A Comparison of MRI and Dual-Energy CT (DECT) for Quantification of Hepatic Steatosis in the ob/ob Mouse

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Introduction Quantiative assessment of non-alcoholic fatty liver disease (NAFLD) currently requires biopsy, which is limited by expense, risk, and sampling variability1. Quantitative MRI methods have shown great promise as a non-invasive biomarker of hepatic steatosis, with validation studies performed in phantoms, animal models, and patients[2-6]. However, CT and increasingly Dual-Energy CT (DECT), is used for most advanced volumetric imaging studies in the abdomen. If DECT can accurately detect NAFLD in patients undergoing CT scans for other purposes, it may provide an unprecedented screening opportunity as an estimated 20-30% of the US population has hepatic steatosis. The purpose of this study was to compare MRI and DECT measurements of fat using tissue triglyceride (TG) concentration as the reference standard in an animal model.

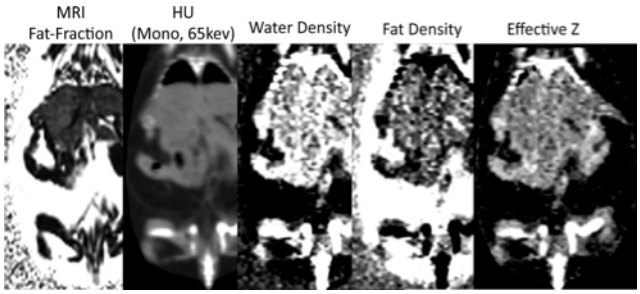

Figure 1 MRI Fat-fraction and DECT images for an ob/ob mouse.

Methods A phantom correlation experiment was performed prior to the mouse study. Five gel phantoms (agar and peanut oil), with different TG contents (0, 10, 20, 30, & 50%) were imaged with MR and DECT. MR imaging was performed at 3T using an eight channel wrist coil and a multi-echo 3D spoiled gradient (SPGR) method: first TE=2.2ms, TR=24.4ms, BW=± 100kHz, α=5°, 256x256 matrix, FOV=16x9.6 cm, 28 slices (0.8mm thick), for a total scan time of 6 min.[3] The reconstruction algorithm provided fat-fraction (FF) images over the entire FOV. A GE Discovery VCT scanner was used for the DECT scan (140/80 kVp, 630 mA, rotation time=0.5s, 32 slices/0.63 mm thick), which reconstructed four image volumes: attenuation (Hounsfield Units, HU), effective Z (eff-Z), fat density, and water density images. Mean regions of interest (ROI) measurements were made in each phantom for MRI and DECT images.

All animal studies were approved by our institutional animal research center. Leptin-deficient ob/ob mice, an established model of obesity and NAFLD[3], were used in this study. 20 mice were divided into three groups: low fat (lean, male, wild-type mice, n=6), medium fat (male ob/ob mice aged 4 weeks, n=7), and high fat (male ob/ob mice aged 8 weeks, n=7). MR imaging was performed using the parameters described above. DECT was performed immediately after MRI.

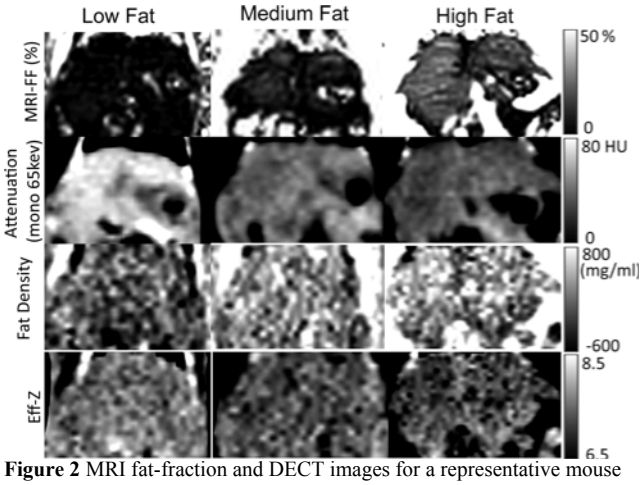

Figure 2 MRI fat-fraction and DECT images for a representative mouse from each of three groups: low fat, medium fat, and high fat.

Following DECT, the caudate lobe was harvested, frozen at -70°C and sent to AniLytics Inc (Gaithersburg, MD) for tissue TG analysis. ROI's were placed in the corresponding liver lobes in the MR-FF image and CT images (attenuation, eff-Z, fat density) and mean values recorded. Linear regression and Pearson correlation was performed between the various measures.

Results Phantom results demonstrated excellent correlation with TG content and all image measurements (MRI-FF, HU, fat density, and eff-Z), with correlation values above 0.99 ($p < 0.001$, **Table 1**). In-vivo results demonstrated good image quality for all DECT reconstructions (**Fig 1**). **Fig 2** demonstrates signal changes between mice with low, medium, and high fat livers in the MRI FF and DECT images. Excellent correlation with tissue TG content was observed in-vivo for both MRI-FF ($r=0.96$, $p<0.01$) and HU ($r=0.95$, $p<0.01$) (**Fig 3**). High correlation r(=-0.93) was observed between MRI-FF and HU. In-vivo fat density and effective Z demonstrated good, but inferior, correlation with both MRI and tissue TG (**Table 1**).

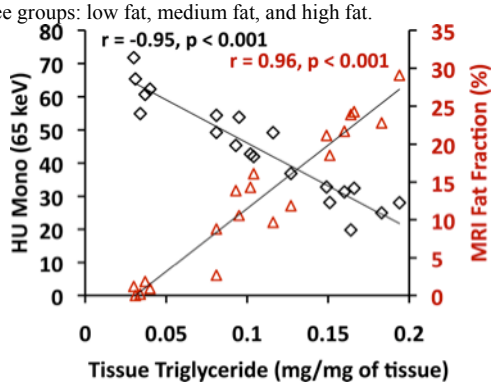

Figure 3 HU and MRI fat-fraction vs. tissue triglyceride for all mice.

Discussion To our knowledge, this is the first in-vivo data with direct correlation of MRI, DECT, and extracted tissue TG concentration. While excellent correlation was observed in *phantom* experiments for all DECT measurements as in the literature[7], in-vivo results only demonstrate excellent correlation for conventional HU compared to MRI and TG concentration. These results demonstrate that both CT and MRI may play an important role for clinical fat quantification, and established MRI methods may provide an excellent surrogate reference standard when investigating new DECT methods for fat quantification in human subjects.

Table 1	Compared Measures	r	p-value
Fat Phantom	MRI-FF vs TG	0.998	<0.001
	HU vs TG	-0.999	<0.001
	Fat density vs TG	0.996	<0.001
	Eff-Z vs TG	-0.99	<0.001
In-Vivo	MRI-FF vs TG	0.96	<0.001
	HU vs MRI-FF	-0.93	<0.001
	HU vs TG	-0.95	<0.001
	Fat density vs MRI-FF	0.81	<0.001
	Fat density vs TG	0.75	<0.001
	Eff-Z vs MRI-FF	-0.82	<0.001
	Eff-Z vs TG	-0.76	<0.001

References [1]Ratziu et al, Gastroenter 2005. [2]Reeder et al, MRM 2004. [3]Hines et al, Radiology 2010. [4]Meisamy et al, Radiology 2011. [5]Yokoo et al. Radiology 2009. [6]Yokoo et al. Radiology 2011. [7]Fischer et al. Invest Rad 2011.

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