A Variable Bandwidth Radial Gradient and Spin-Echo (VB-radGRASE) Method for Improved T2 and Fat-Water Parameter Estimation

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Introduction: Lately there has been a great interest in the quantification of T2 and fat content as these parameters yield important diagnostic information related to inflammation, iron deposition and metabolic disorders involving the accumulation of fat [1]. A series of methods based on the acquisition of gradient echoes have been presented for the simultaneous quantification of fat and T2*[2]. A drawback of gradient echo methods is that the multi resonances of the lipid molecule have to be accounted for in the signal model which requires the acquisition of more data for accurate estimation. Also, T2 cannot be estimated from the data. Acquisition schemes based on gradient and spin-echo (GRASE) methods are an alternative for fat-water and T2 estimation [3]. Both T2 and fat-water maps are estimated from the data acquired at the SE point thus the multi resonances of the lipid molecules do not need to be modeled or estimated since spins for all chemical species are refocused. It was also shown that if data are acquired using a radial trajectory the TE data sets used in the estimation can be generated from highly undersampled data, thus allowing for faster data acquisition (breath hold) [3]. With the use of undersampled data there is always a loss in SNR which could in turn affect parameter estimation. In this work, we present a new variable bandwidth radial GRASE (VB-radGRASE) for optimized SNR of the TE data points used in the T2 and fat/water estimation.

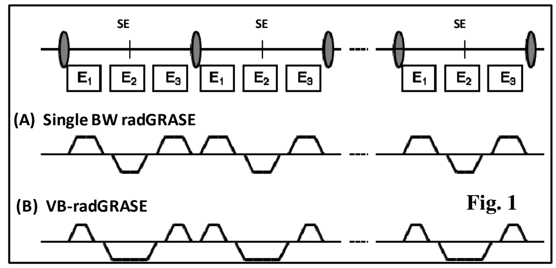


Fig. 1

Technique: The technique is based on a radial GRASE sequence where 3 echoes are acquired per spin echo (SE) point (Fig. 1). If we assume that the main components on each pixel within an image are lipid and water, the data at the SE points (echoes E2) follow the signal equation:

$$s(TE) = \rho_w e^{-TE/T2_w} + \rho_l e^{-TE/T2_l}$$

[1], where ρ_w, ρ_l are the spin densities of the water and lipid components and $T2_w$, $T2_l$ are their T2 decay times. Eq. [1] requires a non-linear bi-exponential fit which relies on good initial conditions for accurate parameter estimation. Since in GRASE we collect data at echoes E1 and E3 in addition to E2, these are used within a Dixon type method for the initial estimation of ρ_w, ρ_l [3,5]. The initial condition for $T2_w$ for each pixel can be obtained assuming a single exponential decay. $T2_l$ can be estimated from areas containing pure lipid (eg, areas of subcutaneous fat in vivo) and used as an initial condition or as a known parameter in Eq. [1].

To improve the SNR of the estimation, each TE data point can be acquired with a lower receiver bandwidth (BW). If BW is lowered for E1-E2-E3 (Fig. 1A) the disadvantage is that the echo train length is significantly increased. In VB-radGRASE we adjust BW so that E1 and E3 are acquired at the highest BW allowed by the scanner (BW1) and echo E2 is acquired at a lower bandwidth (BW2) (Fig 1B). The rationale is that E1 and E3 are only used in the estimation of initial conditions whereas E2 is used in the final T2 estimation. In this way the SNR for E2 is increased with a minimal increase in the echo train.

