Overestimation of liver fat content in fast Dixon-based MRI method compared with multi-voxel MR spectroscopy quantification.

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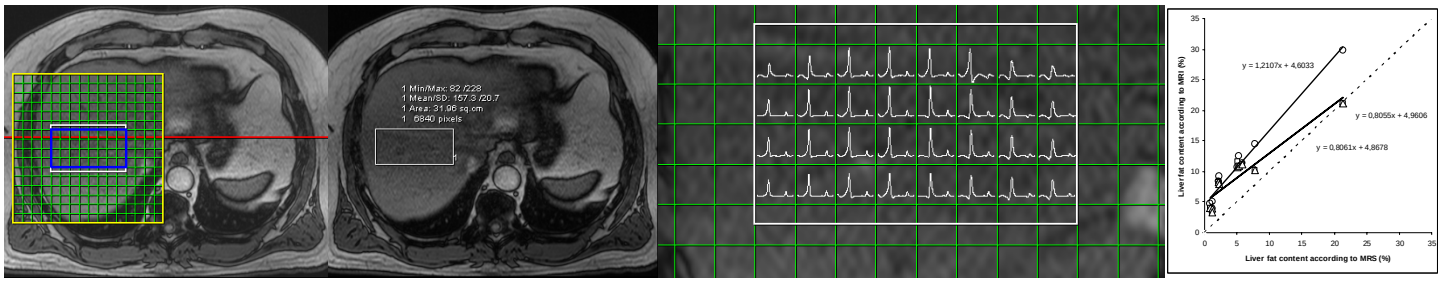
Purpose A recently published Dixon-based MRI method for quantifying liver fat content using dual-echo breath-hold gradient echo imaging was validated by phantom experiments and compared with results of biopsy in two patients (1). We applied this method in ten healthy volunteers and compared the outcomes with the results of MR spectroscopy (MRS), the gold standard in quantifying liver fat content. Novel was the use of spectroscopic imaging yielding the variations in fat content across the liver rather than a single value obtained by single voxel MRS.

Methods We used ^{1}H MRS to determine the lipid concentration in the livers of 10 healthy subjects (body mass index 20-34 kg/m2, age 22-58 years). In both MRI and MRS, performed using a 1.5 T Siemens Sonata system, a large flex coil placed over the liver was used simultaneously with the spine array coil as receiver. For MRS hybrid 2D-chemical shift imaging (CSI), using PRESS with a TR of 5000 ms and a TE of 30 ms, was performed using a field of view of 16x16 cm^2 and a volume of interest of 5x8x4 cm^3 positioned inside the liver. The CSI measurement took 16x16x5s = 1280 sec or 21 min. Water suppression was not applied in order to be able to calculate the fat-water ratio distributions in liver directly. Fat to water ratios, defined as usual by the ratio of the curve fitted -CH_2- lipid signal (1.3 ppm) divided by the sum of the same lipid signal and that of H_2O (4.7 ppm), are equal to the weight fat/(fat+water) ratio because the relative hydrogen contents of water and fat are identical (approximately 11%). Determination of the fat contents for each of the above mentioned 24 MRS voxels thus led to estimates of the mean value and heterogeneity (standard deviation) in the liver fat content of patient and volunteers. At the used TR of 5s T1 saturation of the water and fat signals is negligible and at TE = 30 ms the correction required to compensate for the fact that the fat signal has a longer T2 than that of water, should be in the order of 10% (2,3). Our data have not been corrected for this. MRI of the liver was performed by using a breath-hold dual-echo T_1 weighted gradient echo sequence with a 6 mm slice thickness, section gap 0 mm, matrix 256x160 and a repetition time (TR) of 155 ms. Dual-echo spoiled gradient recalled images were acquired with TE = 2.4 ms (OP) and TE = 4.8 ms (IP) and flip angles of 70^o and 20^o to generate T_1-weighted and intermediate-weighted images, respectively. These images were corrected for T_2^* decay using $S_{corrected} = S\,e^{\frac{\tau}{T2^*}}$,where τ is the echo time difference between IP and OP images, and *S* represents the signal intensity in a defined region of interest (ROI) (1). Under these conditions τ = 2.4 ms combined with T_2^* = 19.44, calculated from the mean spectral line width of the water peak in human liver measured by MRS in the ten volunteers, gave a correction factor of 1.13 for S_{ip} relative to S_{op}. The recently published algorithm for estimating fat content consists of (a) adjustment for T_2* relaxation using the above equation, (b) calculation of the apparent fat content using $\%\,fat = \frac{(S_{IP} - S_{OP})}{2S_{IP}} \times 100\%$ for both intermediate or hydrogen density weighted, (%fat_{Hwt} at 20^o flip angle) and T1-weighted (%fat_{T1wt} at 70^o flip angle) image pairs, and (c) if %fat_{Hwt} ≤ %fat_{T1wt}, then %fat = %fat_{Hwt}; otherwise, %fat = 100% - %fat_{Hwt} (1).



Figures: MRS volume of interest (32 voxels), the same VOI reproduced for MRI analysis (7 slices), spectral map showing water and fat peaks and plots of the MRI determined fat percentages as a function of the liver fat content according to MRS, with linear fit lines. o = T_1-weighted MRI series (70°); □ = Intermediate weighted MRI series (20°); Δ = Corrected algorithm using T_1-weighted and Intermediate weighted MRI series.

Results Compared with results of MRS, liver fat content according to MRI was too high in nine subjects (range 3.3-10.7% vs. 0.9-7.7%) and correct in one (21.1 vs. 21.3%). Furthermore, in one of ten subjects the MRI fat content according to the Dixon-based MRI method was incorrect due to a (100-x) versus x percent lipid content mix-up. The second problem can be fixed by a minor adjustment of the MRI algorithm. Despite systematic overestimation of liver fat contents by MRI, Spearman's correlation between the adjusted MRI liver fat contents with MRS was high ($r = 0.927$, $P < 0.001$). Even after correction of the algorithm, the problem remaining with the Dixon-based MRI method for the assessment of liver fat content, is that, at the lower end range, liver fat content is systematically overestimated by approximately 3%.

Discussion Further studies on larger study populations are needed to confirm the descrepancies between MRI and MRS results in a broader range of liver fat content. An advantage in clinical practice of being able to use an MRI method rather than multiple voxel MRS would be the smaller patient examination time (5 min vs. 21 min). The problem with Dixon-based MRI methods appears to be that at the lower and range the liver fat contents are systematically overestimated as compared with MRS (present study) or results obtained at histology (4). Alternative MRI methods using chemically selective saturation might be preferable (5,6) and should in future studies be compared with the results of spectroscopic imaging.

References 1.Hussain et al. Hepatic fat fraction: MR imaging for quantitative measurement and display-early experience. Radiology 2005;237:1048-1055. 2.Longo R, et al. Fatty infiltration of the liver; quantification by^{1}H localized magnetic resonance spectroscopy and comparison with computed tomography. Invest Radiol 1993:4:297-302. 3.Thomsen C, et al. Quantification of liver fat using magnetic resonance spectroscopy. MRI 1994; 12:1994;12:487-495. 4.Biglands et al. Comparison of MRI and histopathologic methods of quantifying hepatic liver fat fraction. ISMRM 2007; abstract 2701. 5. Machan et al. Hepatic lipid accumulation in healthy subjects;a comparative study using spectral fat-selective MRI and volume-localized^1 H MR spectroscopy. MRM 2006;55;913-917. 6.Cotler et al. Measurement of liver fat using selective saturation at 3.0T. JMRI 2007:25:743-748.