Whole-mouse MR imaging of fat fraction at 7 Tesla using a Fourier-based many-echo technique

Greg O. Cron[1,2], Ryan J. Mailloux[3], Mary-Ellen Harper[3], Ian G. Cameron[1,2], and Mark E. Schweitzer[1,2]

[1]*Ottawa Hospital Research Institute, Ottawa, Ontario, Canada,* [2]*Radiology, University of Ottawa,* [3]*Biochemistry, Microbiology, and Immunology, University of Ottawa*

Introduction: Obesity is an increasing public health concern because of its causative link to diabetes, cardiovascular disease, and osteoarthritis. Mice are considered excellent models for many of these diseases, and MR is the most commonly used imaging modality to follow these disorders in vivo. Thus a crucial component of this research is in vivo quantitative assessment, as well as compartmental localization, of mouse body fat, to allow longitudinal follow up (1). Unfortunately, there exists no widely available, universally agreed-upon MR imaging method for measuring fat, especially for very high-B_0 scanners ($\geq$ 7 T) with consequent B_0 inhomogeneity issues. Furthermore, some of the more advanced techniques such as IDEAL (2) are vendor- or platform- specific.

Purpose: Develop a simple, precise, MRI fat quantification technique for whole-mouse imaging at 7 T.

Methods: MRI was performed on 11 phantoms having fat fractions ranging from 0.0 to 0.9, and also on 6 sacrificed mice (three C57Bl/6 wild-type and three Grx2-/- knockout) with a GE/Agilent Discovery MR 901 using a 72 mm ID T/R coil. The MRI fat quantification technique developed was akin to chemical shift imaging, with 16 separate 3D data sets acquired with 16 different echo times (total time = 13 min) (3). A 3D gradient-echo pulse sequence was used with TR=24 ms; flip=15°; BW=125 kHz; FOV=10x5 cm; slab thickness=2.4 cm; matrix = 256 x 128 x 28; spat. res.=0.39 x 0.39 x 0.86 mm, TE=3.0, 3.3, 3.6, ..., 7.5 ms (spacing 0.3 ms). TR and flip were chosen to equalize the T1-weighting of fat and muscle. For each voxel, complex MR signal-vs-TE was converted to a spectrum by applying a Fourier Transform, taking the magnitude, then performing a baseline correction. The entire fat peak was then integrated, regardless of frequency position. This fat integral was then divided by the maximum image magnitude signal of the 16 echoes, to obtain an uncalibrated MRI fat fraction. A linear calibration curve (obtained from the phantom data, Fig. 1) was then applied to obtain the MRI fat fraction. For our reference standard, fat composition of each mouse was independently determined by weighing the whole mouse, dissecting out the inguinal adipose tissue (IAT), weighing the IAT, then taking the ratio of IAT mass to whole-body mass. A linear regression fit was performed for uncalibrated MRI fat fraction versus known fat fraction in the phantoms (Fig 1) and median whole-body MRI fat fraction versus the ratio of IAT mass to whole-body mass in the mice (Fig 3).

Results: The MRI technique strongly correlated with known fat fraction in phantoms (Fig. 1) and with the dissection results (Fig. 3).

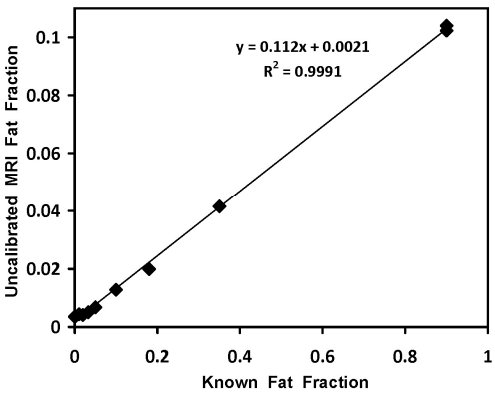

Figure 1 (left): Uncalibrated MRI fat fraction versus known fat fraction in phantoms. Solid line shows linear fit which was then used for calibration.

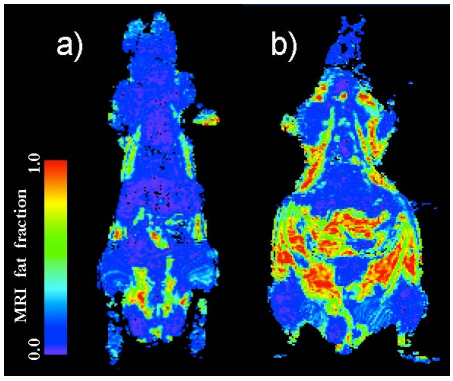

Figure 2 (center): Example parametric images of MRI fat fraction. a) knockout mouse b) wildtype mouse.

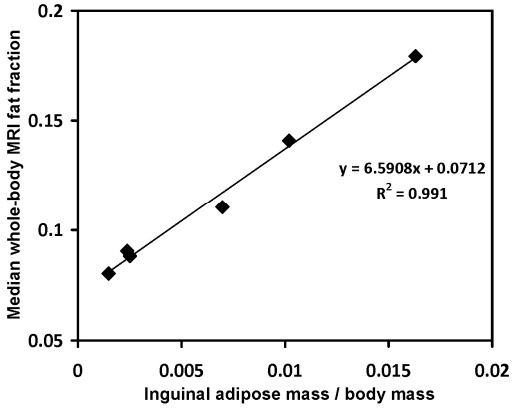

Figure 3 (right): MRI versus dissection.

Discussion: The MRI fat quantification technique described here exploits the chemical shift of fat. Considering the frequency spectrum, the entire fat peak is integrated, regardless of its width or position. This reduces errors in the presence of B_0 inhomogeneities, a particular concern with very high field MRI machines. The technique is not computationally intensive, requiring only a Fourier Transform, and could potentially be applied to data from any MRI vendor. Fully three-dimensional parametric maps of fat fraction are generated, which could be used to quantify whole-body, subcutaneous, visceral, or ectopic organ fat.

Conclusion: We have developed a Fourier-based MRI fat quantification technique for use on whole mice at 7T. The technique correlates strongly with phantom and mouse dissection data (R^2=0.99) and is very straightforward to implement.

References: 1. Hu et al. Obes Rev 12:e504. 2. Reeder et al. MRM 54:636. 3. Ye et al. Proc. ISMRM 20 (2012), p. 1368.