Free-breathing Artifact-free Liver Imaging at 3T Incorporating Phase-cycled TrueFISP and Motion Correction

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Target Audience: Clinicians and researchers with interest in high-resolution, free-breathing liver imaging at 3T.

Purpose: TrueFISP sequence allows fast liver imaging at 1.5T with good image quality [1]. Its application at 3T has been challenged mostly by increased banding artifacts from phase dispersion. Multiple phase-cycling acquisitions have shown to eliminate TrueFISP banding artifact in stationary tissues [2 – 3]. For liver imaging, motion (breathing, suboptimal breath-hold) must be addressed in order to using such a phase-cycling method. In this study we sought to develop a robust free-breathing liver imaging method at 3T using TrueFISP. Alternate phase-cycling scheme and non-rigid motion correction were incorporated to eliminate off-resonance artifact, to improve SNR and to compensate breathing motion.

Methods: As illustrated in Fig. 1, multi-slice 2D images were repetitively acquired using a prototype single-shot TrueFISP sequence with altered phase-cycling scheme from one repetition to another. Images from multiple repetitions underwent non-rigid motion correction [4] before slice by slice averaging. Simulation: Blood signal intensity vs. phase error was simulated with flip angle (FA) and number of phase-cycling schemes as input variables. Furthermore, blood-liver contrast was simulated to determine the optimal FA. Parameters for simulation included: blood T1/T2 = 1932/275 ms; liver T1/T2 = 812/42 ms [5], other parameters were matched to those used for in-vivo imaging. Volunteer study: Three healthy volunteers were scanned on a 3T clinical scanner (MAGNETOM Prisma, Siemens) using an 18-channel body array coil and a 32-channel spine array coil for signal reception. Imaging parameters included: TR/TE = 5.0/2.5 ms; FA = 80°; FOV = 340 x 340 mm^2 with additional 50% phase-oversampling; matrix size = 336 x 336; 20 slices; acquisition resolution =1.0x1.0x5.0 mm^3; parallel imaging (GRAPPA) acceleration factor of 4; 4 measurements with 0, 90, 180, and 270 degree phase cycling; total scan time 2:04 minutes. Original images, motion corrected images and averaged images were reconstructed on the standard scanner in-line image reconstruction system.

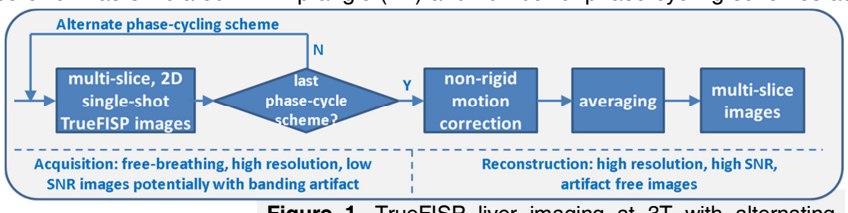

Figure 1. TrueFISP liver imaging at 3T with alternating phase-cycling and with non-rigid motion correction.

Results: Simulated blood signal at different FA is shown in Fig. 2a. Improved blood signal intensity and reduced signal variation are expected by using an 80° FA. Fig. 2b shows that by averaging signals from four phase-cycling schemes, homogeneous blood signal intensity is achieved independent from local phase errors. Fig. 2c demonstrates that highest blood-liver contrast is expected at around 80° FA.

