Simultaneous Estimation of Water-T2 and Fat Fraction Using a Single Breath Hold Radial GRASE Method

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Introduction: T2 and lipid-water content are important parameters for the characterization of liver lesions. Currently the information is obtained in a qualitative manner from the visual inspection of T2-weighted images and in- and out-of phase images. Recently, a radial gradient and spin-echo (GRASE) method has been developed for liver imaging [1]. The method not only provides high spatial resolution and motion insensitivity but also T2 and fat-water mapping from data acquired in a single breath hold. In the method presented in [1], however, the calculated T2 is dependent on the amount of fat present in the pixel. This precludes the proper characterization of tissue when fat is present. In this work we present a new algorithm where the estimation of T2 is decoupled from the fat-water estimation, providing a fast method for the estimation of the T2 of the water component ($T2_w$) and fat fractions thus improving the characterization of fat-containing pathologies.

Methods: A diagram of the radial GRASE pulse sequence is shown in Fig. 1. The echoes ($E_{0\text{-}3}$) which are collected during each spin-echo (SE) period are used to obtain initial fat-water estimates without the effects of field inhomogeneities using the iterative fat-water decomposition previously described in [2].

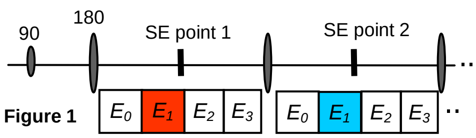


Figure 1

For T2 estimation we use the echoes that are closest to the SE point (E_1). The E_1 data sets are undersampled (only 24 views per TE) but since data are collected with a radial k-space trajectory we can obtain images at various effective TEs (TE_{eff}) using a Compressed Sensing approach [3] or the echo sharing technique described in [4]. The data presented here uses the latter approach.

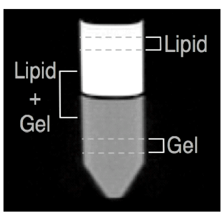
$T2_w$ and the final fat-water estimates are then calculated by fitting the signal intensity of each pixel in the TE_{eff} images (typically 8-10 images) to:

$$|S(TE_{eff})| = |I_w e^{-\frac{TE_{eff}}{T2w}} + I_f e^{-\frac{TE_{eff}}{T2f}} e^{iC_s\Delta_n}| \quad \text{(Eq.1)},$$

where I_w and I_f are the water and fat estimates and $T2_f$ is the T2 of fat. C_s is the chemical shift between fat and water and Δ_n is the time shift of the echo E_1 relative to the SE point. Both C_s and Δ_n are known quantities. $T2_f$ is treated as a known constant in Eq. 1. In vivo $T2_f$ is estimated for each subject using the average T_2 value from regions in the body that contain mostly fat (e.g. the subcutaneous fat layer) using the single exponential decay model:

$$|S(TE_{eff})| = |I \cdot e^{-\frac{TE_{eff}}{T_2}}| \text{ (Eq.2)}.$$

Figure 2



	Fat Fraction	T_2 (ms) from Eq. [2]	T_{2w} (ms) from Eq. [1]
GEL	0.04(0.006)	37(3)	36(3)
GEL + LIPID	0.25(0.010)	50(3)	39(3)
	0.47(0.010)	64(4)	38(3)
	0.64(0.008)	80(5)	39(3)
	0.72(0.007)	90(5)	40(3)
LIPID	0.94(0.003)	135(10)	

Results: The radial GRASE method was implemented on a 1.5T GE Signa NV-CV/i scanner. Data were acquired on a single breath with BW=±125 kHz, ETL=10, matrix size=256×192, TR=1s, NEX=1. The phase shifts between the SE points and the echoes ($E_{0\text{-}3}$) were ($-5\pi/2$, $-\pi/6$, $\pi/2$, $7\pi/6$). C_s at 1.5 T is 220 Hz and Δ_n=0.37 ms.

Figure 2 shows a lipid-gel phantom together with fat fraction and T2 results for slices in the pure-gel and pure-lipid regions as well as in regions with different lipid:gel ratios. Note that when we use Eq. 2 (the single exponential decay) the T2 of the slice increases as the fat-fraction increases. When we use Eq. 1, the $T2_w$ for all fat fractions is similar to the T2 of the pure-gel. Thus we can estimate the T2 of the water component independently of the fat fraction.

Figure 3 shows results for 3 subjects: (a) a normal volunteer (fat fraction=0.11±0.02), (b) a patient with a fatty liver (fat fraction=0.35±0.13) and (c) a patient with a hepatocellular carcinoma (*yellow arrow*) with a central necrotic core. In the latter, the periphery of the lesion (non-necrotic part) has a small amount of fat (fat fraction=0.18±0.04).

In (a) the T2 from a single exponential (55±8 ms) is slightly higher than the $T2_w$ obtained from Eq. 1 (43±6 ms). In (b) the T2 from Eq. 2 (73±11 ms) is significantly higher than the $T2_w$ obtained from Eq. 1 (39±8 ms) due to the presence of fat. In (c) the T2 of the periphery of the hepatocellular carcinoma calculated with Eq. 2 is 62±10 ms whereas the $T2_w$ from Eq. 1 is 50±9 ms. Note that patient (c) has a cyst in the left kidney (*blue arrow*), a lesion that does not contain fat. The T2 of the cyst from Eq. 2 (325±62 ms) is similar to the $T2_w$ calculated from Eq.1 (350±66 ms).

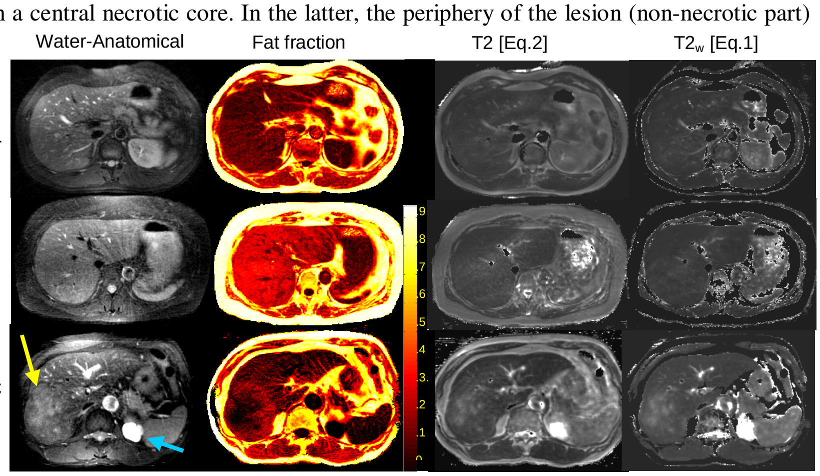


Figure 3

Conclusion: A new algorithm for processing radial GRASE data has been developed. With this algorithm one obtains both fat-water information and T2 of the water component within a breath hold. This novel method is fast and should provide valuable information for the characterization of pathologies in the clinic.

Acknowledgement: This work was supported by NIH grants CA099074 and HL085385. **References:** [1] Altbach MI et al ISMRM 16, 708, 2008. [2] Reeder SB et al MRM 51:35, 2004 [3] Candes E et al IEEE IT 52:2, 2006 [4] Altbach et al, *MRM* 54:549, 2005.