Quantitative Whole-Body Fat-Water MRI with R2* Estimation at 3 Tesla Using a Custom Tabletop for Multi-Station Parallel Imaging with a Single 16-Channel Surface Coil

E. Brian Welch[1,2], Aliya Gifford[2,3], Johan Berglund[4], Joel Kullberg[5], Nils Paaske[6], Anne-Lise Schierup[6], Erik M. Pedersen[7], and Malcolm J. Avison[2,8]

[1]*Department of Radiology and Radiological Sciences, Vanderbilt University, Nashville, Tennessee, United States,* [2]*Institute of Imaging Science, Vanderbilt University, Nashville, Tennessee, United States,* [3]*Chemical and Physical Biology Program, Vanderbilt University, Nashville, Tennessee, United States,* [4]*Philips Healthcare, Stockholm, Sweden,* [5]*Department of Radiology, Uppsala University, Uppsala, Sweden,* [6]*X-tend ApS, Hornslet, Denmark,* [7]*Department of Radiology, Aarhus University Hospital, Aarhus, Denmark,* [8]*Department of Pharmacology, Vanderbilt University, Nashville, Tennessee, United States*

Purpose: The objective of this research is to demonstrate the feasibility for accelerated acquisitions of whole-body (WB) multiple fast field echo (mFFE) protocols on a 3 Tesla (3T) scanner for fat-water MRI (FWMRI) with a custom tabletop that allows a single 16-channel surface coil array to be used at every table position in a multiple station data collection strategy. The acceleration afforded by the strategy enables the collection of a high number of echoes in a reasonable acquisition time. The additional echoes enable WB quantitative fat-fraction mapping including R2* estimation.

Methods: Subjects were scanned using a Philips Achieva 3T (Philips Healthcare, Best, Netherlands) scanner equipped with two-channel parallel transmit capability, a 16-channel Torso-XL surface coil (Invivo Corp., Gainesville, Florida), and an X-tend tabletop (X-tend ApS, Hornslet, Denmark). **Figure 1** shows the general setup for the X-tend tabletop. The anterior portion of the Torso-XL hangs from the top of the scanner bore in a fabric sling. The sling is intentionally allowed to hang low enough to slide against the subject's body in order to maximize SNR. The posterior portion of the coil is placed in a rolling "coil wagon" sandwiched between two layers of the X-tend tabletop. As the X-tend table moves through the scanner bore, the coil wagon is held at isocenter by straps attached to the scanner covers so that the posterior coil elements remain stationary. FWMRI was acquired using a multi-stack, multi-slice, mFFE acquisition with either 18 stacks of 12 axial slices or 12 stacks of 20 axial slices. Slices were contiguous with a 0 mm gap between slices. Scanner software was modified to enable the acquisition of 8 echoes acquired as two interleaved sets of four echoes with TE_1=1.024 ms and effective ΔTE = 0.779 ms. Other acquisition protocol details included: flip angle = 20º, water fat shift = 0.323 pixels, readout sampling bandwidth = 1346.1Hz/pixel, axial in-plane field of view = 520 mm × 408 mm, acquired voxel size = 2 mm x 2 mm x 7.5 mm, and sensitivity encoding (SENSE) parallel imaging factor= 3. Preparation phases for each station included center frequency (F0) optimization and first order linear shimming. Acquisition time was 17.4 s for stacks of 12 slices and 27.8 s for stacks of 20 slices. Breath holds were performed for stations covering the pelvis to the base of the lungs with two breath holds per station, i.e. no breath hold was longer than 14 s. At each table position, a dual angle B1 calibration scan (acquisition time 15.1 s) was acquired to enable optimized RF shimming (relative RF amplitude and phase adjustments) for the two-channel transmit capability of the scanner. A SENSE reference scan was also acquired at each table position with an acquisition time of 12.1 s. Real and imaginary images were saved for off-line processing. Three-dimensional water/fat separation and R2* estimation based on a multi-scale whole-image optimization algorithm [1] implemented in C++ was performed for each individual slice stack. Fat was modeled using 9 peaks [2]. The first echo of each 4-echo train was discarded to avoid potential contamination of eddy current in the complex water-fat signal model. The separate 3D stacks of axial fat, water, R2* and static field off-resonance (ΔB_0) images from each table station were collated and reformatted to coronal images using MATLAB (Mathworks Inc., Natick, MA).

