CT-like 3D Isotropic Fat-Suppressed Dynamic Contrast Enhanced MR Enterography

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INTRODUCTION: Crohn's disease is an inflammatory condition that affects predominantly the small bowel in young individuals. Crohn's disease patients have recurrent flares requiring repeated imaging studies to assess the degree of inflammation and complications such as strictures, fistulas, and abscesses. While fluoroscopy and CT are frequently used, repeated exposure to ionizing radiation is a concern. MR Enterography (MRE) is emerging as a suitable alternative due to lack of radiation and excellent sensitivity to detect mucosal inflammation in the bowel. MRE protocols often include 3D coronal dynamic contrast-enhanced (DCE) images of the abdomen and pelvis. Because these patients may be debilitated, imaging with their arms above their head, so that to reduce the acquired left-to-right (LR) FOV and thus speed up the scan, is not always possible. Clinical DCE MRE with the patient's arms down is challenging as it requires simultaneous: (1) imaging the entire abdomen and pelvis with high resolution in a single breath-hold, and (2) excellent fat suppression. To address these challenges we combine: (a) massive parallel imaging acceleration in two directions with (b) aggressive reduction of the LR FOV without wrap-around from structures outside of FOV (e.g. subcutaneous fat, the arms). This is achieved with suppression of out-of-FOV signals by combining sagittal 3D excitation for coronal imaging with custom-designed minimum-phase excitation RF pulses having near-zero stopband excitation. These minimum-phase RF pulses allow, even at high resolution, for shorter TEs such that the mathematical conditions for proper fat-water reconstruction via mDIXON are maintained. Using these strategies we achieve high-resolution fat-suppressed 3D isotropic, *CT-like* MRE images that can be reformatted in any plane.

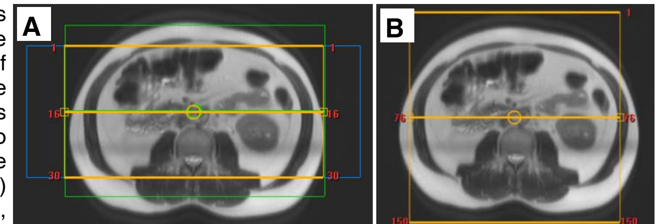

Fig.1. (**A**) Standard planning requires larger LR FOV to include the arms (blue outline). (**B**) Tight LR planning with mATISSE.

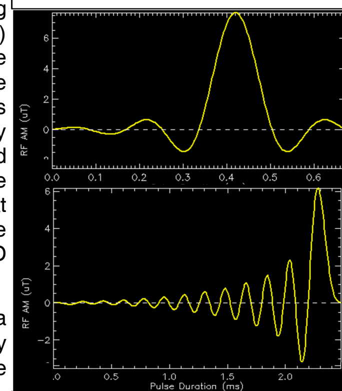

Fig.2. (Top) Standard excitation RF pulse. (Bottom) Minimum-phase RF pulse used in mATISSE.

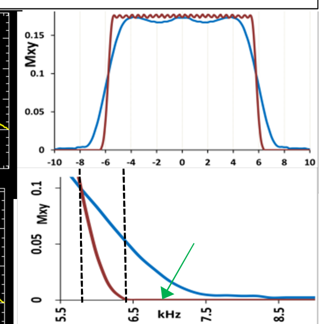

Fig.3. (Top) Excitation profiles of the standard (blue) and min-phase (red) pulses. (Bottom) Sharp transition band (dashed-lines) and zero-stopband (green arrow) for min-phase pulse.

