Rapid Whole-Body Quantitative Fat Water Imaging with Golden Angle Continuously Moving Table MRI at 3 Tesla

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TARGET AUDIENCE: Researchers interested in moving table MRI methods and whole body fat/water MRI as markers of obesity and diabetes.

INTRODUCTION

The mapping and quantification of fat/water content in the human body is of high interest in the treatment of a number of illnesses linked to obesity and diabetes (1). Whole-body fat/water separation based on multiecho MRI can provide accurate, clinically relevant measurements of water and fat fractions, as well as estimates of the background off-resonance field (ΔB_0) and transverse relaxation rate, R_2* (2). Accelerated mapping of whole-body fat/water distribution can be achieved using Continuously Moving Table (CMT) MRI, where scanning is performed with concurrent motion of the patient table (3). In general, the moving table in CMT MRI imposes trade-offs between Z resolution and repetition time (TR), which in the case of fat/water MRI, limits the number of echoes that may be acquired for accurate fat/water separation. In this abstract, we demonstrate whole-body fat/water separation at 3 Tesla using a CMT MRI scan based on a golden angle (GA) radial sampling pattern, where radial projections are azimuthally stepped by 111.25° (Figure 1). GA sampling allows retrospective profile binning for arbitrary slice thickness reconstructions and high degrees of radial under-sampling without coherent artifacts in the image (4). This property loosens the limits on slice thickness imposed by the table speed and allows the collection of higher number of echoes per TR for accurate fat/water separation, as well as whole body ΔB_0 and R_2* mapping. We demonstrate high-quality whole-body (1.8 m Z coverage) fat/water separation with this technique in a rapid 90-second scan.

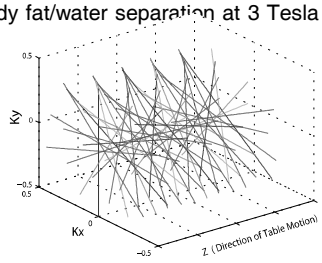

Figure 1: GA CMT acquisition.

METHODS

Acquisition: Whole-body CMT MRI was implemented on a Philips Achieva 3 Tesla scanner (Philips Healthcare, The Netherlands) with a 2-channel receive body coil and table velocity of 20 mm/s. Fat/water MRI was performed on a single adult volunteer with a 4-echo radial GA CMT scan with the following imaging parameters: Full zFOV = 1800 mm, in-plane FOV = 400 x 400 mm^2, inplane resolution = 2.5 x 2.5 mm^2, TR = 6.6 ms, first TE/ΔTE = 0.99/1.4 ms, excited slice thickness = 12 mm. All the shims were set to zero to maintain a globally acceptable shim and preparation phase calibrations were performed on the abdomen. The total acquisition time was 90 seconds.

Reconstruction: Complex axial images for the whole-body volumes of all four echoes were reconstructed offline using 128 profiles per slice (*128 * 20 mm/s * 6.6 msec = 16.9 mm slice thickness*) in a sliding window format in Python (Anaconda version 3.4.2, Austin, TX). Shifts in the k-space readouts were compensated by 0th and 1st order phase shifts calculated in the spatial domain (5). Slicewise data were corrected for sampling density, gridded, transformed using 2D FFT and then roll-off compensated to produce final reconstructed slices. A total of 720 axial slices were reconstructed with a center spacing of 2.5 mm to enable isotropic reformatted display.

Water/Fat Separation: 3D water/fat separation and R_2* estimation based on a multiscale whole image optimization algorithm (6) implemented in C++ was performed for the full image volume. Fat was modeled using 9 peaks (7). Whole-body fat, water, R_2* and ΔB_0 were estimated from the 4 echo volume with inplane resolution of 2.5 x 2.5 mm^2 and at slice intervals of 2.5 mm. The whole-body fat signal fraction (FSF) map was also estimated as the |*fat image*| / (|*fat image*| + |*water image*|).

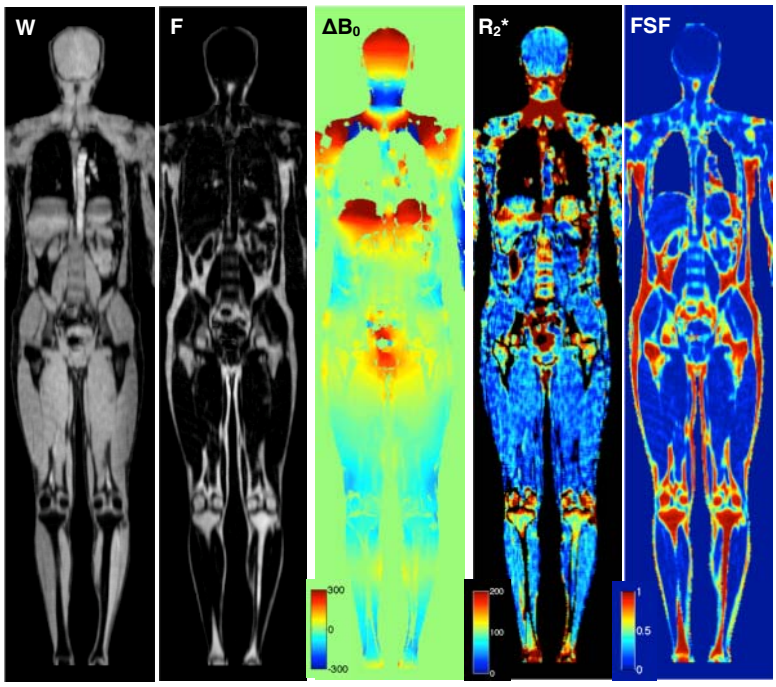

Figure 2: Whole-body water, fat, ΔB_0, R_2* and FSF maps acquired at 3 Tesla in 90 seconds using a continuously moving table and golden angle radial sampling. (W: Water, F: Fat).

RESULTS

Figure 2 shows results of fat/water separation for the adult volunteer. The quality of the maps is generally high throughout, including the difficult to estimate locations near the neck and shoulders. ΔB_0 and R_2* maps show expected variations, with tissue interfaces near the diaphragm and neck revealing extreme values.

DISCUSSION

GA CMT MRI produces excellent image quality and enables whole-body fat/water scanning in as little as 90 seconds. Artifact free flexible image reconstruction allows for the acquisition of 4 echoes per TR, and water/fat separation with estimation of ΔB_0 and R_2*. With table speeds lower than the relatively high 20 mm/s employed in this study, image resolution and fat/water separation performance can be improved further using the GA approach.

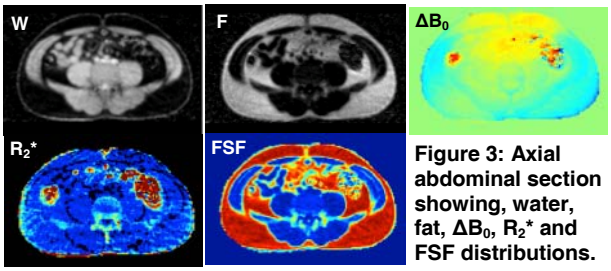

Figure 3: Axial abdominal section showing, water, fat, ΔB_0, R_2* and FSF distributions.

REFERENCES

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