Clinical Evaluation of Fast T2-Corrected MR Spectroscopy Compared to Multi-Point 3D Dixon for Hepatic Lipid and Iron Quantification

Puneet Sharma¹, Xiaodong Zhong², Jean-Philippe Galons³, Bobby Kalb³, Maria Altbach³, and Diego R Martin³

¹Medical Imaging, University of Arizona, Tucson, Arizona, United States, ²MR R&D Collaborations, Siemens Healthcare, Atlanta, GA, United States, ³Medical Imaging, University of Arizona, Tucson, AZ, United States

Target Audience: Translational Scientists, Body Radiologists, Sequence Developers

Background: Advanced MR imaging, using multi-point Dixon reconstruction, allows 3-dimensional assessment of hepatic fat fraction (FF) and local R2*, which is a surrogate for iron concentration (1-5). In addition, a high-speed, T2-corrected single-voxel spectroscopy (HISTO-MRS) approach has been developed to interrogate hepatic water and lipid compartments, and to elucidate FF and R2 values of these components in a single breath hold (6). Thus far, this fast single breath-hold HISTO-MRS has not been formally evaluated in the clinical environment, nor compared to current 3D multi-point Dixon imaging in terms of lipid and iron estimation.

Purpose: 1) To evaluate breath hold HISTO-MRS in a routine clinical environment, in consecutive patients; 2) To correlate hepatic FF from HISTO-MRS and 3D multi-point Dixon at 1.5T; and 3) to compare HISTO-R2 measures with R2* for sensitivity to iron content.

Methods: This investigation was approved by the IRB, was HIPPA-compliant, and all participants signed informed consent prior to imaging. All imaging was performed on a Siemens 1.5T Aera system using an 18-channel phased-array body coil. Thirty-nine consecutive patients arriving for routine abdominal MRI over a two week period were recruited for this study. The exclusion criteria consisted of standard MR contraindications. Each patient received two additional breath hold acquisitions: 1) single-voxel HISTO-MRS; and 2) 6-point 3D GRE (3D Dixon FQ). The HISTO-MRS voxel was prescribed using available T2-weighted single-shot localizer acquisitions. The voxel was placed in a region free of major hepatic vessels, usually in the right lobe. The MRS parameters were: STEAM sequence; TR/TM = 3000ms/10ms; 5 TEs = {12, 24, 36, 48, 72}ms; voxel = 20-30mm3; 1 signal average; time = 15sec. The 3D Dixon FQ sequence consisted of 80 slices prescribed to cover the full liver volume. Other parameters included: TR = 9.1ms; 6 TEs = 1.2/2.53/7.5/0.6/3.7/6.2ms; matrix = 256 x 154; FOV = 400-420mm; phase FOV = 75%; slice thickness = 3mm; BW = 1085Hz/px; time = 18sec. Post-processing for both techniques were performed automatically on the scanner console with inline reconstruction. For HISTO-MRS, the integral signal area of both water and total lipid (~1.3 ± 0.8ppm) spectra were automatically tabulated at each TE, whereby T2 of both components (R2water and R2lipid) were quantified using a non-linear least squares algorithm, and a goodness-of-fit measure (r²). The fat fraction (FFHISTO) was calculated from the ratio of T2-corrected lipid integral to T2-corrected lipid + water integral (1). Using a multi-step fitting approach, the 3D Dixon FQ data was processed automatically by fitting the multi-echo data to the magnitude of the complex signal model that included the coefficients and frequency components for a seven-peak fat model (5). Volumetric T2*-corrected fat fraction (FFDIXON) maps were calculated from the fitting, along with R2 maps. Analysis: Mean and standard deviation measurements of FFDIXON and R2* were performed in Clear Canvas Workstation 2.0 (Toronto, CA) from region-of-interests (ROIs) in approximate region of the HISTO-MRS voxel. Agreement of FFDIXON and R2* was performed with Bland-Altman analysis, with measures of bias and 95% confidence limits. Since R2* has been shown to correlate with hepatic iron content (7), Pearson correlation was performed against both R2water and R2lipid. Significance was set to p<0.05.

Results: All patients tolerated the additional MR acquisitions. 1/39 patients were excluded due to large metal artifact, 3/39 3D Dixon FQ cases experienced fat-water “swap”, leading to uncalculated R2 maps, while 1/39 HISTO-MRS case suffered from poor T2 fit (r²<0.6) due to severe iron deposition. Therefore, 34 patients were included in the analysis. For low FFHISTO (< 6.0%, n=22), R2water could not be reliably calculated due to poor lipid SNR. Figure 1 shows representative HISTO-MRS spectra and corresponding FFDIXON and R2* maps in one patient. Figure 2 shows the Bland-Altman plot comparing FFHISTO and FFDIXON. The bias was -0.5%, and 95% confidence was ±4.8%, which represents a significant correlation (r=0.99, p<0.01), despite 1 outlier at high FF (red circle in Fig. 2). R2water measurement from HISTO-MRS correlated significantly with R2* (r=0.87, p<0.01), while R2lipid did not correlate (r=0.12, p=0.5), and remained relatively constant in patients with elevated FF (R2lipid = 20.5 ± 4.1s⁻¹, FF > 8.0%, n=7).

Discussion: With automatic post-processing, HISTO-MRS was efficiently performed in a routine clinical setting. Significant agreement in FF was found between HISTO-MRS and 3D Dixon FQ. From the behavior of R2water and R2lipid, the results also confirm that hepatic iron content affects R2water compartment more significantly than R2lipid. Limitations of the current HISTO-MRS include poor estimation of severe iron deposition (due to long initial TE) and unreliable R2lipid for low FFHISTO.

Conclusions: Both HISTO-MRS and 3D Dixon FQ are viable clinical methods for the estimation of hepatic fat fraction (FF) and iron content (R2* and R2water).