The Use of Heavily T1-Weighted Sequences for Fat Quantification

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Introduction: Separation of fat and water in MRI has been a topic of long-standing interest. The use of such techniques for quantification is of considerable clinical interest, however one of the confounding issues for accurate quantification is the different T1s of the water and fat components. As shown in several previous studies, this leads to a systematic overestimation of the fat fraction (i.e. fat signal divided by total signal). A straightforward solution is to minimize T1-weighting (T1W) by use of a low flip angle and a long TR although this tends to increase the random noise error in the estimate.

An alternative approach may be to use a higher flip angle and correct for the T1W induced in the fat estimate, which may be less susceptible to noise error. As shown in Ref 1, the relationship between the measured fat fraction (F_{meas}) and the true fat fraction (F_{true}) has a simple relationship in the limiting case of a heavily T1W gradient echo sequence. For sufficiently high flip angle & short TR, the amplification due to T1 is a function of only R = T1(water) / T1(fat) given by Eq 1. If the ratio is known then F_{true} can be estimated directly by a rearrangement of Eq 1 (given by Eq 2).

$$F_{meas} \approx \frac{RF_{true}}{1+(R-1)F_{true}} \text{ ----- [1]} \qquad F_{true} \approx \frac{F_{meas}}{R+(1-R)F_{meas}} \text{ ----- [2]}$$

As well as potentially higher SNR, an advantage of using heavy T1W is that the error propagation due to uncertainty in the flip angle does not translate into large errors in the measured fat fraction. Figure 1 plots the error in F_{meas} due to a 20% error in the flip angle, showing that at higher flip angles the propagation is negligible. The choice of TR is also important in imparting heavy T1W; Figure 2 shows the expected amplification of F_{true} as a function of TR. Clearly the maximum amplification (given by Eq 1) is only attained with very small values of TR.

This abstract study considers the use of heavily T1W SPGR imaging to quantify fat.

Figure 1

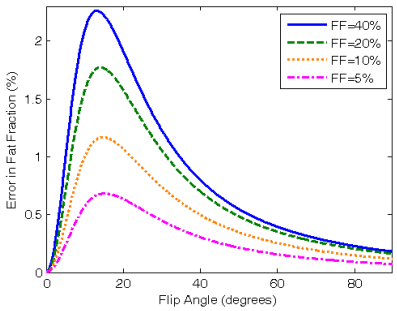


Figure 2

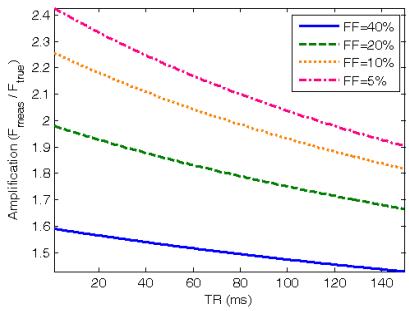
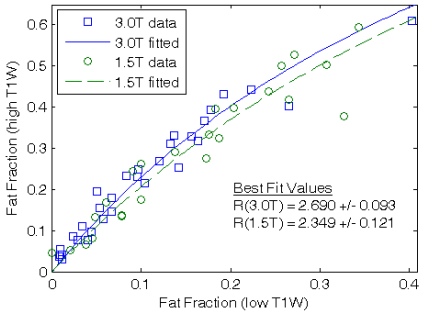


Figure 3



Methods: In this prospective, HIPPA compliant study 24 / 31 subjects were imaged at 1.5T / 3.0T using two SPGR protocols: low T1W (flip angle 10°, TR 122-240ms) and high T1W (flip angle 65-90°, 9-18ms). A 6-echo SPGR sequence was implemented on GE 3.0T and Siemens 1.5T scanners and fat was calculated by fitting the SPGR signal equation to variation in the signal amplitude with TE. A model was used that included T2* decay and 6 components of the lipid spectrum, shown in Table 1. Spectroscopy (STEAM, TR 5000ms, TE 10-50ms, TI 88-4000ms) was performed at 3.0T on one subject with high fat fraction to obtain estimates of the T1s and T2s of the lipid components.

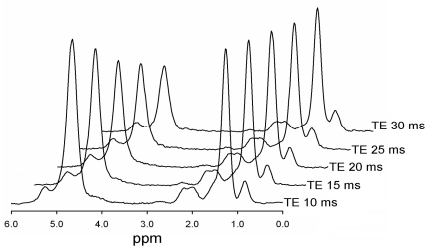
Results: Figure 3 shows fat fractions from the SPGR experiments. Nonlinear least squares fitting was used to determine values of R at 3.0T and 1.5T of 2.690 and 2.349, respectively. The 15% differences indicate the T1s of fat and water scale differently with field strength. Table 1 shows properties of the lipid spectrum determined at 3.0T in human fatty liver and Figure 4 shows typical spectra. Calculated spectra for the low T1W and high T1W protocols are given in Table 1. These indicate the effective spectrum may differ for the low T1W and high T1W protocols.

Conclusions: Fat fractions obtained at low flip angle and long TR provide a "safe" regime for quantification, since the T1 effects are minimal. However, the SNR may be low which introduces noise-related errors (2). As an alternative, heavily T1W, higher SNR measurements may provide another "safe" regime, since the fat fraction is overestimated in a predictable way. The T1 effects on the fat spectrum must be considered.

Table 1 Lipid properties determined by spectroscopy at 3.0T.

Peak (ppm)	T1 (ms)	T2 (ms)	Peak Area (%) Low T1W	Peak Area (%) High T1W
5.3	535	-	4.8	7.9
4.2	278	-	3.9	5.0
2.75	411	56	0.4	0.2
2.1	268	58	12.8	20.2
1.3	341	74	69.3	57.3
0.9	783	130	8.7	9.3

Figure 4 Spectra obtained at 5 echo times.



References: (1) Bydder et al, *Magn Reson Imaging* 2008;26:347 (2) Liu et al. *Magn Reson Med* 2007;58:354