Variable Refocusing Flip Angle Single-Shot Fast Spin Echo of the Bowel, Initial Experience

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Target Audience: Physicians and scientists interested in bowel imaging, fast spin echo, and modulated refocusing techniques.

Purpose: There are a number of clinical indications for MR imaging of the bowel, such as inflammatory bowel disease, where the appearance of wall-thickening and/or edema can play a significant role in diagnosis and follow-up. Bowel imaging is challenging for a variety of reasons, including peristalsis, respiration, intraluminal flow, and the existence of gas-tissue interfaces [1]. Balanced steady state techniques (FIESTA or true FISP) and single-shot fast spin echo (SSFSE or HASTE) are typically utilized for rapid T2-weighted imaging of the bowel. Balanced SSFP is the generally preferred method for its high signal-to-noise efficiency, robustness to motion, uniform intraluminal signal, and in spite of its T2/T1-weighted contrast, and tendency to exhibit off-resonance artifacts such as banding and in-phase/out-of-phase cancelation of water and fat signal. Though SSFSE is relatively immune to off-resonance effects, and typically provides more T2-weighted contrast, it suffers from strong blurring due to T2 signal decay, among other limitations. SSFSE with variable refocusing flip angle (vrf), however, may offer several advantages over conventional SSFSE with static refocusing flip angles, including improved sharpness, due to reduced T2 signal modulation, and reduced SAR, allowing shorter breath-holds and/or greater slice coverage [2]. The purpose of this work was to establish the feasibility of using vrfSSFSE for MR imaging of the bowel.

Methods: Imaging was performed on a 60-cm bore 3.0T MRI scanner (MR750, GE Healthcare, Waukesha, WI) using a 32-channel torso array. Following informed consent, breath-held images of the bowel were acquired in a normal volunteer, lying prone, after drinking approximately 1 liter of water, with the vrfSSFSE pulse sequence and the following parameters: coronal oblique, TR = 1000 ms, TE = 90 ms, FOV = 46 x 41.4 cm, 4 mm slice, 0.5 mm gap, 320 x 224 matrix, ±125 kHz bandwidth, 3x acceleration (ARC, GE Healthcare, Waukesha, WI), 0.58 effective NEX. Refocusing flip targets [3], were 130, 60,100 and 100 degrees, respectively. For comparison, images were also acquired with a typical clinical SSFSE enterography protocol using the following parameters: minimum TR = 1271 ms, TE = 80 ms, FOV = 46 x 41.4 cm, 4 mm slice, 0.5 mm gap, 512 x 256 matrix, ±83.3 kHz bandwidth, 2x acceleration (ARC), 0.53 effective NEX. Images with adiabatic fat suppression were also acquired, as is routine in clinical practice.

Results & Discussion: Figure 1 demonstrates a striking improvement in the visualization of the small bowel and mesentery (a-d) for vrfSSFSE, exhibiting sharpness that is typically lacking in conventional SSFSE images. Similar improvement is seen in the fat-suppressed vrfSSFSE image of large bowel (Figure 1e vs. 1f). It is worth noting the appearance of improved resolution in the vrfSSFSE images in spite of the lower relative imaging matrix. Image quality is also improved for vrfSSFSE in spite of the reduced scan time. Without the SAR limitation of high static refocusing flip angles, vrfSSFSE offers more flexibility to the user to trade SNR for imaging speed and/or improved slice coverage. As noted in prior works, intermittent signal voids due to cardiac motion may be observed in the upper abdomen with vrfSSFSE, which is most easily mitigated with cardiac gating [4,5]. The shorter repetition times achievable with vrfSSFSE, mean that gating can also be accomplished more efficiently than with conventional SSFSE.

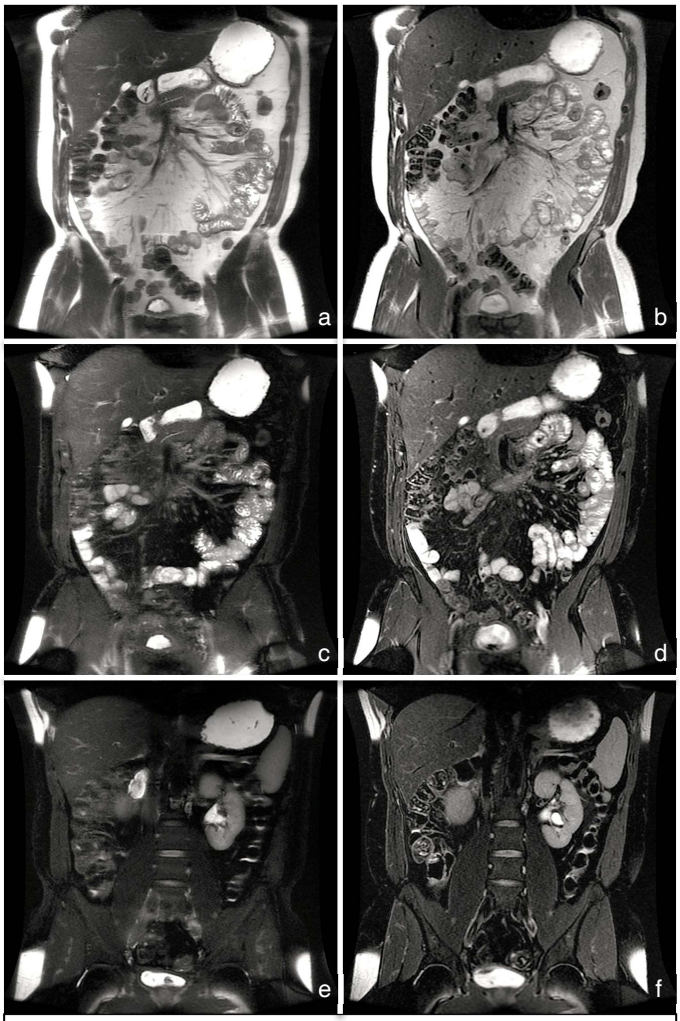

Figure 1: Conventional SSFSE (left) vs. vrfSSFSE (right). Representative coronal section of the small bowel (a,b), and with adiabatic fat-suppression (c,d), demonstrating marked improvement in the visualization of the bowel wall and mesentery for vrfSSFSE (b,d) vs. static refocusing (a,c). Representative fat-suppressed section of the large bowel (e,f), showing a similar improvement in visualization for vrfSSFSE in spite of the extensive gas-tissue interface.

Conclusions: These initial findings demonstrate the potential for variable refocusing flip angle SSFSE to increase the sharpness and speed of SSFSE for MRI of the bowel, improving the utility of SSFSE for MR enterography and other bowel imaging applications. In addition, we expect these benefits will readily extend to multi-phase and real-time MR fluoroscopic applications employing SSFSE.

References: 1. Lomas DJ. Eur Radiol. 2003, May;13(5):1058-71. 2. Saranathan M, Loening AM, Litwiller DV *et al.*, ISMRM, Milan, 2014, #2175. 3. Busse R, Brau AC, Vu A, *et al.*, MRM, 2008 Sep;60(3):640-9. 4. Madhuranthakam AJ, Busse R, Brittain JH, *et al.*, ISMRM, Berlin, 2007, #2523. 5. Litwiller DV, Holmes JH, Saranathan M, *et al.*, ISMRM, Milan, 2014, #1613.