Respiratory navigator-triggered, multi-slice turbo spin echo with motion-sensitized driven equilibrium prepulse: a novel sequence for black-blood T$_2$-weighted imaging of liver

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Introduction Fat-suppressed (FS), T2-weighted (T2w) imaging is an important sequence for the detection and characterization of focal liver lesions by MRI. Excellent image quality can be obtained with respiratory-triggered, multi-slice (MS) turbo spin echo (TSE) sequences. Furthermore, black-blood (BB) T2w imaging can increase lesion conspicuity by removing intravascular signal.[1] However, black-blood liver imaging is typically performed with echo-planar imaging (EPI) readout, which can lead to detrimental image distortions. In this study, a novel imaging sequence was implemented to evaluate black-blood, FS, T2w imaging using a standard MS TSE readout for improved image quality.

Method All imaging was performed on a 1.5T Achieva with release 2.6 software (Philips Healthcare, Best, the Netherlands) using a 16-element SENSE Torso Coil. The sequence is illustrated in Figure 1. Respiratory-triggering
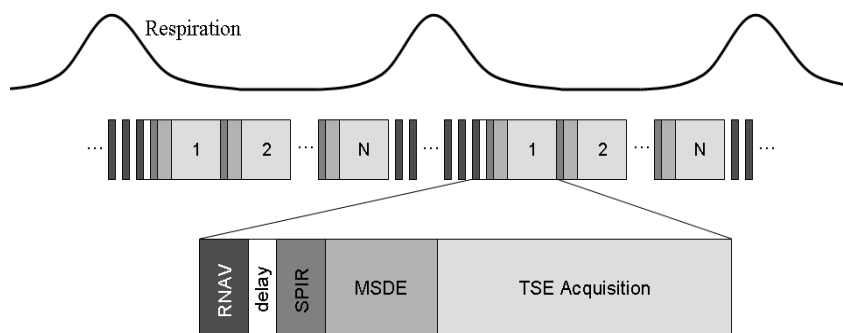

Figure 1. Illustration of sequence timing for the RNAV-triggered, fat-suppressed, black-blood, multi-slice TSE acquisition. N slices are acquired per package. Acquisition begins when the RNAV detects expiration.

was accomplished with a navigator (RNAV) pencil-beam placed on the diaphragm to monitor respiratory motion. A motion-sensitized driven equilibrium (MSDE) pre-pulse with 2 refocusing pulses and user-specified gradient direction was used for blood-suppression.[2,3] The sequence used spectral fat-saturation (SPIR) and a standard, MS TSE readout (FOV: 360x254mm; voxels: 1x1.3mm; 10 slices; thickness = 7mm / 7mm gap; TE=100ms; linear profile order; turbofactor 28; 1 package, nominal scan time 1:15). RNAV variable trigger delay was set to 300ms to center the acquisition in the most quiescent period of respiratory motion. In this preliminary study, the MSDE TE was set to 80 ms, MSDE motion-sensitizing-gradient strength (equivalent velocity encoding, VENC) was varied between 300, 600, and 1000 cm/s (applied in LR gradient direction only), and the MSDE gradient direction was evaluated (with VENC 1000 cm/s) in LR, FH, and AP directions.

Results The acquisition was successful for all VENC values and each motion-sensitized gradient direction. The images show no respiratory motion artifacts and no susceptibility-related distortion, thus are sharp images of quality similar to standard T2w MS TSE images (Figure 2). In this initial evaluation, the long MSDE TE (80 ms) resulted in heavy T2-weighting and sub-optimal fat-suppression. Minimal variation was observed in the evaluated range of motion-sensitizing-gradient strengths and directions.

Discussion RNAV triggering provided robust removal of respiratory motion artifacts. Figure 2 illustrates the high image quality provided by RNAV triggering in both standard FS T2w MS TSE and the black-blood FS T2w MS TSE. In addition, the MSDE TSE sequence provides images without image distortion as in black-blood imaging with the more common EPI readout. The lack of distortion in this sequence will likely allow image co-registration (e.g. with dynamic contrast-enhanced images) and improved diagnostic accuracy of black-blood images. Within the parameter ranges used in this study, there was no detectable variation in image quality with the three motion-sensitized gradient directions. Likely, motion-sensitization in the LR direction will lead to the least amount of image degradation secondary to respiratory motion, as respiratory motion is more pronounced in the AP and FH directions. However, the preference for gradient direction will also be impacted by the prevailing direction of blood flow. A limitation of this technique is the reduced efficiency of the TSE readout compared to EPI, resulting in less opportunity to suppress flow in multiple directions. Future work will explore optimal gradient orientation as well as decreased T2-weighting (shorter MSDE TE) in combination with an expanded range of motion-sensitized gradient strengths. This parameter optimization will likely provide images of high image quality as demonstrated in this preliminary study, while improving the T2-weighting and suppression of blood signal to diagnostic quality. Patient studies are required to evaluate the diagnostic efficacy of the new sequence.
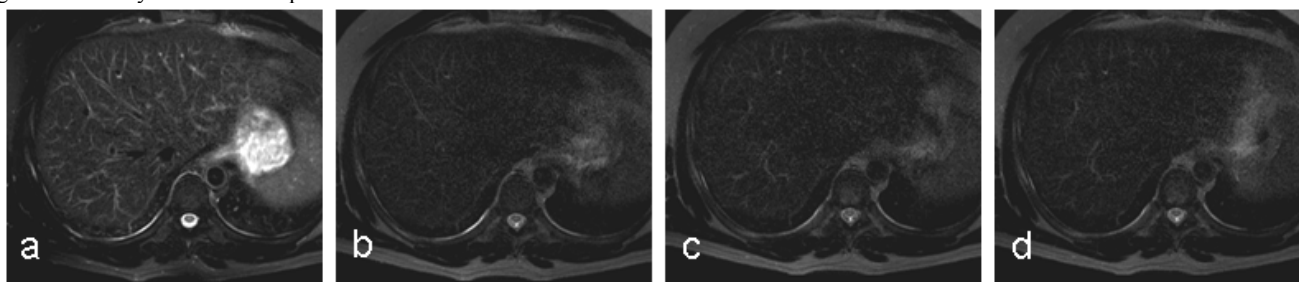
Figure 2. Example images in normal volunteer: a) RNAV-triggered FS T2w image, b-d) RNAV-triggered FS T2w images with MSDE motion-sensitizing gradients in LR, FH, and AP direction, respectively. Preliminary images are high resolution and without motion artifacts or distortion. Further study is warranted to optimize T2-weighting and blood suppression, and to assess lesion conspicuity in patients.

References
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3. Wang J, et al. MRM 58:973-981(2007).