +/- the standard deviation.

Results: Figure 2 plots FF measured from imaging vs. FF measured from spectroscopy. Linear regression demonstrates better correlation for single-R_2* (r^2=0.90) than dual-R_2* (r^2=0.64). Further, figure 3 plots the R_2* of fat vs. R_2* of water (measured from MRS) showing good overall agreement, i.e., R_2* of water and fat are very similar, on average. The mean difference between the two is very small: 0.95 s^{-1} ± 8.28 s^{-1}. Results of the simulation demonstrate that the worst-case bias from single-R_2* leads to 2.6% at its maximum (at a true FF of 55%). At more typical FF values of 20, 10, and 5%, the errors are 1.5, 0.8, and 0.4%, respectively.

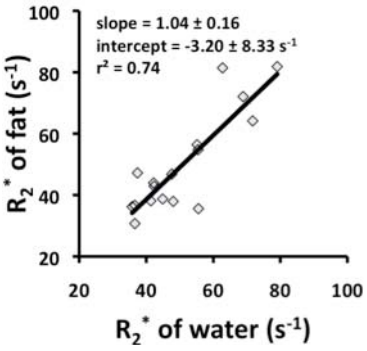

Figure 3. The R_2* of fat and water are very similar. This figure plots the R_2* of fat and water measured in the liver using MRS data fit to a two-peak Lorentzian model (water peak and methylene peak). The fat and water R_2* values are fitted linearly.

Discussion and Conclusion: The R_2* of fat is very similar to the R_2* of water in each patient. Single-R_2* is more accurate than dual-R_2* correction for liver fat quantification. A limitation of this study is that none of our subjects exhibited severe iron overload. The effect of iron overload on R_2* values of fat and water in the liver is unknown and warrants additional study.

References: **1.** Yokoo T *et al*. Radiology 251(1):67-76. **2.** Chebrolu VV *et al*. MRM 63(4):849-857. **3.** Hines CD *et al*. JMRI 33(4):873-81. **4.** Hines C *et al*. Proc. 19th ISMRM 2011:4514. **5.** Yu H *et al*. MRM 66(1):199-206.

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