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Liver fat fraction estimation at 1.5T clinical MRI system using a fast in-house software tool: a phantom study

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1. Background-Aim

- Liver Fat Fraction (FF) quantification is essential for the early diagnosis and monitoring of various liver diseases, including Non-Alcoholic Fatty Liver Disease (NAFLD) and metabolic syndrome.
- Accurate assessment of liver FF can help prevent disease progression and aid in the management of liver disorders.
- The DIXON MRI method is widely used for FF estimation, but there's a need to optimize the existing imaging protocols in terms of accuracy and reproducibility

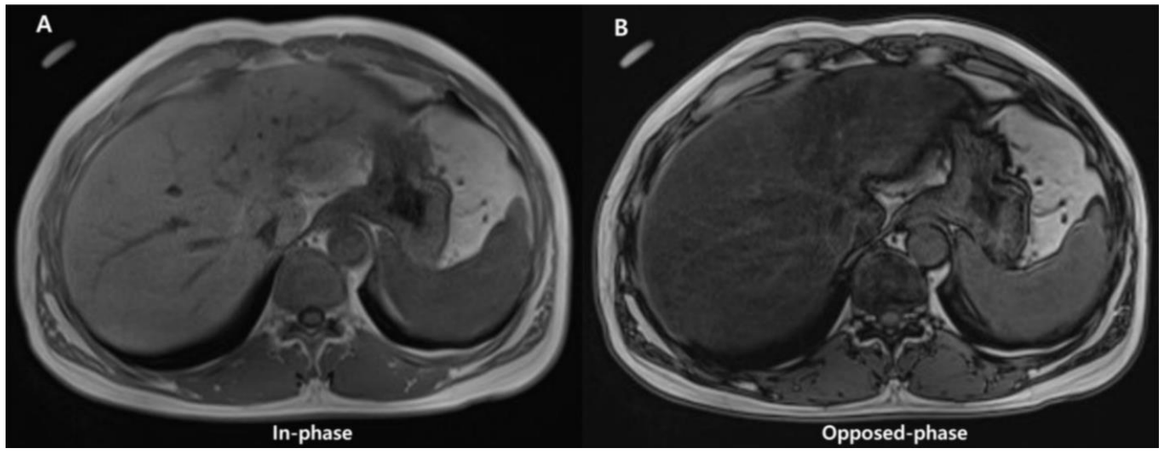


Figure 1. Images of in- (A) and opposed-phase (B) of chemical shift MRI. In (B), the liver parenchymal signal is lower compared with (A) due to signal drop caused by hepatic fat deposition.

Jang W, Song JS. Non-Invasive Imaging Methods to Evaluate Non-Alcoholic Fatty Liver Disease with Fat Quantification: A Review. Diagnostics. 2023; 13(11):1852.

Aim:

- To introduce a novel MRI phantom for simulating Fat Fraction (FF) measurements
- To optimize liver FF quantification with the aid of the multi-component tissue mimicking phantom.
- To compare %FF measurements using a modified Multi-Echo Gradient Echo (MEGRE) Dixon-based technique and a PACS embedded tool.

2. Materials & Methods (I)

1. Phantom Fabrication

- Fat fraction simulation: Different fat fraction values were simulated using materials embedded in 14 test tubes. Each of the 25 mL tubes contained a solution with varying fat content (% w/v) ranging from 0% to 100%.
- Fat component: Peanut oil was chosen to replicate liver triglycerides due to its proton NMR spectrum being similar to those found in adipose tissue triglycerides.
- Materials used: Distilled water, agarose, water-soluble surfactant, sodium benzoate, gadolinium (DTPA) contrast agent, peanut oil, and oil-soluble surfactant.
- Gadolinium-DTPA: Used to simulate the MRI relaxation characteristics of liver tissue.

Figure 1. FF-MRI phantom: Fat content solutions with different fat concentrations (w/v) (0%-100%), Corn Oil (CO) and Double Distilled Water (DWW) test tubes, as they appear in order.

2. MRI acquisition

- Acquisition protocols:
  - -PD-T2* weighted single slice (1 coronal slice, breath-hold MEGRE sequence) with 12 echoes ***(LP-1)***
  - -PD-T2* weighted multiple slice (5 coronal slices, breath-hold MEGRE sequence) with 8 echoes ***(LP-2)***
- MRI clinical scanner: 1.5T MAGNETOM Sonata/Vision (Siemens Healthcare)

2. Materials & Methods (II)

3. MRI Relaxometry

- PDin, PDout: Proton Density of in and opposed phase
- T2*in, T2*out: T2* of in and opposed phase
- Voxel signal parameters: PDin (x, y, z), PDout (x, y, z), T2in (x, y, z), T2out (x, y, z) were determined by fitting equations on a voxel-by-voxel basis in all 3 dimensions (x, y, z).

