Balanced Steady-State Free Precession Abdominal Imaging Using Two-point Dixon Fat/Water Decomposition

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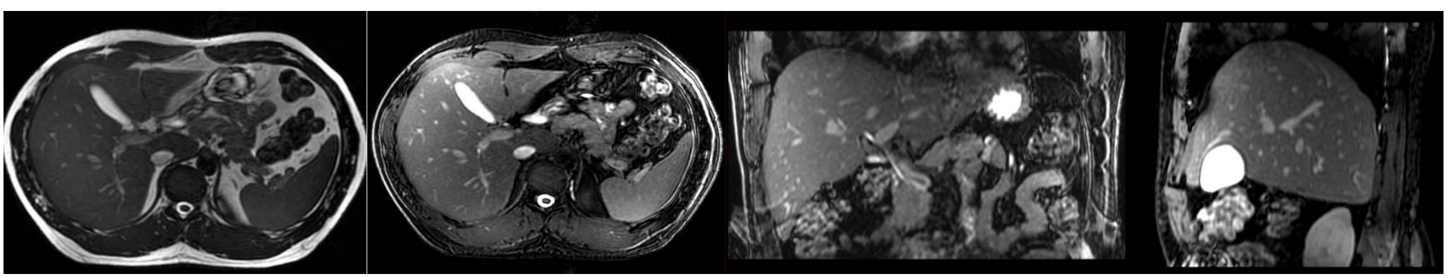
INTRODUCTION: Fully balanced coherent steady-state free precession (SSFP) techniques such as FIESTA, b-SSFP, true-FISP etc. yield high signal in short scan times and have found applications in abdominal MRI for visualizing liver vasculature, biliary and small bowel imaging. Balanced coherent steady-state sequences are very sensitive to B_0 inhomogeneities, manifesting as banding artifacts due to signal cancellations. Robust fat suppression is also problematic particularly at 3T. Magnetization preparation and signal saturation based fat suppression methods perform suboptimally due to their sensitivity to B_0 and B_1 inhomogeneities, causing non-uniform fat suppression across the image and compromising the steady state. We report a new technique that combines fully balanced steady-state free precession scan with a two-point Dixon fat-water reconstruction algorithm [1] to generate high resolution fat-only and water-only image within breath-hold times.

METHODS AND MATERIALS: A 3D dual echo bipolar readout fully balanced steady-state free precession pulse sequence followed by 2-point Dixon fat-water reconstruction algorithm [1] was developed. Dixon methods have been investigated before with 2D SSFP, but without bipolar implementation, scan times were doubled [2]. A 3D bipolar implementation uses the shortest possible opposed-phase and in-phase echoes, minimizing TE/TR and consequently, reducing banding artifacts and scan times. The 2-point Dixon based fat-water decomposition ensures robust fat suppression independent of field strength and eliminates the need for a fat suppression pulse and the associated interruption of steady state. After obtaining informed consent, healthy volunteers were scanned on a 3T scanner (Discovery® MR750, GE Healthcare, Waukesha, WI) using an 8-channel torso coil, auto-calibrated 2x1 acceleration [3] and partial Fourier factor of 70%. Opposed-phase and in-phase TE values were 1.2ms and 2.4 ms, respectively resulting in 3.8ms TR. Frequency direction matrix size is intentionally kept lower than phase encode direction to keep the TR under 4ms and minimize banding artifacts. This is due to the fact that dual echo bipolar readout effectively collects twice the prescribed frequency resolution per TR.

RESULTS and DISCUSSION: Figure 1 is the high-resolution scan matrix of 224x288x78. It was acquired in 29 seconds and yielded 1.9x1.2x2.8 mm^3 acquired and 0.8x0.8x1.4 mm^3 reconstructed resolution after zero-padded interpolation. Image A is the acquired in-phase echo in native axial plane, which could be used as the non-fat suppressed SSFP image. Image B is the synthesized water-only native axial slice, and C and D are the corresponding coronal and sagittal reformats, respectively. Note the high contrast between soft tissue and vascular structures, the anatomical details and the uniformity of the fat suppression. Figure 2 demonstrates the clinical utility of the 2-point Dixon SSFP images via maximum intensity projection (MIP). Image A is a MIP demonstrating the MR cholangiopancreatography (MRCP) capability. Image B and C are the MIP demonstrating the portal venous system visualization capability. Shorter scan times could be achieved via resolution compromise or increased acceleration. For instance, lowering the resolution in slice direction with a scan matrix of 224x288x56 resulted in a more acceptable 21 second scan time and yielded 1.9x1.2x4.0 mm^3 / 0.8x0.8x2.0 mm^3 acquired / reconstructed resolution.

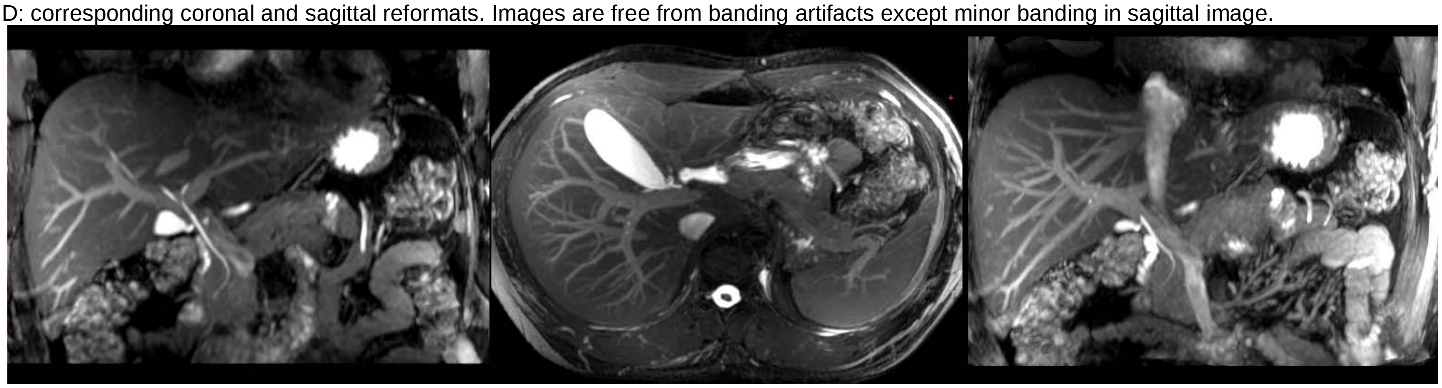
CONCLUSION: The proposed dual-echo bipolar fully balanced SSFP acquisition with a 2-point Dixon-based fat-water separation method yields excellent fat suppression, high SNR, excellent visualization of the vasculature. Despite of dual-echo acquisition, this novel sequence maintains sub-4ms TR values to minimize banding artifacts. The acquired in-phase and opposed-phase images along with the water and fat images could be used for a perfectly registered, non-fat suppressed contrast within single SSFP acquisition

REFERENCES: 1) Ma et al. MRM. 52:415-419 (2004) 2) Huang et al. MRM 51:243–247 (2004) 3) Beatty et al. Proc ISMRM, p1749 (2007)



A B C D

Figure 1: High-resolution 2-point Dixon SSFP scans. A: Acquired in-phase echo in native axial plane. B: Synthesized water-only image. C and D: corresponding coronal and sagittal reformats. Images are free from banding artifacts except minor banding in sagittal image.



A B C

Figure 2: A: MIP showing MRCP capability. B and C: MIPs showing portal venous system in native and coronal plane, respectively