

Highly Efficient Motion Corrected 3D Liver MRI from Undersampled G-RPE Acquisitions

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INTRODUCTION: Respiratory gating is commonly employed to compensate for respiratory motion in free-breathing 3D MRI of the abdomen but leads to low scan efficiency since only a portion of the acquired data is used for reconstruction. Recently, an imaging technique was proposed for a whole heart acquisition that combines data from different respiratory motion states using an image-based affine registration [1]. However, image acquisition is performed until a predefined k-space coverage is reached leading to increased scan times. Additionally, affine motion compensation cannot be applied to abdominal applications. Recently, we have exploited a free-breathing Golden Radial Phase Encoding (G-RPE) MRI acquisition [2] to form a motion model of the abdomen using a non-rigid registration algorithm [3]. Here, we propose to use such a G-RPE trajectory in combination with a motion compensated weighted averaging approach (that compensates for variations in undersampling artifacts) to obtain a motion compensated 3D MRI dataset of the abdomen in 1.1min using all the acquired data (100% scan efficiency).

METHODS: **1) Reconstruction and motion modeling:** MRI data is acquired using the G-RPE trajectory, which allows a retrospective sorting of the collected samples according to their appearance in the respiratory cycle. G-RPE combines Cartesian sampling in the read-out direction (k_z) with a radial-like pattern in the phase encoding plane (k_y, k_z). Each radial phase-encoding spoke is separated from its successor by the golden angle, $\theta = 111.25^\circ$ (Fig. 1a.) [2]. This trajectory is (a) self-gated, i.e. the respiratory signal can be derived from the centre k-space line (centre line in Fig. 1a) and (b) flexible in terms of arbitrary retrospective data combination. After deriving the respiratory signal (Fig. 1b), all of the radial spokes being acquired are combined (to achieve 100% scan efficiency) according to their appearance in the respiratory cycle (Fig. 1c). Non-Cartesian iterative SENSE [4] is applied to reconstruct N highly undersampled images I_i at N different respiratory positions P_i (exhale to inhale). Multiple non-rigid image registrations are performed [5] that are used to compute deformations I'_i of all images at a common respiratory position where they are combined to a composite image I_c (Fig. 1d) using weighted averaging. **2) Weighted averaging:** Due to variations in breathing pattern, the amount of data for each respiratory position might vary resulting in different undersampling artifacts for each I'_i . In [3] we used the maximum k-space trajectory angle α_i for each respiratory position i to predict the suitability of an image I_i for motion estimation. Here, we use α_i to estimate the amount of undersampling artifacts. We include a factor $w_i = 1/\alpha_i$ to weight the contribution of I'_i to the composite image I_c . In other words, if an image shows low undersampling artifacts (α_i is low), its contribution to the composite image shall be higher than an image with high undersampling artifacts (α_i is high). The final image is computed as: $I_c = w_i I'_i / \sum_i w_i$.

EXPERIMENTS: Ten healthy volunteers were scanned under free-breathing on a 1.5T Philips Achieva scanner using a 32 channel coil. A balanced SSFP sequence was employed with the following sequence parameters: field of view 287^3 mm^3 , resolution 1.75^3 mm^3 , $TR/TE = 3.0/1.4 \text{ ms}$, flip angle 30° . Two reconstructions from the same data set were performed: (i) the proposed motion compensated weighted averaging (MCWA) and (ii) the commonly employed gated reconstruction. For gating, a 3mm gating window was placed around the most visited end-exhale position. $N_{\text{recon}} = 258$ spokes were chosen to reconstruct an approximately fully sampled image (this means that more spokes have to be acquired to fill the exhale gate). To allow a fair comparison, the same amount of spokes were considered in our proposed MCWA method ($N_{\text{recon}} = 258$). Note that all the acquired data was used for reconstruction now to achieve 100% scan efficiency. MCWA was compared against respiratory gating in terms of apparent SNR, image sharpness and scan efficiency.

RESULTS: The distribution of $N_{\text{acq}} = 258$ spokes of MCWA with an average of 76.2 ± 10.1 spokes per bin as well as the undersampled images I_i are shown in Fig. 2 (coronal view only). The deformations I'_i are combined to form the composite image I_c using the weights w_i (indicated under each I'_i). Compared to the image from gating (Fig. 3), MCWA achieves an improvement in apparent SNR by 65% (over all volunteers), while image sharpness is slightly decreased by 14%. However, MCWA achieves nearly 100% scan efficiency (47% in gating), and time scan time was reduced to 1.1min (2.5min in gating).

