

Respiratory Self-Gating for Free-Breathing Abdominal R2* Mapping

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INTRODUCTION

Accurate R2* measurements are critical for a wide range of applications, particularly for evaluating blood oxygen level dependent (BOLD) contrast mechanism (1,2), iron-overload measurements (3) and the in vivo quantification of SPIO-labeled cell concentrations (4). Abdominal R2* mapping requires breath-holding (BH) to avoid respiratory motion artifacts. However, overall spatial resolution and slice coverage is limited by the requisite BH duration. Alternative free-breathing (FB) methods may be necessary for gas-challenge BOLD studies that require subjects to breath gases with different oxygen concentration during imaging to produce functional contrast (1,2) and also for severely ill patients or those under sedation unable to comply with BH commands. Self-gating approaches, sampling additional k-space data for respiratory synchronization, have permitted FB acquisition of MR imaging data for both cardiovascular and abdominal applications (5,6). We recently developed a respiratory self-gated (RSG) imaging strategy for FB abdominal R2* mapping. The purpose of our study was to compare conventional BH R2* measurements to FB RSG R2* measurements in the liver and kidneys.

METHODS

3D RSG multiple gradient-recalled echo (mGRE) A 3D RSG-mGRE sequence was developed based upon a modified 3D mGRE sequence. We added a time delay of 120 μ s after the slice refocusing gradient to permit the acquisition of 8 RSG samples in the k-space center, which corresponded to the sum of all magnetization in the 3D excited slab (5,6). 10 slices (N_s) were acquired for each slab with 128 phase-encoding lines (N_{pe}), TR = 80 ms, ETL = 9 (3.4 ms spacing), FA = 30°, 5mm slices, FOV = 350 mm. All gating and imaging data were acquired continuously and reconstruction was performed retrospectively. For each phase-encoding position, 10 slice encoding steps were sampled and this process was repeated 5 times (N_r) in order to sample each k-space line at least once during the quiescent phase of the respiratory cycle, resulting in an acquisition time of T_{acc} = N_{pe} × TR × N_s × N_r = 8min 32s.

RSG reconstruction All images were reconstructed off-line using the MATLAB software package (The Mathworks, Inc., Natick, MA). The phases of 8 RSG samples were unwrapped, averaged, low-pass filtered and used as RSG signal, reflecting respiratory motion. At each echo time, RSG-mGRE images were reconstructed at expiration position according to the RSG signal. For each free-breathing dataset, a second image set (representative of conventional data averaging) was also reconstructed irrespective of respiratory position.

MR Experiments were conducted in four healthy volunteers using a 1.5T Magnetom Espree clinical MRI scanner (Siemens Medical Solutions) with a body matrix coil and spinal array for signal reception. Axial and coronal TSE images were acquired for localization. R2* measurements were performed in the coronal direction with slice encompassing both liver and kidneys. Images were acquired using 2D mGRE sequence during BH at end-of-expiration and 3D RSG-mGRE sequence during FB.

Data Analysis R2* maps were calculated by employing the non-linear Levenberg-Marquardt algorithm to fit the mono-exponential function S(TEi) = S(0) × exp(-R2* × TEi). Region of interest (ROI) was drawn in the liver parenchyma, left and right kidney medulla, excluding blood vessels, to measure the mean R2* values. Mean R2* values of the liver, left and right kidney medulla measured using BH mGRE were compared to corresponding RSG-mGRE and signal averaging measurements using a pair-wised student t-test with significant level of 0.05. All statistics were performed using SPSS (Chicago, IL, USA).

RESULTS

Our 3D RSG-mGRE approach clearly depicted respiratory motion in each volunteer study. Fig. 2 shows a portion of low-pass filtered RSG signal. Valley values (red) represent expiration positions. Fig. 3 shows T2*-weighted mGRE images at TE = 3.4 ms (first line) and 26.7ms (second line) and corresponded R2* maps (third line) from FB signal averaging (Group A), RSG (Group B) and BH at expiration position (Group C). In FB signal averaging mGRE images, the overall liver and kidney anatomy was blurred and at higher TE, the signal in the liver decayed faster compared with BH-mGRE due to the respiratory motion. 3D RSG-mGRE effectively suppressed blurring and fast signal decay caused by respiratory motion. Table 1 summarized the resulting mean R2* values of liver and kidney medulla. FB signal averaging approach significantly overestimated the mean R2* values (p < 0.01, Fig. 3(A3)). There were no significant differences between R2* measured with RSG-mGRE and BH mGRE R2* measurements (p = 0.19).

CONCLUSION

3D RSG-mGRE effectively reduced respiratory motion induced artifacts and produced accurate FB R2* maps in the liver and kidneys; 3D RSG-mGRE is a promising method for FB abdominal R2* mapping.

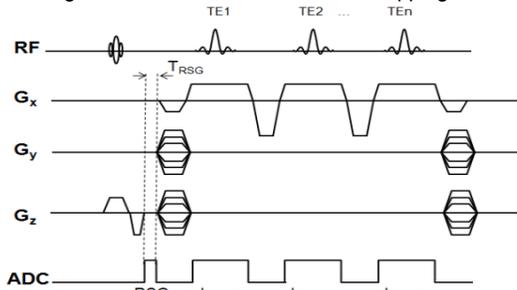


Fig. 1. Pulse sequence diagram of 3D RSG mGRE sequence. The prephase gradient on G_x and the phase-encoding gradients on G_y and G_z axes were shifted to a slightly later time to permit the acquisition of RSG data at the k-space center.

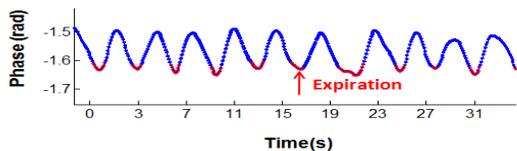
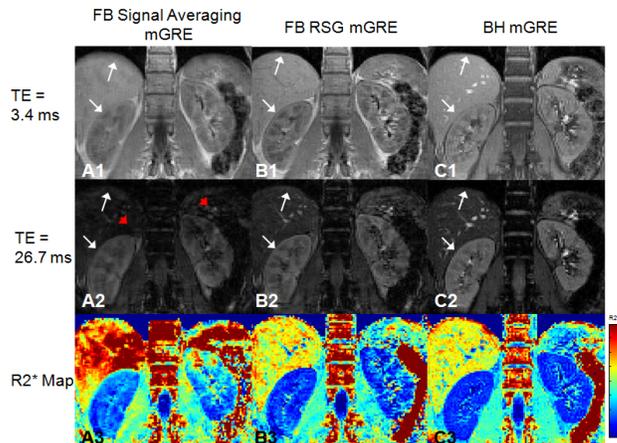


Fig. 2. RSG signal vs. time. Valley values correspond to expiration position.

Table 1. Mean R2* values.

	Liver (s ⁻¹)	Left Kidney Medulla (s ⁻¹)	Right Kidney Medulla (s ⁻¹)
BH mGRE	30.5 ± 13.2	14.2 ± 1.6	14.1 ± 2.1
FB signal-averaging	53.6 ± 23.3	57.8 ± 29.7	62.5 ± 30.5
RSG mGRE	31.6 ± 11.1	14.9 ± 2.1	15.6 ± 4.1



References:

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Fig. 3. T2*-weighted images and corresponding R2* map acquired using FB signal averaging (A), FB RSG mGRE (B) and BH mGRE (C). RSG-mGRE effectively removed respiratory induced blurring compared to FB signal averaging.