Magnetic Susceptibility as a Field-Independent MRI Biomarker of Liver Iron Overload

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Target audience: Basic researchers working on MR-based susceptibility measurement, and clinical scientists working on iron quantification.

Purpose: Liver iron quantification is needed for diagnosis, staging and treatment monitoring of iron overload (1). MR-based quantification of liver magnetic susceptibility may enable field strength-independent measurement of liver iron concentration (LIC). However, susceptibility measurement is challenging, due to the non-local effect of the susceptibility distribution on the measured B_0 (2). The purpose of this work is to demonstrate feasibility of MR-based LIC quantification using a fat-referenced approach to estimate liver susceptibility from the measured magnetic field map.

Methods: After IRB approval and obtaining informed consent, 27 subjects (9 controls and 18 volunteers with liver iron overload) were scanned at both 1.5T (HDxt, GE Healthcare, Waukesha, WI) and 3T (GE MR750). Spin-echo acquisitions at 1.5T were used as reference R2-based LIC measurements (Ferriscan). Multi-echo 3D SPGR sequences at both 1.5T and 3T were used for fat-water separation, B_0- and R2*-mapping. Liver R2* was measured in each subject. Liver susceptibility (and subsequently LIC) was estimated from the difference in B_0 (ΔB_0, expressed in ppm) (3,4) between the lateral aspect of the right lobe of the liver and adjacent subcutaneous fat. LIC (mg Fe/g dry tissue) was obtained from the measured ΔB_0.

The theoretical relationship between ΔB_0 and LIC can be derived through the known relationships between ΔB_0 and susceptibility (3), susceptibility and wet iron concentration (5), and the wet LIC and dry LIC (6), ie:

$$\text{LIC} = 14.08 \Delta B_0 - 4.07 \Delta\chi_{base} \quad \textbf{[Eq. 1]}$$

where $\Delta\chi_{base}$ is the baseline susceptibility difference between liver and fat tissue, calibrated from a set of control subjects by assigning them an average LIC = 1.0 mg Fe/g dry tissue (7). B_0-LIC estimates were compared to Ferriscan-LIC, and ΔB_0 was compared to liver R2*.

Results: ΔB_0 correlated strongly with R2* (1.5T: r^2=0.86; 3T: r^2=0.93), and B_0-LIC had good agreement with Ferriscan-LIC (1.5T: slope=0.93±0.13, intercept = 1.94±0.78, r^2=0.67; 3T: slope=1.01±0.09, intercept = 0.17±0.52, r^2=0.84).

Discussion: These results illustrate the potential of complex 3D chemical shift-encoded imaging to quantify liver iron through measurement of the B_0 field map. This technique allows simultaneous measurement of PDFF (with 0-100% dynamic range), R2* maps and B_0 field maps. Fat constitutes a promising reference for the development of QSM techniques because of the ability to automatically segment fat tissues using chemical shift-encoded techniques. In this way, PDFF (and potentially R2*) can be used to enable or improve susceptibility measurements based on the B_0 field map.

Conclusion: Susceptibility-based field-independent LIC estimation is feasible by using subcutaneous fat as an internal reference. This approach may enable susceptibility mapping in the abdomen, exploiting the presence of abdominal fat near the organs of interest.

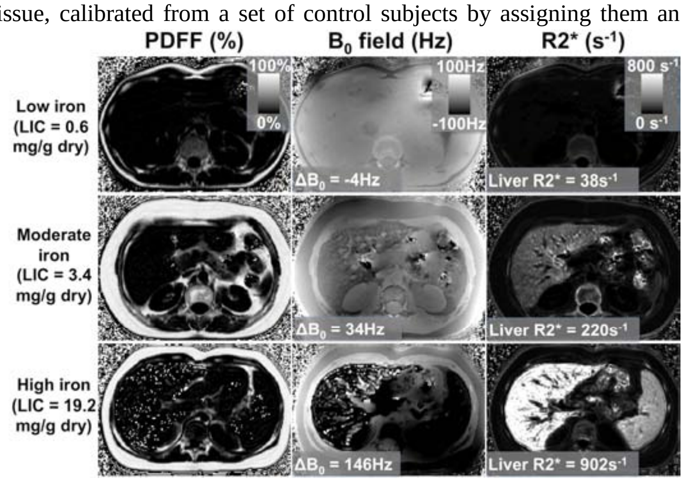

Fig 1: *Example 3T maps of proton-density fat-fraction (PDFF), B_0 field and R2*, in subjects with three different levels of liver iron.*

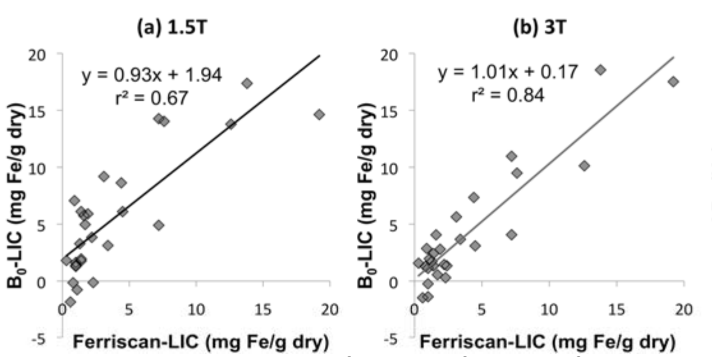

Fig. 2: *LIC predicted by the Bo field map referenced to fat shows good correlation and near agreement at both 1.5T (a) and 3.0T (b).*

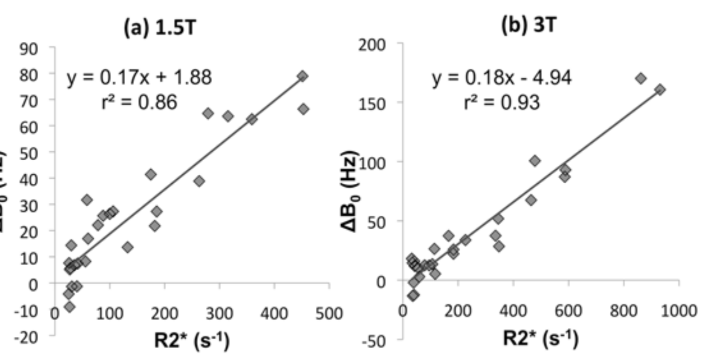

Fig 3: *The Bo field map in the liver referenced to fat correlates very closely with R2*, demonstrating its potential to quantify liver iron*

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