Free Breathing 3D Abdominal T_1 Mapping with 3D Golden Angle Through-Time Spiral GRAPPA

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Target audience: Clinicians and MR scientists interested in quantitative abdominal MRI.

Introduction: Quantitative magnetic resonance imaging has been employed to assess liver fibrosis and monitor disease progression. High spatial resolution 3D T_1 maps can be generated using a modified Look-Locker technique in conjunction with a stack-of-spirals trajectory and parallel imaging [1]. However, breath-holding is still required to yield images free of motion artifact, and the entire dataset can be corrupted if the patient resumes breathing during the acquisition. However, by employing respiratory navigator gating, data can be collected during free-breathing and separated into respiratory bins using information from the navigator [2]. While fully-sampled data could be collected in this manner, the scan time may be long without prospective selection of the spiral arm to be acquired. Instead, a golden angle ordered spiral trajectory can be used in combination with 3D through-time spiral GRAPPA to reconstruct images from undersampled T_1-weighted data [3]. The purpose of this study was to develop an imaging technique that could produce 3D high-resolution abdominal T_1 maps during free-breathing by combining the inversion-recovery Look-Locker method, respiratory navigation, and 3D golden angle through-time spiral GRAPPA reconstruction.

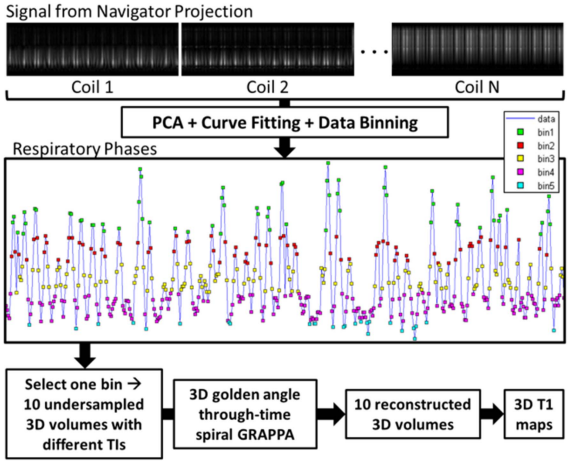

Fig. 1 Schematic of the proposed respiratory navigator, data binning, and reconstruction method.

Methods: This study is IRB compliant and all subjects provided written informed consent. Free-breathing 3D abdominal data were acquired from three volunteers on a 3T Skyra scanner (Siemens Medical Solutions, Erlangen, Germany) using a 20-channel receive array with an inversion-recovery Look-Locker sequence and golden angle stack-of-spirals trajectory. The following sequence parameters were employed: spiral arms = 48, readout points=1704, field-of-view=384 mm^2, in-plane resolution=1.5 mm, TR/TE=6/0.82 ms, slice thickness =2.5 mm, flip angle=7°, partitions=64. After an inversion pulse, all partitions for a single spiral arm were collected at 10 inversion times ranging from 200 to 2700 ms. The process was repeated 48 times with a pause of 4 sec between each to collect all spiral arms for a total scan time of 6.3 minutes. A respiratory navigator along superior-inferior (SI) direction was inserted before each inversion time. PCA was applied to the navigator to select the virtual coil with the highest signal, and the respiratory waveform was extracted by fitting the signal magnitude from inversion times 3 through 10 and interpolating to obtain the waveform over all the inversion times (Fig. 1). This waveform was divided into five respiratory bins, and data from the bin with the most measurements was selected. Because the 3D spiral data in this bin are necessarily undersampled, 3D golden angle through-time spiral GRAPPA was applied to reconstruct fully-sampled 3D volumes for each inversion time. The acceleration factor for each inversion time ranged from approximately 2 to 4. The calibration and reconstruction for the 3D through-time golden angle spiral GRAPPA are described in [3]. To validate the T_1 values, additional breath-hold data were collected as in [1] with the same parameters except TR/TE=5.92/0.74 ms, slice thickness =2.5 mm, and partitions=32.

