Magnetic resonance imaging and spectroscopy for measuring hepatic steatosis

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Introduction:

Recognition of the role of steatosis in liver injury and impaired response to treatment, has led to a need for accurate, non-invasive methods to quantify liver fat content. Magnetic resonance spectroscopy (MRS) has become the standard for research, but has yet to be adopted in routine clinical practice where biopsy is still the gold standard. The current lack of universal availability of MRS on clinical MRI systems also limits its clinical application. We compared assessment of liver steatosis using biopsy, MRS and imaging techniques.

Methods:

Twelve patients who had a liver biopsy arranged as part of their clinical management were invited to participate in this study. Sequential patients with none (n=1), mild (n=4), moderate (n=4) or severe (n=3) steatosis, were recruited and underwent hepatic MRI and MRS within one month of their liver biopsy. Standard sequences on a Siemens Sonata (Erlangen, Germany) were used: (i) PRESS based single voxel spectroscopy, TE = 30ms, TR = 3 sec, voxel 20X20X20 mm, no water suppression and NEX=4 in a single breath-hold; (ii) Siemens FLASH based in phase/out of phase (IP/OP) images, TE = 2.38ms and 5.04, TR=70 ms, 20 slices of 8mm thickness, NEX=1 in a single breath-hold (iii) T2 weighted HASTE images with TE=121ms, same geometry as IP/OP images, NEX=2 using navigator respiratory gating during free breathing with and without fat suppression (± fat sat). All analysis was performed on the Siemens console. Liver fat derived from spectroscopy was expressed as a percentage using (CH2 + CH3)/ (H2O + CH2 + CH3)*100. Liver fat from IP/OP and ± fat sat images was estimated from the image intensity difference between fat edited pairs of images divided by the non-edited image e.g., ((IP-OP)/IP)*100, by placing a circular region-of-interest (ROI) of approximately 5 cm^2 in a homogeneous region of liver tissue. Percent steatotic hepatocytes in liver biopsy sections was determined by an experienced hepatopathologist, blinded to the laboratory parameters and clinical data. The correlations between histology, ^{1}H MRS and MRI were assessed using Spearman's non-parametric correlation coefficient (r_s) Reproducibility of MR methods was assessed by repeating a single subject 6 times between 9am and midday. Four MRS voxels were positioned in the liver with 4 ROI's in corresponding positions to assess the image protocols (Table 1).

Results and Discussion:

Comparison of biopsy with MRI and MRS:

Extremely good correlation was demonstrated between histological assessment of steatosis and measurement of intrahepatocellular lipid (IHCL) with all three methods. MRS (rs=0.928, p<0.0001); IP/OP (rs=0.942, p<0.0001); +/-fatsat (rs=0.935, p<0.0001).

Reproducibility:

Mean±SD (CofV)	R-lobe, posterior	R-lobe, anterior	Left lobe	R-Lobe Central
Spectroscopy	11.2 ± 0.4 (3%)	10.7 ± 0.8 (7%)	8.6 ± 1.1 (13%)	10.8 ± 0.7 (6%)
Phase edited	30.7 ± 3.1 (10%)	33.3 ± 2.6 (8%)	30.3 ±5.2 (17%)	33.7 ± 4.4 (13%)
Fat sat edited	27.6 ± 1.7 (6%)	32.3 ± 2.2 (7%)	26.5 ± 2.4 (9%)	30.4 ± 2.4 (8%)

Table 5. Reproducibility of spectroscopy and imaging techniques, using difference calculation, for measurement of liver steatosis, mean ± standard deviation (Coefficient of Variation), units; MRS, % H2O peak; MRI, intensity difference as %.

Liver fat estimation by MRS and fat edited MRI, both phase and ± fat saturation, were highly correlated to histological estimation from biopsy. Reproducibility results from the left lobe gave consistently higher CofV and lower estimates of liver steatosis. Factors that may contribute to this include, inhomogeneity of steatosis throughout the liver and the smaller size of the left lobe limiting the placement of the MRS voxel and image ROI to avoid vessels.

These findings support the use of standard MRI protocols to accurately assess the degree of hepatic steatosis, which will provide significant benefit to the clinical management of obesity, liver disease and diabetes.