Highly accelerated 4D radial single breathhold acquisition of the entire gastro-intestinal tract using L1 k-t SPIRiT

Vlad Ceregan[1], Jelena Curcic[1,2], Andreas Steingoetter[1,2], and Sebastian Kozerke[1]

[1]*Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland,* [2]*Division of Gastroenterology and Hepatology, University Hospital Zurich, Zurich, Switzerland*

Introduction: Functional disorders of the gastro-intestinal (GI) tract (irritable bowel syndrome (IBS), dyspepsia, constipation), and also metabolic diseases such as type II diabetes and obesity are often accompanied by changes in motor activity of the GI tract, resulting in irregular nutrient and also drug absorption patterns and frequent abdominal symptoms. Therefore, a detailed understanding of the impact of GI motor function on nutrient and drug digestion, transport and absorption is of great importance. MRI has already been used for studying different functions of the GI tract and its non-invasive nature represents a crucial advantage over traditional methods such as endoscopy and manometry. However, due to the complex 3D geometry of the GI tract, and its irregular peristaltic motion, studies of GI functions still remain challenging. To achieve a temporal resolution of around 1s for resolving complex transport mechanisms in 3D, the data acquisition process needs to be highly accelerated. For this purpose L_1 k-t SPIRiT was implemented to acquire dynamic 3D data sets of the entire abdominal cavity within a single breath hold.

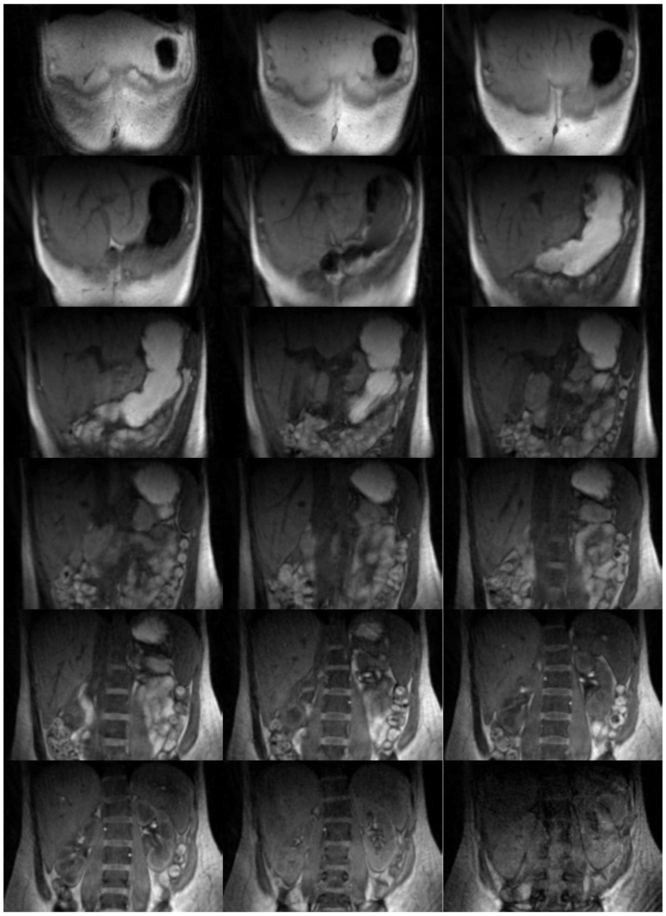

Figure 1: *Slices of the 3D volume covering the entire GI for a single time frame reconstructed with L_1 k-t SPIRiT. Contraciton patterns of the stomach are well visualized.*