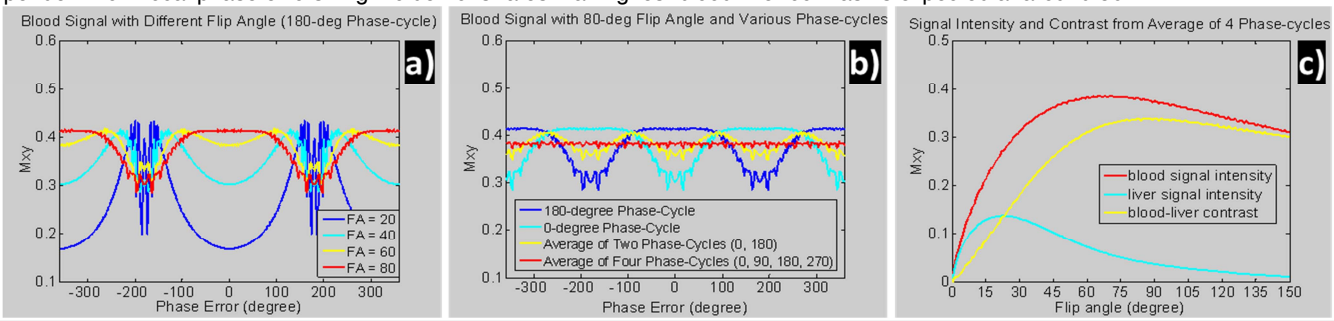

Figure 2. Simulation results of **a)** blood signal vs. phase error at different FA with fixed (180°) phase-cycling scheme; **b)** blood signal vs phase error using single (0° or 180°), average of two and four phase-cyclings; **c)** blood, liver signal intensity and their contrast from averaging four phase-cyclings.

Representative images from one slice are illustrated in Fig. 3. The presence of banding artifact is apparent in individual phase-cycling schemes (Fig. 3a – d). Direct averaging of phase-cycled images eliminates banding artifacts, but blood vessels are blurred (Fig.3 e and g). By performing non-rigid motion correction before averaging, breathing motion is compensated and the image sharpness is preserved (Fig. 3 f, and h).

Discussion and Conclusions: A moderate TR (5 ms) is used in this study that allows high readout matrix size and low energy RF pulse in order to optimize spatial resolution and imaging contrast. By incorporating phase cycling and motion correction, it is feasible to acquire artifact-free liver images at 3T under free-breathing. Further validation in patients is warranted.

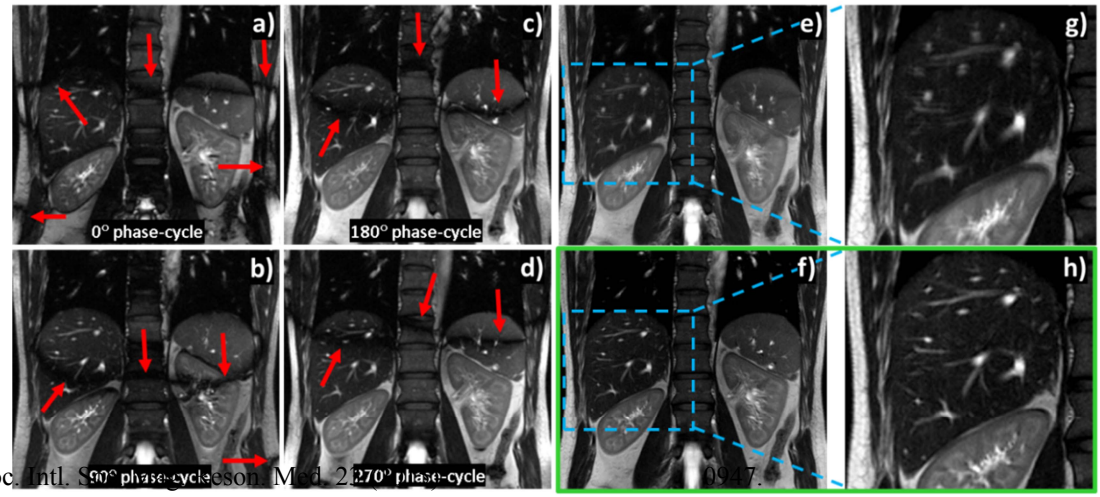

Figure 3. Representative images of one slice acquired with **a)** 0, **b)** 90, **c)** 180, and **d)** 270-degree phase-cycling scheme. Images after direct averaging (**e** and **g**) and after motion-corrected averaging (**f** and **h**) are shown. Banding artifacts (red arrows) were effectively removed after averaging and sharp images (green box) were acquired using the proposed technique.

References.

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