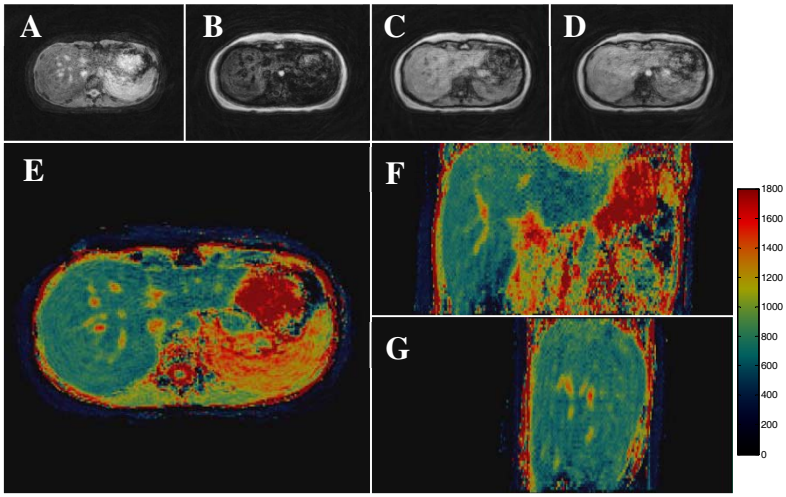

Fig. 2 (A-D) T_1-weighted images of one partition at different inversion times (218, 607, 1775 and 3332 ms) after 3D spiral GRAPPA reconstruction. (E-G) Corresponding T_1 maps in axial plane, coronal plane and sagittal plane.

Results: Figure 2 A-D shows four representative T_1-weighted images at different points along the inversion recovery curve, and a corresponding T_1 map in all three orientations (E-G) to demonstrate the 3D nature of the data acquired from a normal subject during free-breathing. Average T_1 values of different tissues from both the free-breathing and breathhold T_1 mapping methods for the three subjects are shown in Table 1, and are in excellent agreement with the literature [4].

Tab. 1 T_1 relaxation times (ms) for different tissues. Values are means ± standard deviation.

Tissues	Free-breathing T_1 (ms)	Breath-hold T_1 (ms)	Literature
Liver	778 ± 13	775 ± 23	~ 810
Kidney--Medulla	1611 ± 13	1561 ± 25	~ 1545
Kidney--Cortex	1211 ± 18	1175 ± 20	~ 1142
Muscle	1015 ± 22	1067 ± 38	898 ~ 1412
Spleen	1140 ± 81	1124 ± 80	~ 1328
Pancreas	701± 57	722 ± 36	~725

Discussion: 3D through-time spiral GRAPPA has been used previously for single breathhold 3D abdominal T_1 mapping. By including a navigator echo and using the golden angle spiral trajectory, this method can be extended to enable free-breathing 3D abdominal T_1 mapping. Free of the scan time constraint of breath-holds, a larger spatial coverage or higher spatial resolution can be achieved, allowing whole abdomen coverage, rather than organ specific coverage when acquisition is breath-hold limited. Further shortening of the scan time could be achieved by employing higher data reduction factors, up to R=6 as shown in [1]. Sicker patients who cannot hold their breath may benefit from this free-breathing abdominal T_1 mapping approach.

Conclusion: This study presents a technique for accurate 3D abdominal T1 mapping during free-breathing that combines the Look-Locker method, respiratory navigation, and 3D golden angle through-time spiral GRAPPA reconstruction.

References: [1] Chen et al. Proc. of ISMRM 2013, #5320. [2] Pang et al. MRM, 2014;72:1208-1217. [3] Lo et al. Proc. of ISMRM 2014, #5171. [4] Bazelaire et al. Radiol, 2004;230:652-659. **Acknowledgement:** NIH grants NIH/NIBIB R00EB011527, R01DK098503, 1RO1HL09455