Feasibility of quantifying lipid content in muscles, liver and heart of very obese subjects with MRS

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Introduction

Obesity is an alarmingly increasing health problem that can lead to type 2 diabetes mellitus (T2DM) and to heart disease (1). The mechanism by which obesity leads to heart disease is not fully understood. The term metabolic syndrome (MetS) has been proposed to describe the connection between obesity, insulin resistance, hypertension, dyslipidemia, T2DM, and atherosclerotic cardiovascular disease (ASCVD). Cardiac problems could develop independently in parallel to insulin resistance, or as a result of abnormal lipid metabolism in the heart caused by the insulin resistance or T2DM. With ^{1}H-MRS the lipid content of liver, skeletal muscle and cardiac muscle can be studied non-invasively in-vivo. We studied four obese subjects with localized ^{1}H-MRS in heart, liver and leg muscles as the first step in a protocol to compare lipid metabolism pre-and post bariatric surgery. The inclusion criteria for this protocol imply the need for an MR baseline scan of very large subjects. In this paper we show the feasibility of measuring tissue lipid fractions in the heart, liver and leg muscles of such large subjects in a wide wide-bore 3T whole body magnet with a protocol comprising cardiac cine- and tagged MRI, water-fat images of liver thigh and calf and a visceral fat determination. Lipid content was determined with PRESS ^{1}H-MRS using cardiac, navigator gating and outer volume suppression (OVS) to reduce motion artifacts and contamination from surrounding fat.

Materials and Methods

Experiments were performed on a Siemens Verio 70 cm bore 3T MRI scanner using TIM phased-array coils for reception. For spectroscopy and stady state free precession (SSFP) scans the B_0 shimming parameters were optimized with a (breathhold) rapid B_0 mapping method. Four obese individuals (one male) with body mass indices 41-62 and weights 99-152kg were studied. Cardiac short axis (SA) and 4-chamber SSFP cine images were used to prescribe the PRESS voxel location in the septum at late diastole and OVS slabs across subcutaneous and pericardial fat. A breathing navigator was set on the dome of the diaphragm on a free breathing scout. In the heart a 32 averages cardiac gated (500-600ms delay after R-wave) spectrum (TE 35ms) was recorded with modest water suppression, followed by another water reference spectrum with 8 averages scan with the water suppression RF pulses nulled. In the liver the same procedure was applied apart from the cardiac gating, with minimum TR set to 2s. After B_0 optimization of the liver a six slice, six echo GRE image was recorded for water-fat imaging. This was used to calculate fat fractions with the magnitude two echo Dixon method (2) with correction for mean T2* estimates derived from relevant regions the six echo images. A T1 weighted image was recorded to quantify visceral fat in the abdomen and a phased array coil was placed first on the thigh and then on the calf muscle. On the muscle location a scout at B_0 map were recorded, followed by water fat imaging as described above. Then a voxel, typically 10x10x40, mm^3 was placed in the vastus lateralus, tibialis anterior or soleus muscle. Water reference and weakly water suppressed TR2s/TE30ms PRESS spectra were recorded with OVS of subcutaneous and bone marrow fat regions. All MRS results were analyzed with Amares (3) with only the zero order phase fitted and all peaks except residual water constrained to be in phase. For Muscle spectra a ten peak model was used, for heart and liver three peaks were fit on the lipid signals. The water signals in the reference spectra were fitted with up to three peaks depending on peak shape in order to minimize the fit residuals.

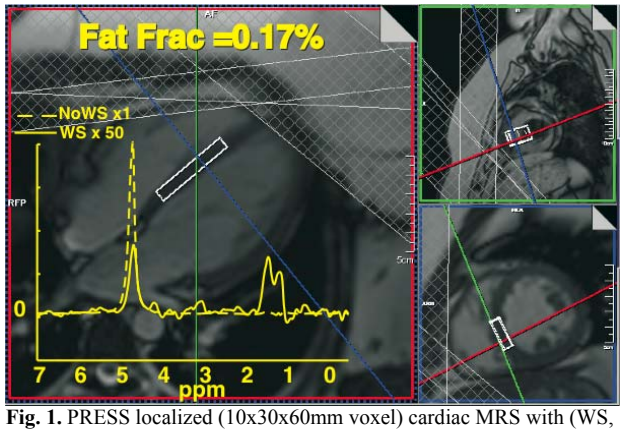

Fig. 1. PRESS localized (10x30x60mm voxel) cardiac MRS with (WS, magnified 50x) and without (NoWS) water suppression on a 36 yo. female 5'4", 238lb, BMI 41. The voxel location is shown on a sagittal scout, a 4-ch and SA cine SSFP image 0.6s post R-wave

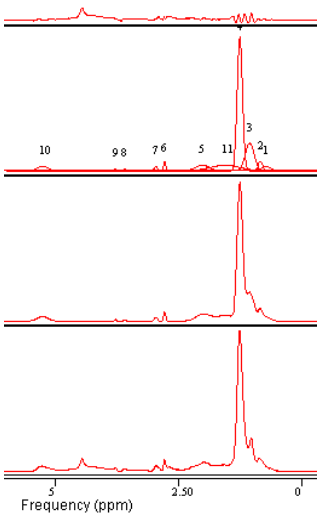

Fig. 2. A sample ten component Amares fit on a spectrum from the tibialis anterior. From bottom to top: measured data, reconstructed spectrum, individual components and residual spectrum. Peaks 1-4 were used to quantify total fat fraction and peaks 3 (IMCL) and 7 (creatine, Cr) were used to determine IMCL/Cr fraction.

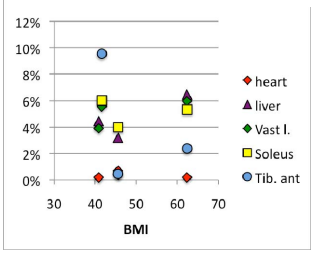

Fig. 3. MRS derived fat fractions vs BMI

Results and discussion

Good spectra were obtained from muscle heart and liver. A sample cardiac spectrum is shown in fig. 1. Note the amount of subcutaneous pericardial fat around apex and right ventricle. The low, normal cardiac fat fraction shows that the localization and OVS is effective. In muscle the spectral quality (see fig 2). was sufficient to quantify creatine (Cr) and separate intra- and extramyocelluar lipids (IMCL and EMCL) The total fat fraction in the three muscle groups was 4±3% with no significant differences between the soleus, ant. tib and l.vast. The average spectroscopy derived fat fraction in the liver was 4.7±1.7% and in the heart 0.34±0,28%. The IMCL/Cr ratio was lowest in the L.Vast at 5±3, and >9 in ant tib. and soleus. We did not get a good correlation between Dixon-method derieved fat fractions and MRS results. Re-analysis of the multiple echo GRE data with Varpro fitting (4) may improve this correlation. At this point in the limited number of baseline studies completed we observed no obvious relation between BMI and fat fractions measured in liver, muscle and heart. In this study the primary objective is to observe the differences pre and post bariatric surgery. Here we show that the first obstacle, to obtain good MR data on obese subjects, has successfully been taken.

References: (1) Poirier P, et.al. Circulation 2006;113(6):898-918. (2) Dixon WT. Radiology 1984;153(1):189-194. (3) Vanhamme L, van den Boogaart A, Van Huffel S. JMR 1997;129(1):35-43. (4) Hernando D, Haldar JP, Sutton BP, Ma J, Kellman P, Liang ZP. Magn Reson Med 2008;59(3):571-580.