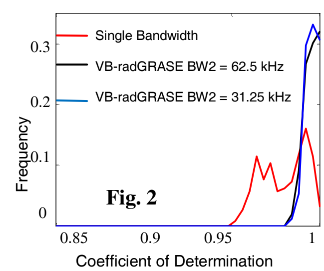
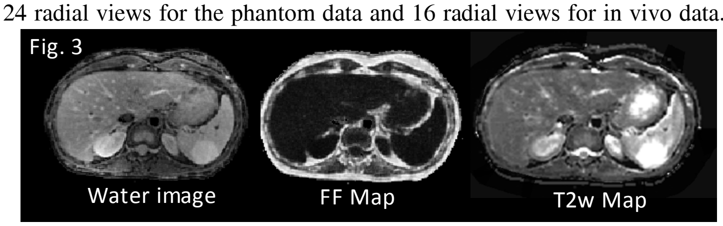


Fig. 2

Methods: VB-radGRASE was implemented on a 1.5T GE Signa NV-CV/i scanner. A set of phantoms (emulsions) with different fat content were prepared according to [6] and data were acquired with BW1=±125 kHz, BW2=±62.5 kHz and ±31.25 kHz, ETL=8, matrix size=256×192, TR=1.5s, slice thickness=8 mm. In vivo abdominal data were acquired on a breath hold with BW1=±125 kHz, BW2=±31.25 kHz, ETL=12, matrix size=256×192, TR=1s, FOV=48 cm, slice thickness = 4 and 8 mm. The time shifts between gradient echoes corresponded to fat-water phase shifts of (-0.82π, 0, 0.82π), (-1.36π, 0, 1.36π) for VB-radGRASE with BW2 = ±62.5 kHz and ±31.25 kHz, respectively and (-0.67π, 0, 0.67π) for the ±125 kHz single bandwidth sequence. The data at each TE point had 24 radial views for the phantom data and 16 radial views for in vivo data. Echo sharing in k-space [4] was used prior to reconstructing each TE image in order to compensate for the undersampling in the data.

Table 1	Fat Fraction		
	Phantom 1	Phantom 2	Phantom 3
Single BW radGRASE	0.025	0.221	0.367
VB-radGRASE BW2 = 62.5 kHz	0.016	0.208	0.329
VB-radGRASE BW2 = 31.25 kHz	0.012	0.209	0.326



Results: Table 1 shows estimated fat fractions (FF) for the phantom. Note that the FF values are similar for single bandwidth and VB-radGRASE (FFs were also similar to MR spectroscopic values). To evaluate the effect of using a lower BW for T2 estimation we plotted the histogram of the coefficient of determination (COD) as a metric of goodness of fit (Fig. 2). Note that the VB-radGRASE sequence with the lowest E2 BW has the highest CODs during the bi-exponential fit.

Fig. 3 shows FF and T2w maps for VB-radGRASE for a 4 mm thick slice abdominal image. FF and T2w histogram parameters for a liver ROI are compared in Table 2 for data acquired with 4 and 8 mm slice thickness. Despite the fact that in the 4 mm thick slice data there is a decrease in SNR of $\sqrt{2}$, the data has the same T2w and FF and the CODs are all above 0.96 for both data sets (Fig. 4).

Table 2	T2w (ms)	FF
8 mm thick slice	58.4 ± 4.08	0.033 ± 0.006
4 mm thick slice	58.6 ± 5.85	0.043 ± 0.01

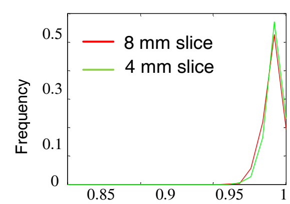


Fig. 4. Coefficient of Determination

Conclusion: A radial GRASE method that acquires the central echo at a lower bandwidth in order to increase the SNR of the TE images was implemented and evaluated using lipid water phantoms and in vivo experiments. The results indicate that using a lower bandwidth decreases the error in the T2 estimation process while still giving good lipid water separation.

Acknowledgement: NIH grant: HL085385. **References:** [1] Chebrolu VV et al, MRM 63:849-857, 2010. [2] Yu H et al, MRM 60:1122-1134, 2008. [3] Li Z et al, MRM 61:1415-1424, 2009. [4] Altbach MI et al, MRM 54:549-559, 2005. [5] Reeder SB et al, MRM 51:35-45, 2004. [6] Hines CDG et al, JMRI 30:1215-1222, 2009.