CONCLUSIONS: A highly efficient 3D motion compensation technique using weighted averaging has been presented that produces images with high isotropic resolution of 1.75 mm from a short overall acquisition time of 1.1min. Compared to a respiratory-gated acquisition, we achieved nearly 100% scan efficiency, we reduced scan time by 56% and increased apparent SNR by 65%, while image sharpness was only slightly reduced. We will address this reduction in image sharpness by further optimizing the accuracy of our registration algorithm but also by investigating alternative image composition strategies.

REFERENCES: [1] Doneva et al, *ISMRM* 2011. [2] Prieto et al, *MRM* 2010. [3] Buerger et al, *ISMRM* 2011. [4] Pruessmann et al, *MRM* 1999. [5] Buerger et al, *Media* 2011.

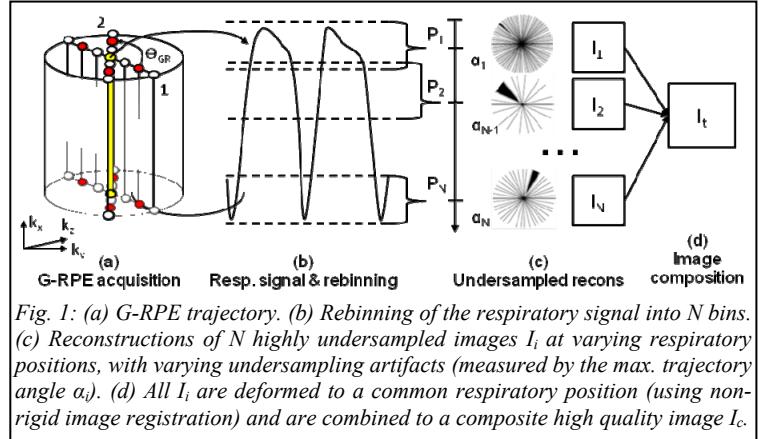


Fig. 1: (a) G-RPE trajectory. (b) Rebinning of the respiratory signal into N bins. (c) Reconstructions of N highly undersampled images I_i at varying respiratory positions, with varying undersampling artifacts (measured by the max. trajectory angle α_i). (d) All I_i are deformed to a common respiratory position (using non-rigid image registration) and are combined to a composite high quality image I_c .

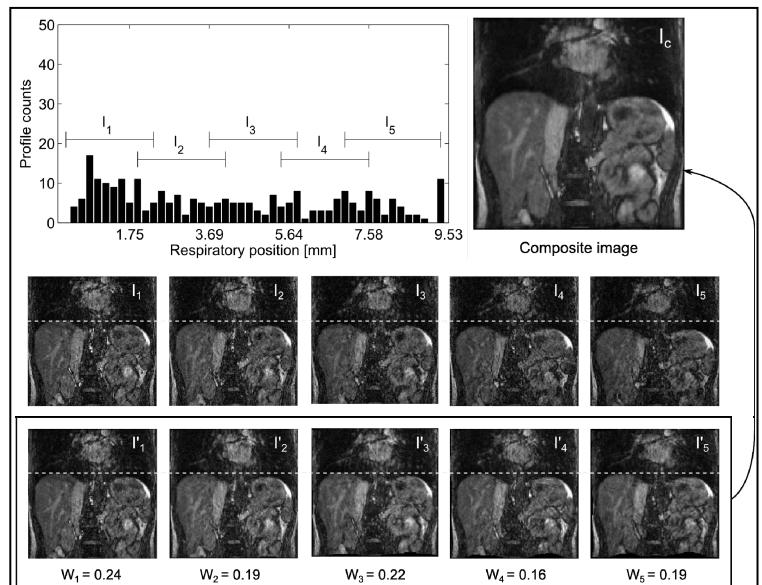


Fig 2: Volunteer 1. Distribution of the acquired spokes, reconstructions I_i from exhale (left) to inhale (right) and the deformations I'_i (at exhale) which are combined to I_c .

