Whole Body Fat Water Imaging at 3 Tesla Using Multi-echo Gradient Echo

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Introduction: The potential of whole body MRI for visualizing adipose tissue distribution has long been recognized [1]. More recently, multi-gradient-echo MR acquisitions have been successfully used at 1.5T to quickly acquire whole-body data sets [2]. Automated segmentation and quantification of such whole-body fat images into subcutaneous and visceral adipose tissue compartments [3] shows great promise as a tool in studies of obesity and related diseases such as diabetes. Higher strength 3T scanners offer the potential for improved SNR and CNR, increased spatial resolution and consequently improved lean / adipose tissue classification and quantification, but 3T also presents increased challenges related to B0 and B1 inhomogeneity. Here we present initial results of a 3T multi-gradient echo whole-body fat-water sequence.

Methods: A 26 year old healthy normal female volunteer was scanned on a whole body 3T Achieva MR scanner (Philips Healthcare, Best, The Netherlands) equipped with a Quasar Dual gradient set capable of 40 mT/m peak strength and 200 mT/m/ms peak slew rate in the serial operation mode. The subject entered the scanner feet-first in a supine position with arms extended above the head. A standard commercial tabletop extender was used to increase the length of the table stroke. The integrated quadrature body coil (QBC) was used for both transmit and receive. A multi-station protocol with 17 table positions was used to acquire whole-body data. Each of the 17 stacks was comprised of a multi-slice, multi-echo gradient echo (fast field echo, FFE) acquisition with 12 slices with slice thickness of 8mm and with zero slice gap. Other acquisition details include: TR/TE1/TE2/TE3 [ms] = 75/1.34/2.87/4.40; FA=20º; WFS=0.325 pixels (BW=1335.5 Hz/pixel); FOV = 500 mm × 390 mm, acquired matrix size = 252 × 195; acquired voxel size = 2 mm × 2 mm× 8 mm. First order (“auto”) shimming was performed for each slice stack. Flyback gradients were employed between echoes so that the chemical shift direction for all echo readouts was the same. The total duration of data acquisition was 4 minutes and 16 seconds. However, approximately 5 minutes of additional time was needed for the table movement, preparation phases at each table position, and for breath holding instructions and pauses. Breath holding was performed for only the table positions including the body region from the waist to the shoulders (6 of 17 stations for this subject). Each breath hold was 15 seconds in duration. The normal phase correction algorithms applied by the scanner’s reconstructor were disabled to allow for proper separation of the fat and water signals. Real and imaginary images were reconstructed and exported in DICOM format for off-line processing. Reconstruction of water and fat images from the acquired multi-echo data sets was performed using a novel algorithm [4] in which two solutions are found analytically in each voxel. Fat and water signal components are found by least squares fitting [5] after the true solution is identified by imposing spatial smoothness in a 3D multi-seeded region growing scheme with a dynamic path that allows low confidence regions to be solved after high confidence regions have been solved.

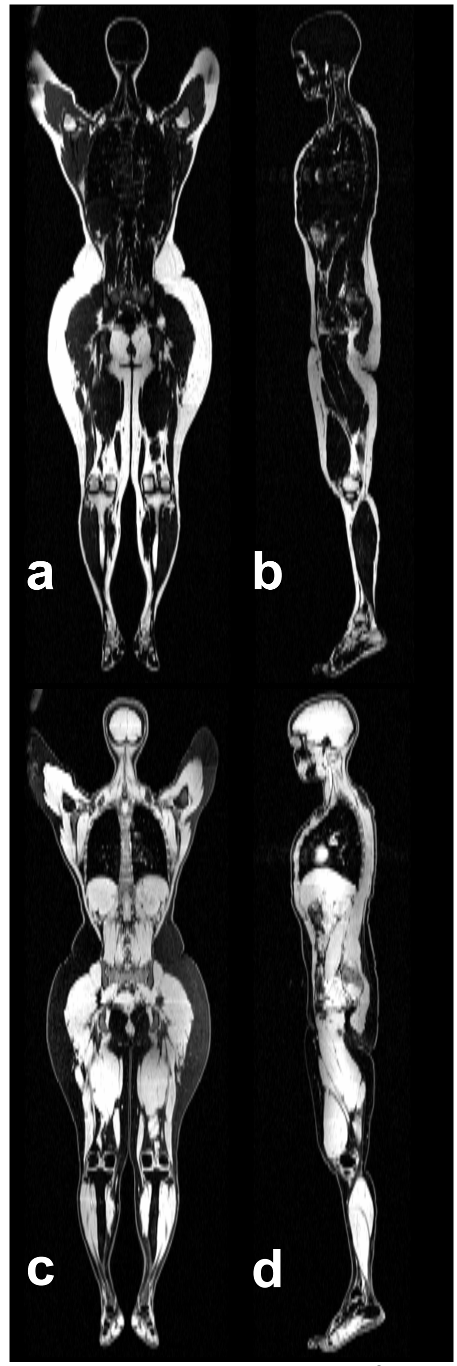

Figure 1. Example whole-body fat (**a**,**b**) and water (**c**,**d**) images acquired at 3 Tesla.

Results: Figure 1 shows example coronal (**a**,**c**) and sagittal (**b**,**d**) cross-sections from a whole-body data set acquired at 3T separated into fat (**a**,**b**) and water (**c**,**d**) images. The images show excellent adipose tissue contrast and are well-suited for segmentation and further quantification. Typically, 3T body imaging is more sensitive to B0 and B1 inhomogeneity than are 1.5 T studies. However, for this subject, no significant B0 or B1 imaging artifacts are noticeable.

Discussion: This implementation of a rapid 3T multi-station multi-gradient-echo based fat-water imaging sequence shows promise for high resolution whole body imaging and quantification of adipose tissue distribution in human subjects. Such a tool will be invaluable in human subject studies of obesity and its associated complications. Pilot studies assessing the robustness of the sequence for imaging of subjects with body sizes and shapes more typical of overweight and obese persons are underway. In case B0 homogeneity becomes problematic on such subjects, alternative shimming strategies such as slice-wise dynamic shimming will be pursued. Challenges related to B1 inhomogeneity that may arise could be addressed by scanning on commercially available two-channel parallel transmit 3 Tesla scanners. Furthermore, scan time speedups, especially for specific body regions, could be achieved using multi-channel surface coils to enable parallel imaging acceleration. Scan time could also be reduced with a continuously moving table strategy.

References: 1. Thomas EL et al. JAP (1998) 85:1778-1785. 2. Börnert P et al. JMRI (2007) 25:660-65. 3. Kullberg J et al. JMRI (2009) 30(1):185-193. 4. Berglund J et al. MRM (under review). 5. An L and Xiang QS. MRM (2001) 46(1):126-130.