

# Respiratory Self-Gating for Free-Breathing Magnetization Transfer MRI of the Abdomen

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**TARGET AUDIENCE** Radiologists and researchers who are interested in abdominal organs.

**INTRODUCTION** Magnetization transfer (MT) MRI can be effective for the diagnosis of a broad range of diseases including liver fibrosis [1]. However, for abdominal imaging applications, respiratory motion can lead to significant image quality deterioration and inaccurate measurements. Though breath-holding (BH) is commonly employed to eliminate respiratory motion artifacts, overall slice coverage and spatial resolution are limited by the requisite BH duration. For severely ill patients or those under sedation, it can be difficult to comply with BH commands. The multiple measurements required for each MT experiment (e.g. for calculating MT ratio (MTR)) limit its application in abdominal organs. Alternative free-breathing (FB) techniques could be useful to reduce the motion artifacts [2] and avoid patient compliance issues while providing accurate MT MRI measurements with sufficient spatial coverage. In this study, we explored the potential to combine respiratory self-gating (RSG) methods with MT saturation for FB MTR measurements.

**METHODS MRI sequence:** A RSG-MT sequence was derived via the modification of a standard 2D gradient echo (GRE) sequence to permit the application of a MT pre-saturation pulse and the acquisition of both the RSG signal and imaging data during each repetition time. RSG data points were collected at  $k$ -space center before phase-encoded imaging data acquisition (Fig. 1). Compared to the phase-encoding order for the original GRE sequence with repeated acquisition of each line until all averages were collected prior to proceeding to the acquisition of the next PE line, for the RSG-MT sequence, a segmented phase-encoding method was used to acquire multiple adjacent  $k$ -space lines in order and the acquisition of these lines repeated for all averages [2]. **Volunteer studies:** Seven volunteer studies were performed using a 1.5T clinical MRI scanner (Magnetom Espree, Siemens Medical Solutions, Erlangen, Germany). A body matrix array coil and spinal array were used for signal reception. Seven healthy volunteers were enrolled (four males, three females, age:  $34 \pm 10$ , BMI:  $22.6 \pm 3.3$ ). This study was approved by the Institutional Review Board and informed consent was obtained from all volunteers. For all volunteers, the respiratory bellows device was used to approximate their respiratory rate during MR imaging. The imaging parameters for the RSG-MT sequence were as follows: TR/TE = 40/2.5 ms, flip angle (FA) = 15°, bandwidth = 400Hz/pixel, matrix =  $128 \times 128$ , slice thickness = 5 mm, field of view (FOV) =  $350 \times 350$  mm<sup>2</sup>, in-plane resolution =  $2.73 \times 2.73$  mm<sup>2</sup>, number of slices = 1. Phase lines in one segment = 32. Number of average = 8. MT saturation was applied using a Gaussian RF pulse with pulse length of 10ms, FA of 90°, and off-resonance frequency of 1.5 kHz. Total scan time is 42 seconds. MR imaging was first performed using the conventional MT-GRE sequence during BH at expiration. The typical BH-MT acquisition duration was about 14 sec. Then, another set of RSG-MT images were acquired during FB. For FB scans, volunteers were instructed to breathe evenly and consistently during the scan. High resolution RSG-MT scans were also carried out with in-plane resolution of  $1.82 \times 1.82$  mm<sup>2</sup> and acquisition time of 4.14 min. **Data analysis:** RSG-MT images were reconstructed offline using the MATLAB software (MathWorks, Natick, MA). RSG data points collected prior to phase-encoded imaging data acquisition were used to extract the respiratory signal. Phase lines acquired corresponding to RSG signal amplitudes below a local threshold were selected for inclusion in the retrospectively synchronized reconstruction. MTR maps were generated voxel-wise using the following equation  $100 \times (1 - M_{sat} / M_0)$ , where  $M_{sat}$  represents the signal intensity for image acquired following application of the MT pulse,  $M_0$  is the signal intensity of image acquired without MT saturation.