4. Fat Fraction

- Fat Fraction (%FF) was defined as the relative fat signal intensity amplitude as a percentage of the total signal intensity contributed by water and fat.

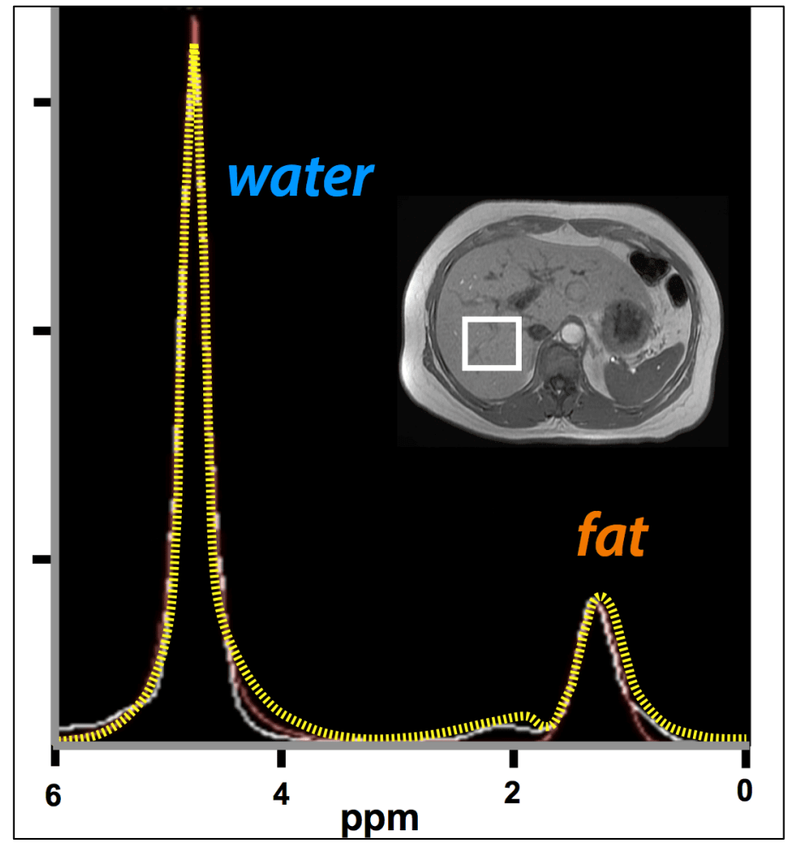


Figure 2. Single-voxel ^{1}H-MRS study of the liver shows dominant water and fat peaks. After correction for T2 effects and modeling, the relative areas under each peak can be used to calculate hepatic fat fraction.
www.mriquestions.com

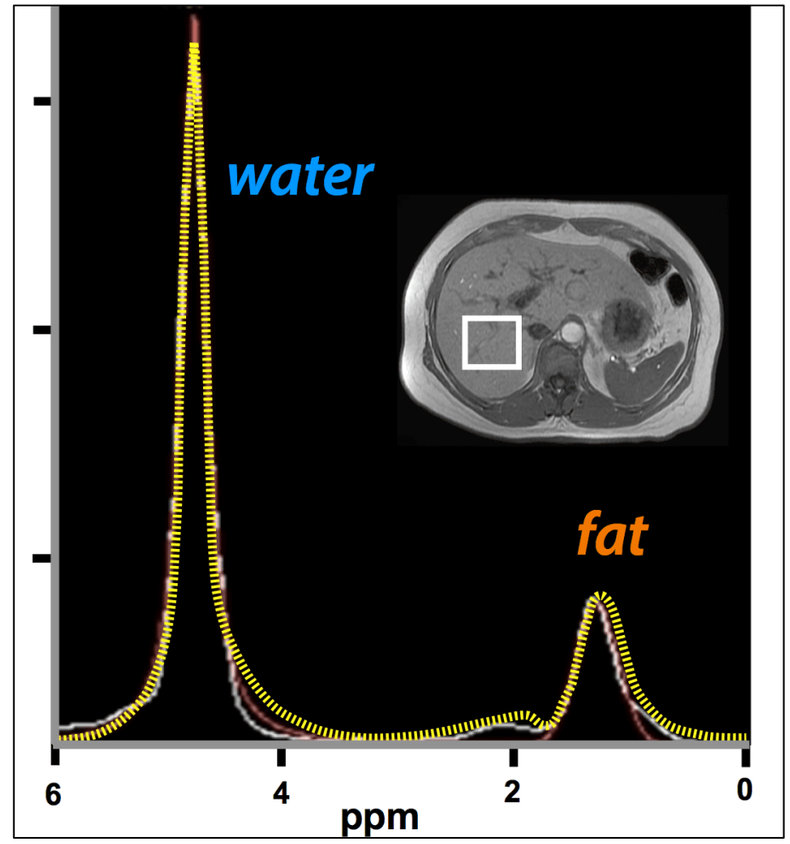
2. Materials & Methods (III)

5. Post Processing

- In-house software tool: *TESLA QMRI Utilities-X*, developed by two of the authors (GK, TGM). Designed specifically for processing T2* weighted images and for fat fraction measurements (%FF).