METHODS: Experiments were performed in a 1.5T wide-bore (70 cm) Ingenia scanner (Philips Medical). We capitalized on the speed and fat-suppression ability of chemical-shift based gradient echo acquisition (3D FFE mDIXON) [1] to generate 3D coronal DCE MRE of the entire abdomen and pelvis within a single breath-hold. The Dixon fat-water decomposition approach does not prolong scan time and is unaffected by B_0 inhomogeneity, resulting in uniform fat suppression throughout large FOVs. To avoid foldover artifacts from arms outside the FOV (i.e. resting on each side of the abdomen) we have combined two approaches: (1) ROSE (Rotated Slab Excitation) sequence [2], in which 3D volume is encoded in the coronal plane while volume excitation is switched from AP to RL direction (sagittal excitation); and (2) Minimum-phase RF excitation pulses with sharp transition band and zero stopband excitation (Fig. 2, 3). This combination allows for volume selection that excludes the arms and parts of the subcutaneous fat while keeping high SENSE acceleration factors LR and AP. This **m**DIXON **A**cquisition for **T**orso **I**maging with **S**elective **S**agittal **E**xcitation (**mATISSE**) provides high-resolution, homogenously fat-suppressed acquisitions of the abdomen and pelvis with a FOV tightly adjusted to the torso, free of foldover artifacts. Other imaging parameters were as follows: 3D mDIXON with 2 echoes, LR FOV 300 (cuts into the subcutaneous fat), SENSE 3.7(LR)x1.7(AP) (thus only 16% of k-space is acquired, allowing for the high-resolution acquisition to fit in a 19s breath hold); TR/TE1/TE2 7.2/1.46/3.5ms; near true-isotropic acquired resolution 1.8x1.8x2.2 mm; overcontiguous slices reconstructed to 1.1 mm; The standard DCE MRE of our clinical protocol (1.8x1.8x4.0 mm, 16s BH) was acquired with arms up, followed by mATISSE, which was acquired with arms down, a few minutes later.

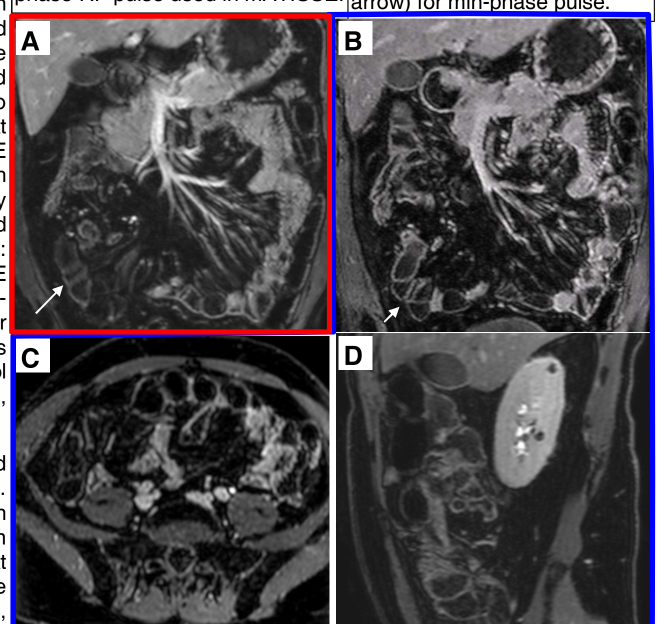

Fig.4. (**A**) Standard DCE MRE (slice **4.0mm**; BH 16s) (**B**) High-res. (slice **2.2mm**; BH 18.6s) mATISSE MRE with improved bowel wall visualization (arrows). Lower contrast enhancement on mATISSE is due to a delayed acquisition after injection. (**C**)(**D**) Axial and sag. reformats of the cor mATISSE show *CT-like* reformatting capability.

RESULTS AND DISCUSSION: **mATISSE** speeds up the scans by allowing for reduced RL FOV planning (1B) as compared to the **standard 3D mDIXON** planning (1A). Optimized sagittal volume excitation profile (RF pulses with sharper transition bands and near-zero stopband modulation, Figs. 2, 3) can completely avoid arm excitation. However, these longer pulses result in extension of the minimum TE that may violate the requirements of mDIXON for the use of certain out- and in-phase echo times. We utilized minimum-phase pulses with improved excitation profiles, while still allowing for the first minimum TE to be out-of-phase. Fig. 4 shows improved bowel wall delineation on the high-resolution mATISSE (4B) as compared to the standard 3D mDIXON (4A). Excellent out-of-FOV signal suppression and robust fat-water separation is seen when using this strategy. Importantly, the near-isotropic resolution allows for *CT-like* reformatting of the original acquisition in arbitrary planes (Figs. 4C, 4D). **REFERENCES:** [1]. Eggers H., et al., *MRM* 65(1):96, 2011 [2]. Brau A. et al., *ISMRM* 16, 502, 2008.