Accuracy of liver fat quantification by CT, MRI and US: a prospective comparison with Magnetic Resonance Spectroscopy (MRS)

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Target audience: Clinicians interested in quantitative imaging biomarkers for fatty liver disease.

Purpose: The hallmark feature of non-alcoholic fatty liver disease (NAFLD) is the accumulation of triglycerides within hepatocytes (steatosis), which can lead to inflammation, fibrosis, and cirrhosis [1]. Magnetic resonance spectroscopy (MRS) is widely considered to be the non-invasive reference standard for accurate quantification of fat in the liver [2]. The purpose of this study was to evaluate the accuracy of quantitative confounder-corrected chemical shift-encoded (CSE) MRI [3], single- and dual-energy computed tomography (CT) and ultrasound (US) to quantify hepatic steatosis, using MRS as the reference.

Methods: 50 patients (56±5 years, 23m/27f, 27±5 BMI) scheduled for non-contrast screening CT colonography (CTC) were recruited for this prospective comparative study. All patients underwent MRS, MRI and US within 2 hours of CTC. For MRS, multi-echo T2-corrected STEAM (stimulated echo acquisition mode) was used with three independent 20x20x20mm^3 voxels placed in the left (1) and right (2) lobes of the liver. CT, MRI and US measurements were subsequently co-localized (figure 1). For CT, fat-density (FD) derived material decomposition of DECT in addition to conventional attenuation at both 70 and 140keV were recorded. Acquisition parameters for DECT included 70/140 keV and 1.25mm slice thickness. For MRI, proton density fat-fraction (PDFF) measured from the quantitative chemical shift-encoded method (IDEAL-IQ, 256x160 matrix, 8mm slice thickness, 28 slices, 5º flip angle, ±125kHz receiver bandwidth, TR=13.6ms, and 6 echoes with TE_1=1.20ms, ΔTE=1.98ms) were recorded. For US shear-wave velocity was also recorded. Data were analyzed using linear regression for each technique compared to MRS. 2-sided paired Student t-tests (0.05 significance level) were used to test the hypothesis that the slope coefficient is zero.

Results: There was excellent correlation between MRS-PDFF vs MRI-PDFF (r^2=0.96-0.99, p<0.05) and MRS vs mono energetic CT-HU (70keV r^2=0.88-0.92, p< 0.05, 140keV r^2=0.81-0.91, p< 0.05). CT-FD showed moderate correlation with MRS-PDFF (r^2=0.51-0.68, p<0.05). US based metrics did not show reliable correlation with MRS-PDFF (r^2=0.02-0.19, p>0.05) (figure 2).

Discussion: This study was a comparative effectiveness study of three advanced non-invasive biomarkers of hepatic steatosis. Quantitative CSE-MRI and CT attenuation showed excellent correlation to MRS. Material decomposition with DECT (CT-FD) did not improve the accuracy of fat quantification over conventional attenuation. US had poor accuracy for liver-fat quantification.

Conclusion: MRI and mono energetic CT-HU are accurate biomarkers of hepatic steatosis. Dual-energy CT material decomposition does not improve the accuracy of CT for quantifying liver fat. US accesses liver stiffness but cannot be used to quantify hepatic fat content. A major benefit of MRI and CT is the evaluation of the entire liver tissue instead of only small samples like in biopsy and MRS.

Figure 1: Representative images of MRI PDFF (A), DECT material decomposition (B), mono energetic CT-HU at 70keV (C) and 140keV (D) as well as an US-SW measurement (E). Because of the nearly similar attenuation values of fat and water a separation with DECT is very prone to artifacts (B).

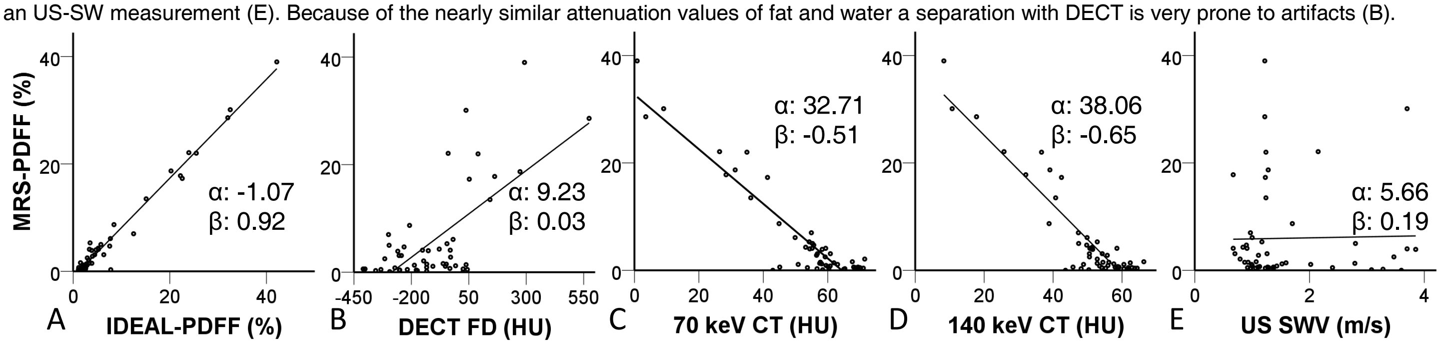

Figure 2: PDFF MRI shows excellent correlation to MRS (A). DECT material decomposition as well as mono energetic CT HU show moderate and good correlation to MRS respectively (B, C, D) whereas US feature only poor correlation (E) to the accepted standard MRS. Representative plots from a region placed in the anterior part of the right lobe. (α: intercept, β: slope)

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