**RESULTS** Fig. 2 shows a representative segment of RSG signal recorded in one volunteer. The blue dots represent the RSG signal with signal amplitude below the local threshold corresponding to the assumed expiration position. Representative MT-weighted images acquired using BH, FB and RSG FB techniques in caudal liver positions are shown in Fig. 3a-c. Fig. 4 shows representative images without/with MT saturation with in-plane resolution of  $1.82 \times 1.82$  mm<sup>2</sup> and acquisition time of 4.14 min and the corresponding MTR map.

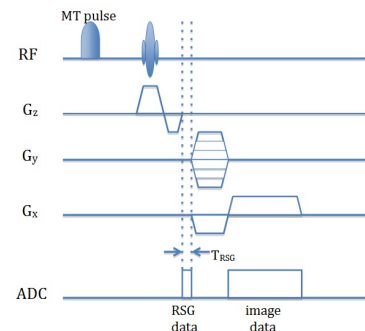


Fig. 1. RSG-MT sequence diagram: A small time delay ( $T_{Rsg}$ ) of 80  $\mu$ s was added after the slice-selective rephasing gradient. The readout pre-phasing gradient and phase-encoding gradient were shifted by  $T_{Rsg}$ .

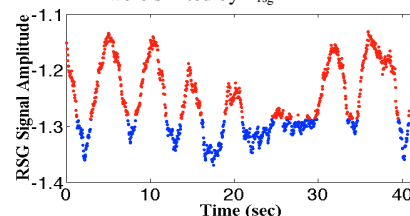


Fig. 2. A representative segment of RSG signal. The blue dots represent the RSG signal with signal amplitude below the local threshold corresponding to the assumed expiration position.

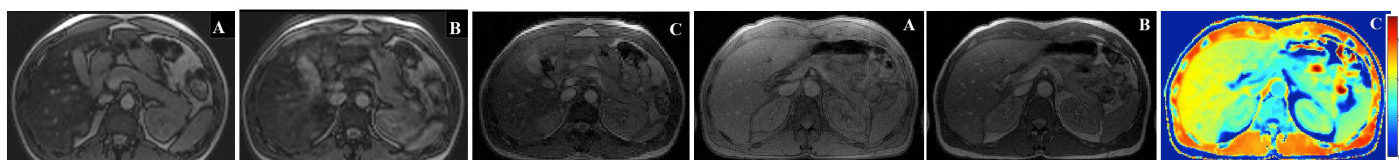


Fig. 3. MT-weighted images acquired with A) BH, B) FB, and C) RSG FB MT-GRE sequences. MT saturation pulse has a FA of 90°, length of 10 msec, and off-resonance frequency of 1.5 kHz.

Fig. 4. MR images acquired using RSG FB MT-GRE sequences and MTR maps map. A) Image without MT saturation, B) Image of the same slice with MT saturation (FA = 90°, pulse length = 10 msec, and off-resonance frequency = 1.5 kHz). C) MTR map.

**DISCUSSION** MT MRI is sensitive to motion artifacts and at least two measurements are required to generate MTR maps. Commonly used BH approaches are limited by the BH duration. The principle aim of this study was to demonstrate the feasibility of combining RSG techniques with MT-GRE sequences for accurate MTR measurements during FB. We found the FB RSG-MT method effectively reduced respiratory motion artifacts. The spatial resolution achievable with the RSG FB MT approach was not limited by BH duration. No clearly apparent motion artifacts were observed for images reconstructed from data acquired using the RSG FB MT method with scanning times of more than 4 min (shown in Fig. 4a-b). High quality MTR maps (Fig. 4c) were generated. Future studies will evaluate the application of these RSG FB MT techniques for the assessment of liver fibrosis and tumor desmoplasia in clinical settings.

**REFERENCE** [1] Rosenkrantz AB et al, Radiology, 2012 Jan;262(1):136-43. [2] Ning J. et al, Magn Reson Med. 2011 Jul;66(1):207-12.

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