Imaging of the Liver at 3.0T. : Optimization of Breath-hold, Volumetric Fat-suppressed Fast Spin-Echo and Diffusion-weighted Black-Blood Echo-Planar imaging

I. C. van den Bos[1], S. M. Hussain[1], P. A. Wielopolski[1]

[1]Radiology, Erasmus Medical Center, Rotterdam, Netherlands

Introduction:

The advantages of 3.0T for morphological liver imaging are yet to be devised. In spite of the inherent signal-to-noise ratio (SNR) enhancement at 3.0T (theoretically on the order of 2 with respect to 1.5T), the increased tissue T1 relaxation times, quality of fat suppression, higher specific absorption ratios (SAR), chemical shift, dialectric resonances, B1 inhomogeneity, larger susceptibility and geometrical distortions must be considered. Relevant sequences must therefore be evaluated and optimized to obtain the highest yield with all the difficulties mentioned. The recent implementation of specialized shaped RF pulses, such as variable-rate selective excitation (VERSE) (1), have reduced SAR figures and hence increased slice efficiency per unit time. Also, the increased SNR at 3.0T can be used to relief some imaging restrictions through the use of parallel imaging and partial Fourier and yet provide good image quality and volume coverage with multiple imaging sequences, including echo-planar imaging (EPI) protocols.

Purpose:

To evaluate and optimize breath-hold fat-suppressed T2-weighted (T2W) sequences at 3.0T MR imaging.

Material and Methods:

Eight volunteers were scanned at 3.0T (General Electric Healthcare, USA, with software release 12 (Excite HD)), using an ASSET compatible 8-channel torso coil. Fat suppressed T2W fast spin-echo (FSE) and diffusion-weighted black-blood echo-planar imaging (DW-BBEPI) were investigated as candidates for breath-hold volumetric imaging. Scan parameters for all sequences were varied interactively with respect to TE, TR, echo train length (ETL), slice-thickness, matrix resolution (imaging voxel size), readout bandwidth (BW), number of slices per breath-hold, applied fat-suppression technique, acceleration factors for parallel imaging (ASSET), partial Fourier scanning and diffusion b-values. Normal and VERSE optimized RF pulses were used for FSE scans and the performance was evaluated with regards to slice coverage per unit time. Protocols and imaging parameters were set to cover the entire liver in one to three breath-holds (max 25 seconds each) per sequence/image contrast (approximate coverage of 25 cm along the z-axis). Volume shimming was performed once over the volume of interest. Image characteristics were evaluated qualitatively with regards to SNR, fat suppression performance, geometric distortions, motion artifacts and suppression of vascular signal.

Results:

Sequence parameters were selected to provide volumetric imaging of the entire liver with good quality for multiplanar reformats in any orientation. Based on the observed SNR, the final voxel size set for imaging with the FSE module was to 1.0 x 1.6 x 3.5 mm^3 (BW = 41.7Khz and ETL = 8); for the DW-BBEPI module the voxel resolution was set to 3.2 x 2.6 x 2.6 mm^3 (example scans are shown in Figure 1 and Figure 2 for fat suppressed FSE and DW-BBEPI, respectively).The number of slices possible with VERSE RF pulses was increased by approximately 35% over the original settings for FSE readouts. Scan times remained unchanged with changing BW, leading to the choice of lowest BW possible so that the sequence avoided any silent periods without data collection. From the two fat suppression schemes available for FSE, namely fat suppression and classic fat suppression, the former was more effective. The quality of fat suppression increased with shorter echo trains although difference was not apparent for different acquisition BWs. Estimated SAR and peak SAR values were 1.6 ± 0.2 and 3.4 ± 0.2, respectively, for all sequence combinations. B1 inhomogeneities were not severe and did not degrade image quality substantially. The liver signal under the heart was more prone to signal loss with thinner slices in both FSE and EPI scans from cardiac motion. In T2W FSE, a saturation band was placed over the subcutaneous fat close to the anterior coils of the torso array to reduce ghosting artifacts. Also, thinner slices proved beneficial to further reduce signal from blood. In DW-BBEPI, geometrical distortions were minimal showing good delineation of liver borders. Acceleration factors greater than 2 were generally met with some form of aliasing. For DW-BBEPI, larger b-values (> 20 s/mm^2) demonstrated better suppression of the blood signal, nonetheless, b = 10 s/mm^2 showed good blood suppression; better multi-slice coverage per unit time (reduced deadtimes related to gradient amplifier duty cycle) and better signal consistency in the liver around the regions of the heart.

Conclusion:

Optimized volumetric breath-hold fat-suppressed FSE and DW-BBEPI at 3.0T MR imaging show potential for large coverage thin slice imaging with multi-planar reformatting capabilities. Also, suppression of the blood signal and improved fat-suppression for both sequences may aid in better delineation of focal liver lesions.

References:

1. Hargreaves BA , et al. Variable-rate selective excitation for rapid MRI sequences. Magn Reson Med. 2004 Sep;52(3):590-7

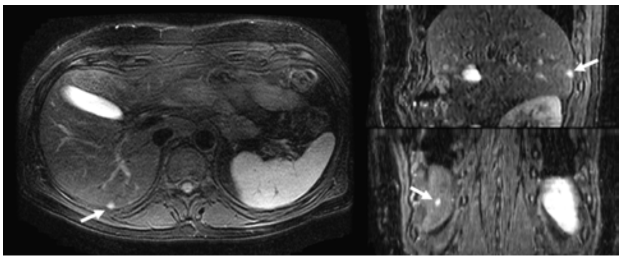

Figure 1: Fat suppressed T2W FSE scan. TR/TE=3400/80 ms, ETL=8, BW=41.7 kHz, slice thickness = 3.5 mm, 62 slices, 2 breath-holds 25 sec, ASSET factor = 2, partial Fourier.The arrows point at a cystic lesion, clearly seen on the original slices and in the reformatted views.

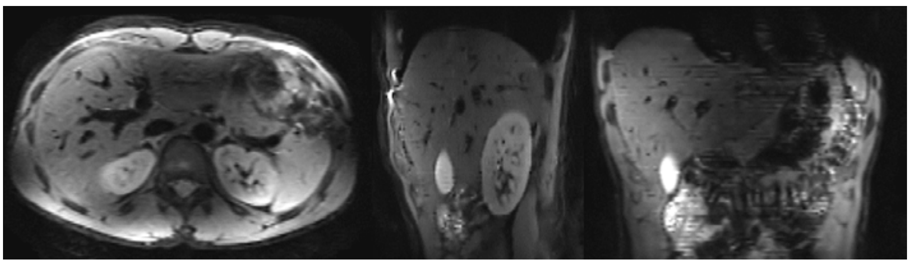

Figure 2: DW-BBEPI. TR/TE=6400/25 ms, BW=250 kHz, b=10 s/mm^2, slice thickness = 2.6 mm, 100 slices, 1 breath-hold 26 sec. Diffusion image resulting from average of 3 images acquired with diffusion gradients along x, y and z.