Abdominal fat measurement: MRS vs. MRI

M-H. Cui[1,2], V. Tomuta[2], C. Segal-Isaacson[2], D. T. Stein[2], and J-H. Hwang[1,2]

[1]Gruss MRRC, Albert Einstein College of Medicine, Bronx, NY, United States, [2]Medicine, Albert Einstein College of Medicine, Bronx, NY, United States

Introduction. Excess abdominal fat has been linked to insulin resistance, diabetes, and other metabolic risk factors for cardiovascular disease (1-4). In recent years, magnetic resonance imaging (MRI) has become the most promising imaging tool for assessment of abdominal fat (1, 3, 5, 6). Proton magnetic resonance spectroscopy (MRS), on the other hand, exploits the differential behavior of protons associated with fat and water (9). With a reference spectrum from a small voxel with known volume in subcutaneous fat (SF), the total fat weight from certain region in abdomen can be calculated after the fat peak intensity is analyzed against that from the reference voxel. This method is not susceptible to bias introduced by "threshold" levels necessary for MRI of fat tissue. However, to the best of our knowledge, no study has been reported in comparing the measurement of abdominal fat through MRS vs. MRI in humans. In this study, we have used both MRS and MRI methods to measure abdominal fat weight on a cohort of human subjects.

Methods. ***Subjects***: 31 subjects (28F/3M: n=21 with BMI > 30 kg/m^2 and n=10 with BMI < 30 kg/m^2) were studied. 17 obese subjects were also studied after 6-wk low fat (LF, n=17) or low carbohydrate (LC, n=17) weight-loss diets in a randomized cross over design. ***MRI:*** T1-wt transaxial images with a 256 × 256 matrix covering a 48 cm field of view (FOV) were obtained on a GE Signa 1.5T MRI scanner (Milwaukee, WI) using the standard body coil on subjects in a prone position with the arms extended. Slice thickness was 6 mm with a 4-mm gap so each slice of image represents 10-mm thickness. Spin echo image sequences were selected (TR/TE= 400/14 ms) with respiratory compensation. Transaxial images were obtained in three segments with each covering 14 cm, between the chest to the level of the pelvic floor. ***MRS***: Abdominal MRS were acquired by using STEAM sequence (TR/TE= 4,000/15 ms). L_{2-3} position (intervertebral disk between the 2nd and 3rd lumbar vertebrae) was measured via the sagittal image and the region of interest (ROI) was chosen to cover the whole axial abdomen area based on transaxial images (Fig.1a). Three acquisitions of 6-cm slabs were performed: 6 cm above L_{2-3} (L_{2-3} + 6) to L_{2-3}, L_{2-3} to 6 cm below L_{2-3} (L_{2-3} – 6), and 6 cm below to 12 cm below L_{2-3} (L_{2-3} -12). Spectra on two small voxels of 4~8 cm^3 located in left and right sides of SF (Fig.1b) were also acquired using the same parameters as the reference. ***Calculation of abdominal fat weight. MRI:*** Abdominal fat was manually selected in the 18 T1-wt MR images ranging from L_{2-3} + 6 to L_{2-3} - 12, using "threshold tool" in Adobe Photoshop® (7). SF (Fig.1c) and intra-abdominal fat (IAF, Fig.1d) were analyzed separately. The weight of abdominal fat was calculated by multiplying the respective fat volume (liters) by the assumed constant density of adipose tissue (0.9196 kg/l) and fat composition in adipose tissue (84.7% fat) (8). ***MRS:*** All spectra were fitted in NUTS (Acorn NMR, Livermore, CA). The peak intensity under the fat region in Fig.1e was normalized to that from 0 to 3 ppm in Fig.1f from a small voxel in SF of known volume. Fat weight from three 6-cm slabs covering L_{2-3} + 6 to L_{2-3} - 12 was then calculated accordingly.