Methods: Radial k-t SPIRiT [1] has been demonstrated to outperform k-t GRAPPA [2] and SPIRiT [3] for time-resolved imaging. However, when tackling acceleration factors higher than 10, k-t SPIRiT needs to be combined with compressed sensing. For this purpose the k-t SPIRiT formalism was extented to yield the following minimization problem: $\boldsymbol{argmin}_{x}\{\|\boldsymbol{Dx}-\boldsymbol{y}\|_2^2+\boldsymbol{\lambda_1}\|(\boldsymbol{G}-\boldsymbol{I})\boldsymbol{x}\|_2^2+\boldsymbol{\lambda_2}\|\boldsymbol{\psi_1 x}\|_1+\boldsymbol{\lambda_3}\|\boldsymbol{\psi_2 x}\|_1\}$. The L_2 terms represent the standard SPIRiT/k-t SPIRiT algorithm where D is the non-uniform Fast Fourier Transform (NUFFT) operator, y represents the undersampled k-space data, x is the image space data and G represents the k-t SPIRiT kernel. $\boldsymbol{\psi_1}$ and $\boldsymbol{\psi_2}$denote temporal total variation (tTV) and temporal Fast Fourier transform (tFFT). In vivo experiments on three volunteers were conducted on a 1.5T scanner (Achieva, Philips Healthcare, Best, The Netherlands) with a 32-element cardiac coil array which was compressed to 8 virtual coils [4].The volunteers received a 400 mL 10% glucose solution with 800 µL DOTAREM® to increase GI contrast with respect to the surrounding tissue. The data were acquired with a spoiled gradient echo sequence, TR/TE=3.66/1.5ms, flip angle=10°, FOV=360x360x108mm^3, voxel size=1.8x1.8mm^2, slice thickness=6mm. The undersampling pattern consisted of a stack-of-stars trajectory with the golden angle profile pattern [5,6]. 21 profiles for each slice at each dynamic were acquired leading to a radial undersampling factor of 15. The acquired volume consisted of 18 slices resulting in a temporal resolutions of 1400 ms. This temporal resolution is required to permit the visualization of the stomach's peristaltic contractions which reoccurs every 20s and progress by ~3 mm/s. Data were acquired during a breath hold of 30s. A radiologist inspected the images grading the image quality according to: 1 = nondiagnostic, 2 = poor, 3 = adequate, 4 = good, and 5 = excellent. For each volunteer a fully sampled radial 3D acquisition was used as reference. The relative signal-to-noise ratio (SNR) was computed for the reference and reconstructed images of the stomach, small intestines, large intestines and the liver regions. The entropy of the edge filtered images was used to compare the sharpness of the reconstructed images with the sharpness of the reference.

	Stomach	Small intestines	Large Intestines	Liver
Reference	17.0±1.0	13.5±0.8	15.4±0.8	15.7±0.7
Reconstruction	16.6±0.8	12.8±1.2	14.9±1.1	14.9±1.1

Table 1: Mean and standard deviation of the relative SNR in dB for the reference and the reconstructed images.

Results: Figure 1 shows 18 slices of the reconstructed volume for a single time frame. Visual scoring was 3.8±0.4. Contraction waves were found to traverse the distal stomach every 20 seconds. The gradient entropy of the reference data sets was 0.46±0.01, while the values for the reconstructed data were 0.43±0.01. Table 1 shows the computed relative SNR for the reference and reconstructed images.

Discussion: A method which allows the acquisition of time-resoved 3D data of the entire GI tract within a single breathhold has successfully been implemented. Oral administration of a paramagnetic contrast agent was required to increase intraluminal contrast. The reconstruction quality i.e. SNR and image sharpness were sufficient to allow detection and extraction of gastric peristaltic activity. However, to quantify small intestinal peristalsis the use of a small bowell distension strategy [7] needs to be considered.

References: [1] Santelli C et al. MRM 2014;72:1233-1245
[2] Huang F et al. MRM 2007;57:1075-1085
[3] Lustig M et al. MRM 2010;64:457-471
[4] Buehrer M et al. MRM 2007;57:1131-1139
[5] Feng L et al. MRM 2013;70:64-74
[6] Chan R et al. MRM 2012;67:363-377
[7] Froehlich JM et al. JMRI 2005;21:370-375