Reproducibility of MRI-Determined Proton Density Fat Fraction (PDFF) across MR Scanner Platforms and Field Strength

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Introduction: As a result of the growing epidemic of obesity in adults and children, fatty liver disease (FLD) has become the most common liver condition in the United States. [1] FLD contributes to the development of cardiovascular disease and type II diabetes and it may progress to cirrhosis and hepatocellular carcinoma. [2] The current clinical gold standard for diagnosis and monitoring of FLD is liver biopsy. Because of its invasiveness, liver biopsy is suboptimal for screening and repeated measurements. These limitations have hampered progress in clinical care and research in FLD. Thus, there is an increasing clinical and research need for a noninvasive fat quantification technique. While conventional MR imaging is often used to detect liver fat, it is rendered inaccurate for quantifications by the confounding effects of relaxation and multi-peak spectral interference. [3,4] To address these confounders, new T1-independent, T2*-corrected, spectral modeled chemical shift based fat quantitation techniques have been developed. These techniques can be implemented using either magnitude or complex data and permit estimation of the proton density fat fraction (PDFF), the fraction of mobile protons in liver tissue attributable to fat. In prior studies, these techniques have shown high accuracy for fat quantification using MR spectroscopy (MRS) as the reference standard. [5] To our knowledge, all prior studies have been single field strength studies performed on a single MRI platform. In order to be accepted as a clinical and research biomarker, the use of MRI-determined PDFF needs to be further validated. Confirmation that MRI-determined PDFF is independent of field strength and MR scanner is an important step in validation. The primary purpose of this study was to evaluate the reproducibility of MRI-determined PDFF across field strengths and MR scanner platforms. The secondary purpose was to evaluate the accuracy of MRI-determined PDFF using MRS-determined PDFF as the reference standard. In this study we utilized a magnitude based MRI sequence that can be implemented easily on different scanner platforms.

Materials and Methods: In this HIPAA-compliant, IRB-approved prospective clinical study, 30 human subjects (16 men, 15 women; median age, 31 years; range, 10-63 years) were enrolled after giving informed consent. All participants underwent MR imaging of the liver at both 1.5T (Siemens Symphony scanner) and 3T (GE Sigma scanner). 24 subjects had MRS at 1.5T and 24 subjects at 3T (20 had MRS at both 1.5T and 3T). 1.5T and 3T MR examinations were performed on the same day in random order. MRI-determined PDFF was estimated using a 2D axial GRE imaging sequence with low flip-angle to minimize T1 effects and multiple echo-times to permit T2* correction. The applied imaging parameters at each scanner are summarized in Table 1. MRS-determined PDFF was estimated using a single-voxel STEAM sequence with long repetition time to minimize T1 effects and multiple echo-times to permit T2 correction. Using a Picture Archiving and Communication System (PACS), three circular regions of interest (ROIs), approximately 400 mm2, were manually placed on one of the multi-echo images. The first ROI was colocalized to the 1.5T MRS voxel. The second ROI was colocalized to the 3T MRS voxel. A third separate ROI was placed in the right hepatic lobe away from either MRS voxel location. The selected ROIs were automatically propagated to the rest of the multi-echo images. The average ROI value at each TE was recorded. MRI-determined PDFF was calculated from T2*-corrected fat and water signals using a 5-peak chemical shift based fat quantification technique. 

Results: Based on MRS, the population sample had mean PDFF of 15.0% (range 0.1-38.8%). At least 4 subjects had PDFF in each of the following ranges: 0-5%, 6-10%, 11-15%, 16-20% and >21%. The linear regression analysis (Figure. 1) compares the PDFF at 1.5 and 3.0T, where the diagonal line represents equality in PDFF calculated from 1.5T and 3T MR imaging. The differences between the 1.5T and 3T PDF estimates were minimal (1.07% (p <0.0001) at 1.5T and 0.99% at 3T), and statistically significant. (P<0.001 for both parameters). Using MRS data as a reference standard, MRI-determined PDFF had high accuracy. The regression slope between MRS- and MRI-determined PDFF was 0.99 at both 1.5T and 3T (Figures 2 and 3), with the MRI-determined PDFF estimates consistently higher than MRS-determined PDFF estimates by 1.07% (p <0.0001) at 1.5T (Figure.2) and lower by 1.24% (p =0.007) at 3T (Figure.3).

Conclusion: MRI-determined PDFF quantification is reproducible across field strengths and MR scanner platforms and shows high accuracy using MRS-determined PDFF as the reference standard.

References:

Table 1: Imaging Parameters of MR Scanners

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<thead>
<tr>
<th></th>
<th>1.5T</th>
<th>3T</th>
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<tbody>
<tr>
<td>TR (msec)</td>
<td>120-150</td>
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<tr>
<td>TE (msec)</td>
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<tr>
<td>FA</td>
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<td>10</td>
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<tr>
<td>ST (mm)</td>
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<tr>
<td>GAP</td>
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Figure 1: MRI vs. MRS Determined PDFF at 1T

Figure 2: MRI vs. MRS Determined PDFF at 1.5T

Figure 3: MRI vs. MRS Determined PDFF at 3T