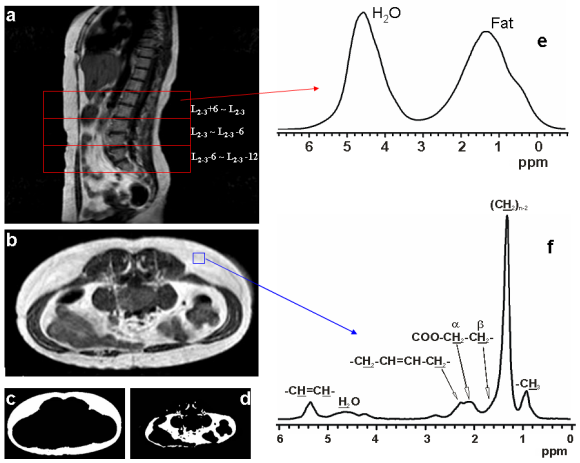

Fig.1 A typical T1-wt sagittal image showing three different 6-cm slabs for MRS acquisition (a), transaxial image of abdomen with a small voxel placed in SF (b) and SF (c) and IAF (d) were separated and quantified after converting image to black and white binary images. (e) and (f) are the representative ^{1}H-NMR spectra from a 6-cm slab and a small fat voxel in SF.

Results. The ^{1}H-NMR spectrum from a 6-cm slab in abdomen shows two broad peaks (Fig.1e): the peak centered at 1.3 ppm is the resonance from CH_2 and CH_3 proton of triglyceride (TG) acyl chains. The broad peak at 4.6 ppm is mainly water protons plus double bond protons of TG acyl chains. Even when the slice thickness was decreased to 1 cm, the spectrum still does not show more resolved resonances (spectrum not shown here). However, the ^{1}H-NMR spectrum from a much smaller voxel, e.g., ~8 cm^3, in SF region gives more resolved resonances (Fig.1f). The CH_3 peak at 0.9 ppm overlaps slightly with $(CH_2)_{n-2}$ peak at 1.3 ppm while double bond proton resonance at 5.3 ppm is well separated from water proton resonance and other resonances.

The abdominal fat weight as measured by MRS is well correlated with that as measured by MRI (slope = 1.117, r^2 = 0.880, $p<0.001$) as shown in Fig.2. The better resolved spectra from a small voxel in SF provide additional information other than as the reference for abdominal fat measurement by MRS. The proton intensity ratio of the double bond proton peak at 5.3 ppm to $(CH_2)_{n-2}$ proton peak at 1.3 ppm was monitored after weight-loss diet. Compared to baseline before weight loss (BL: 0.097 ± 0.020), the ratio after LF diet (0.100 ± 0.004) was not changed while it decreased slightly but significantly after LC diet (0.087 ±0.002. $p < 0.001$ vs. BL).

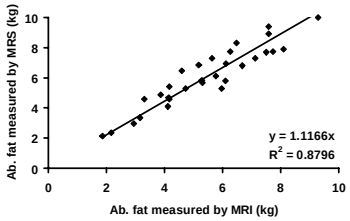

Fig.2 Abdominal fat measured through MRS vs. MRI.

Discussion and Conclusion. Both MRI and MRS can be used to measure abdominal adipose tissue weight in obese and non-obese subjects. The results from both methods correlate very well as shown in Fig. 2. This shows that MRS and MRI provide the same measures of the abdominal fat weight. Nevertheless, currently MRS alone cannot be used to determine the weight of SF or IAF. MRI is still a better choice since the transaxial images can be analyzed separately for SF and IAF. A set of MRI images covering a large range of body sizes can be acquired within a short time and they can provide information such as regional differences of the abdominal fat depots. Though the MRS method can also provide similar information, it usually requires a longer acquisition time. However, MRS on a small voxel in SF can give unique information unavailable by MRI. The signal intensity ratio of double bond proton to $(CH_2)_{n-2}$ proton from TG acyl chain decreased after the LC diet indicating that fat with increased levels of saturated fatty acids may be stored in adipose tissue with a LC diet high in fat content.

In conclusion, this study demonstrates that abdominal adipose tissue weight can be measured by MRS or MRI methods. Both methods are quantitatively comparable. MRI is a convenient and reliable method for assessment of adipose tissue. MRS, on the other hand, can provide unique information such as changes in TG fatty acid composition with different diets.

References. 1. Gan SK et al. Obes Res 11: 1295-1305, 2003. 2. Puche ME et al. Diabetes 54: 770-777, 2005. 3. Abate N et al. Diabetes 45: 1684-1693, 1996. 4. Miyazaki Y et al. Am J Physiol Endocrinol Metab 283: E1135-1143, 2002. 5. Sironi AM et al. Hypertension 44: 127-133, 2004. 6. Machann J et al. J Magn Reson Imaging 21: 455-462, 2005. 7. Gronemeyer SA et al. Magn Reson Imaging 18: 815-818, 2000. 8. Abate N et al. J Lipid Res 35: 1490-1496, 1994. 9. Weis J et al. Magn Reson Imaging 19: 1239-1243, 2001.