In Vivo MR Quantification of Liver Fat Content in Obese Mice: Comparison of Dual-Echo Dixon Imaging, Chemical Shift Selective Imaging and Hydrogen MR Spectroscopy

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INTRODUCTION

During the past decade, there has been evidence of an epidemic increase in the non-alcoholic fatty liver disease. Fatty liver often leads to obesity, insulin resistance and metabolic syndrome. Liver fat quantification has generated considerable interest; it may be of clinical importance to be able to reliably measure liver fat content (FC). Noninvasive analysis of fat quantification by MR would have major advantages. Present study aims to evaluate dual-echo Dixon (in-phase and out-of-phase, IP-OP) MR imaging, chemical shift imaging (CSI), and MR spectroscopy (MRS) in estimating FC in livers of obese and normal mice. at high field 7.0 Tesla MR.

METHODS

Experimental paradigm was proposed based on single-voxel proton MRS, water or fat selective CSI method and dual-echo Dixon in-phase and out-of-phase method. Three MR methods were performed to measure FCs in livers of six *ob/ob* and six wild type (WT) mice using 7T micro-MR scanner. The results were compared to reference standard from mice by histological semi-automatic vacuole segmentation procedure (HIS-S) and liver lipid (LL) chemical analysis. Independent-sample t test, paired-sample t test and correlation test were performed in comparison.

RESULTS

In vivo, liver FC in *ob/ob* mice measured by all three MR methods was significantly higher than that of WT mice ($P < .01$). For *ob/ob* mice, liver FC measured by IP-OP are significantly lower than that measured by CSI and MRS ($P = .000$) with no significant difference between CSI and MRS ($P = .612$). CSI and MRS showed a linear correlation with LL ($r = 0.996$ and 0.912, respectively, $P < .05$) and with each other ($r = 0.937$, $P < .01$). For WT mice, FC measured by IP-OP was significantly lower than that measured by CSI ($P = .000$), but no significant difference compared to MRS and HIS-S ($P = .104$ and .420, respectively). CSI showed a linear correlation with LL ($r = 0.996$, $P < .05$).

CONCLUSION

IP-OP MR imaging underestimated FC, while CSI and MRS are more accurate for quantifying fat in liver. CSI and MRS have the potential to replace HIS-S and LL analysis in longitudinal studies

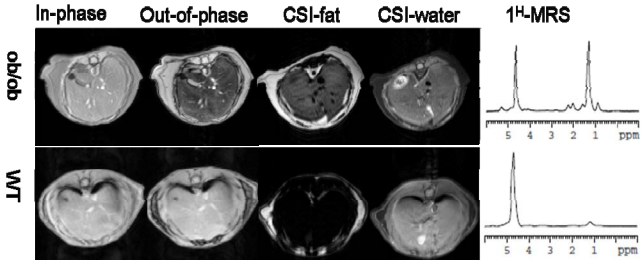

Fig 1. *In vivo* Dixon dual-echo IP-OP MR imaging, CSI and ^{1}H MRS and lipid quantification in mice liver.

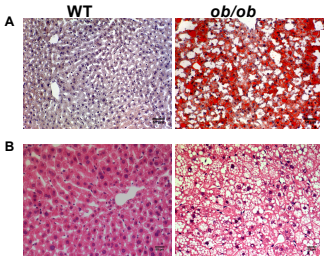

Fig 2. Histology of liver from ob/ob mice and WT mice (scale bar, 50 μm). A: Oil Red O staining (× 200); B: H&E staining (× 200).

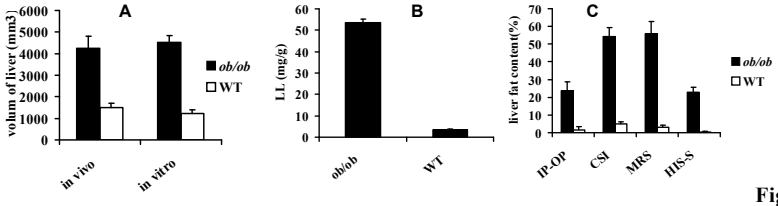

Fig 3. *In vivo* and in vitro measurements of volume of liver, liver FC and LL in mice. A: liver volume measured in vivo and in vitro; B: LL calculated by chemical method; C: liver FC measured by IP-OP, CSI and ^{1}H MRS in vivo and by HIS-S in vitro.

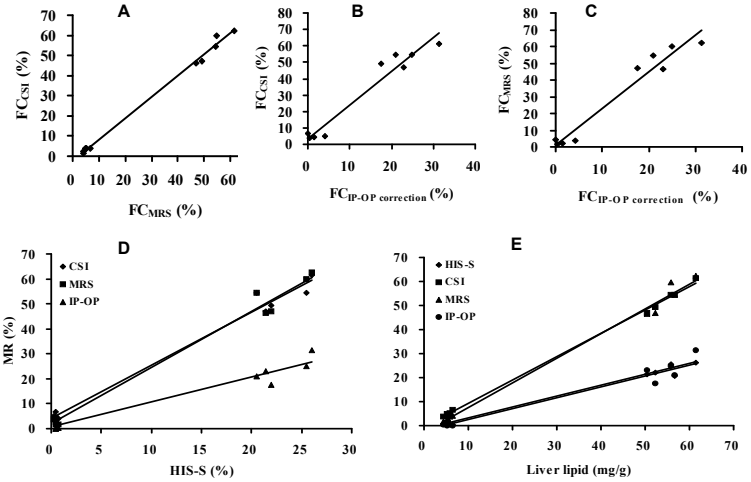

Fig 4. Graph shows relationship between FC in liver performed by using three MR methods in vivo and that measured by using histological and chemical methods in vitro. A, B, C: Correlation between corrected IP-OP, CSI, MRS (FC_{CSI} and FC_{MRS}, $r = 0.998$, FC_{CSI} and $FC_{IP\text{-}OP}$ correction, $r = 0.977$, FC_{MRS} and $FC_{IP\text{-}OP}$ correction, $r = 0.980$, respectively, $P < 0.001$); D: Correlation between HIS-S and three MR methods ($FC_{HIS\text{-}S}$ and $FC_{IP\text{-}OP}$ correction, $r = 0.978$, $FC_{HIS\text{-}S}$ and FC_{CSI}, $r = 0.994$, $FC_{HIS\text{-}S}$ and FC_{MRS}, $r = 0.994$, respectively, $P < 0.001$); E: Correlation between chemical method and three MR methods and HIS-S (LL and $FC_{HIS\text{-}S}$, $r = 0.994$, LL and $FC_{IP\text{-}OP}$ correction, $r = 0.973$, LL and FC_{CSI}, $r = 0.999$, LL and FC_{MRS}, $r = 0.996$, $P < 0.001$).

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