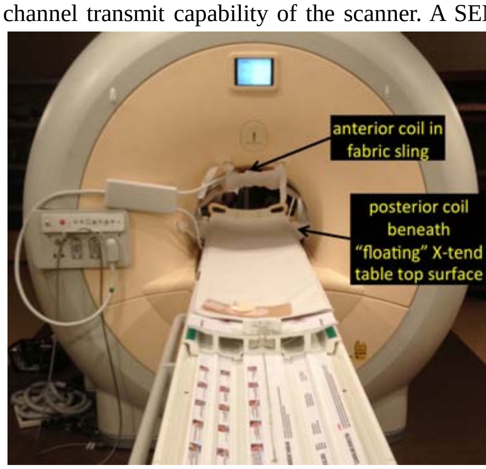

Figure 1. Setup of the X-tend tabletop.

Results: Example maps of fat-fraction, R2* and ΔB_0 are presented in **Figure 2** for a male (**a**-**c**) and female (**d**-**f**) subject. The displayed maps have background areas masked. Processing time for the analyzed 6 echoes ranged from 45 to 60 minutes for each 3D stack. The quality of all maps is high throughout the body except for the arms, which are at the boundaries of the usable FOV of the scanner. Despite being acquired as separate table stations the fat fraction and R2* maps display no visible boundaries between stations. However, the ΔB_0 maps show considerable variation in some stations especially the stations covering the shoulders and the dome of the liver. **Discussion:** Without the ability to acquire images accelerated by parallel imaging, it is not practical to acquire enough echoes to enable robust fat-water separation that includes estimation of R2*. Future work will include the application of a voxel-by-voxel mixed magnitude and complex model-fitting algorithm [3] to overcome eddy current corruption of first echoes (in each echo train) initialized by the results of the 6-echo analysis.

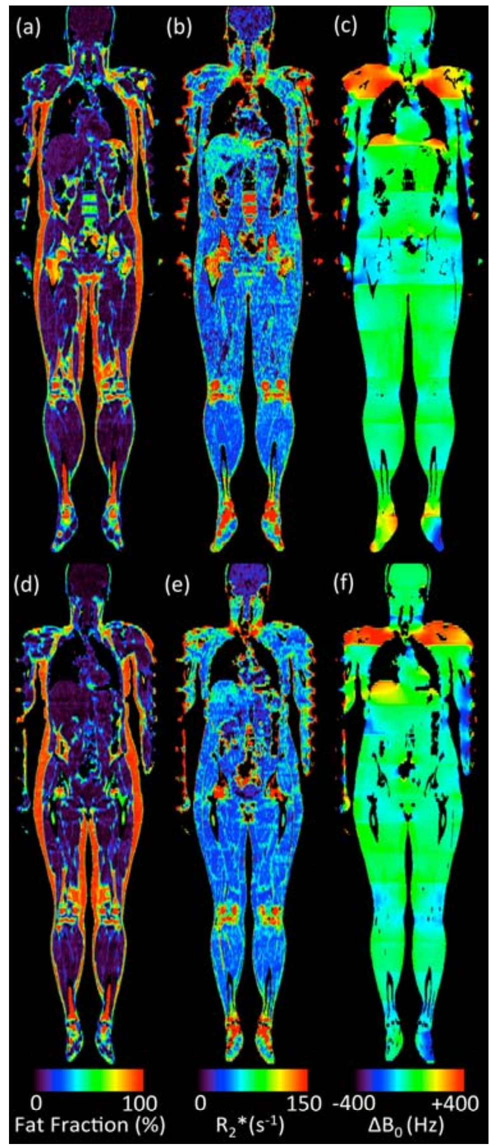

Figure 2. Coronal fat fraction (**a**,**d**), R_2* (**b**,**e**), and off-resonance (**c**,**f**) maps for a male (**a**-**c**) and female subject (**d**-**f**) acquired using the X-tend tabletop.

References: [1] Berglund J, et al. MRM 67(6):1684-93; 2012. [2] Hamilton G, et al. NMR Biomed 24:784-790; 2011. [3] Hernando D, et al. MRM 67(3):638-44; 2012.