High Spatiotemporal Dynamic Contrast-Enhanced MRI of the Small Bowel in Active Crohn's Terminal Ileitis using Compressed Sensing, Parallel Imaging, and Golden-Angle Radial Sampling

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Purpose: Morphologic evaluation of dynamic-contrast enhanced (DCE) T1-weighted imaging has an established role in assessing active bowel inflammation in patients with Crohn's disease [1,2]. Recent studies have investigated the role of high temporal resolution perfusion weighted imaging (PWI) to assess the degree of bowel-wall inflammation and possibly guide treatment and patient management. Current DCE-MRI acquisition protocols require trade-offs between temporal resolution, volumetric coverage, and spatial resolution. Furthermore, protocols with high temporal resolution require additional contrast injection for morphologic clinical interpretation, as dynamic high temporal resolution images usually lack suitable spatial resolution and SNR for morphologic assessment. To overcome these limitations, our group has developed a novel acquisition and reconstruction method that combines compressed sensing and parallel imaging for golden-angle radial trajectories called GRASP (Golden-angle RAdial Sparse Parallel) [3,4]. With GRASP, dynamic k-space data is acquired continuously during free-breathing and can be reconstructed retrospectively with flexible temporal resolution by grouping different numbers of consecutive spokes in each single-dynamic frame. The purpose of this study is to assess the feasibility of applying GRASP acquisition to provide morphologic as well as perfusion information simultaneously from a single acquisition in patients with known Crohn's disease.

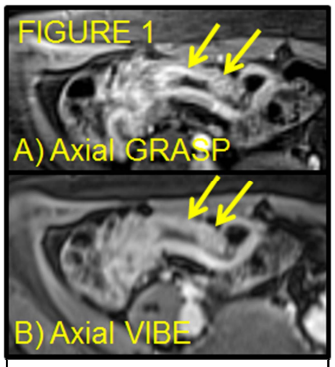
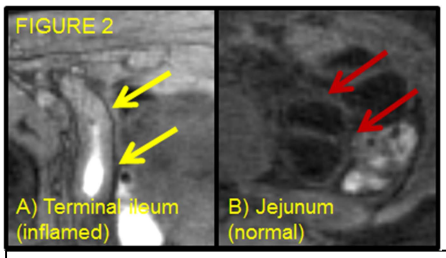


Fig. 1: Morphologic GRASP images (A) and VIBE images (B) in a patient with active terminal ileitis (yellow arrows in both A and B).

Methods: In this retrospective, IRB approved study, 7 patients (4 M / 3 F, mean age of 27 years) with a clinical diagnosis of Crohn's disease who underwent magnetic resonance enterography (MRE) with active inflammation of the terminal ileum were included. GRASP imaging was performed during injection of IV contrast (Magnevist, Bayer Healthcare) using a fat-suppressed radial "stack-of-stars" 3D GRE sequence with golden-angle ordering (TR 4.08 ms, TE 1.65 ms, FA 12°, slice thickness of 3.0 mm over 160 slices with a matrix of 256 x 256). 400 radial spokes were acquired continuously over 120 seconds. Patients were injected with 1 mL of glucagon prior to GRASP imaging per clinical protocol to minimize bowel peristalsis. Dynamic GRASP images were reconstructed offline using a C++ implementation of the algorithm, grouping consecutive 8 spokes into one dynamic frame, which results in a temporal resolution of 2.4 seconds per volumetric coverage of the abdomen and pelvis. Using in-house DCE-MRI analysis software, regions of interest were drawn over a segment of inflamed terminal ileum and over the mucosa/wall of a normal loop of jejunum, and time/normalized signal intensity (SI) curves were generated for both the inflamed and normal loops of bowel. Time-to-peak (TTP), maximum slope, and area under the curve (AUC) were calculated. An additional region of interest was drawn in a distal branch of the superior mesenteric artery to derive an arterial input function (AIF). Using the AIF and time/SI data, DCE perfusion parameters (K_{trans} and V_e) were calculated. This was feasible in 5 subjects. In addition, a radiologist scored the image quality of post-contrast morphologic GRASP images and Cartesian VIBE images, which were acquired as part of the clinical exam protocol during breath-holding.

Results: Morphologic GRASP images were rated as having higher score for overall image quality relative to BH Cartesian images (4.0±0.8 versus 3.4±0.5; p=0.03, Fig. 1). There was a significant difference in several DCE parameters (Table 1), including AUC (p< 0.0001), slope (p=0.0005), and V_e (p=0.005). Time to peak and K_{trans}, although higher in inflamed TI, did not reach statistical significance (p=0.50 and 0.27, respectively), likely due to the small sample size in this pilot study.



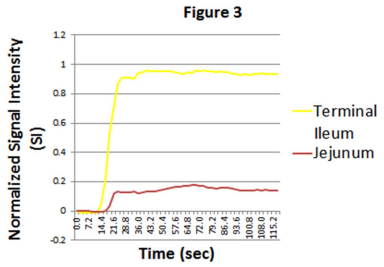


Fig 2: Pre-contrast fat-saturated T1-weighted MRI shows a thickened and inflamed loop of terminal ileum (TI; yellow arrows in A) and a normal loop of jejunum (red arrows in B) in this patient with a clinical diagnosis of Crohn's disease.

Fig 3: Time/normalized SI curve in the same patient demonstrates a more rapid rise in SI and a higher sustained peak SI (with increased AUC) after contrast administration in the inflamed TI (yellow) relative to the normal jejunum (red)

Discussion and Conclusion: This proof-of-concept study demonstrates that a single GRASP acquisition can be used to simultaneously provide morphologic and perfusion information. Thus, perfusion metrics can be generated in every patient undergoing contrast-enhanced MR imaging of the abdomen for Crohn's disease. This will provide a tool to investigate whether these perfusion parameters can be used to predict the course of disease and response to treatment.

Table 1: comparison of DCE-MRI parameters in normal and inflamed bowel in Crohn's disease

	Normal bowel	Inflamed TI	p-value
AUC	35.3±13.4	91.1±9.4	< 0.0001*
Slope	8.7±5.9	20.1±8.7	0.0005*
TTP	40.0±5.4	45.1±15.8	0.50
K_{trans}	0.5±0.5	4.0±7.4	0.27
V_e	0.27±0.14	0.49±0.15	0.005*

References:
[1] Oto et al *JMRI* 2011; 33(3):615-624.
[2] Rottgen et al *Clin Imaging* 2010; 34:29-35.
[3] Chandarana et al *Invest Radiol* 2013; 48:10-16.
[4] Feng et al *MRM* 2013; early view.