- The software tool was developed on the local PACS system (EVORAD® platform).

- Post-processing was applied to the PD-T2 weighted images* obtained from both *(LP-1)* and *(LP-2)* protocols.



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3. Results (I)

Fat Fraction – FF MRI Phantom Measurements

- *%FF* parametric maps: Generated using both *LP-1* (*Fig. 3a*) and *LP-2* protocols (*Fig. 3b*). Results for vials 1-12 were in agreement with known phantom values (± tolerance range).
- For vials 13-15: %FF measurements were not achieved due to high fat content (>50%).
- Summary of %FF measurements: All measured values and their standard deviations (SDs) are summarized in *Table 1*.

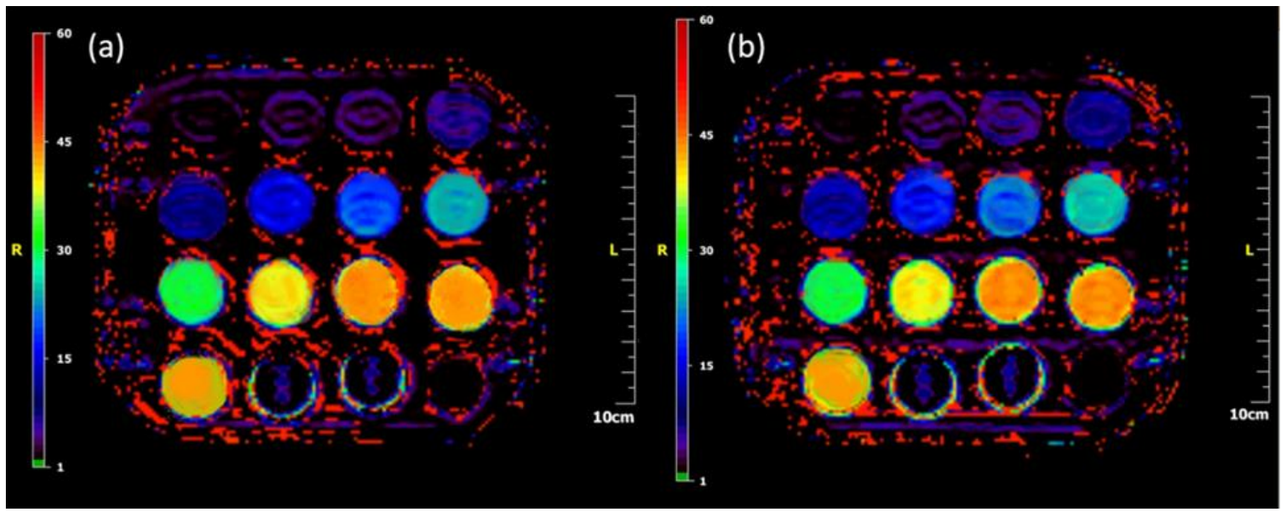

Figure 3. Color-coded %FF maps in FF-MRI phantom using the LP-1 (a) and LP-2 protocol (b).

Table 1. FF-MRI Phantom measurements: % fat fraction values

		LP1		LP2	
Vial no.	**%FF**	**Mean %FF**	**SD**	**Mean %FF**	**SD**
1	0	0.67	0.87	0.46	0.78
2	3	2.80	1.41	3.17	0.72
3	5	4.62	0.52	4.62	0.89
4	7	6.93	1.25	6.40	0.70
5	10	10.88	0.99	10.25	1.16
6	15	15.04	1.02	15.89	0.88
7	20	18.58	1.39	20.75	0.75
8	25	23.75	0.71	24.50	0.53
9	30	28.33	0.78	32.33	0.52
10	40	39.75	6.12	39.05	0.61
11	50	50.00	0.00	44.08	0.29
12	50	49.56	2.20	43.38	0.50
13	75	50.00	0.00	42.08	4.81
14	100	8.00	2.76	7.66	3.39
15	100	8.12	2.80	7.84	3.84
16	0	1.25	0.96	0.33	0.65

3. Results (II)

Bland-Altman tests – FF MRI Phantom Measurements

❑ Bland-Altman tests: Performed to compare LP-1 and LP-2 protocols with the known phantom reference values.

❑ LP-1 comparison (Fig. 4a):

- Mean %FF value difference: +2.3%.
- 95% Confidence Interval (CI) SD range: -7.1%-11.7%
- SD Span: 18.8% for %FF range [1–50]%

❑ LP-2 comparison (Fig. 4b):

- Mean %FF value difference: +1.8%.
- 95% CI SD range: -13.0% - 16.6%.
- SD Span: 29.6% for %FF range [1–50]%

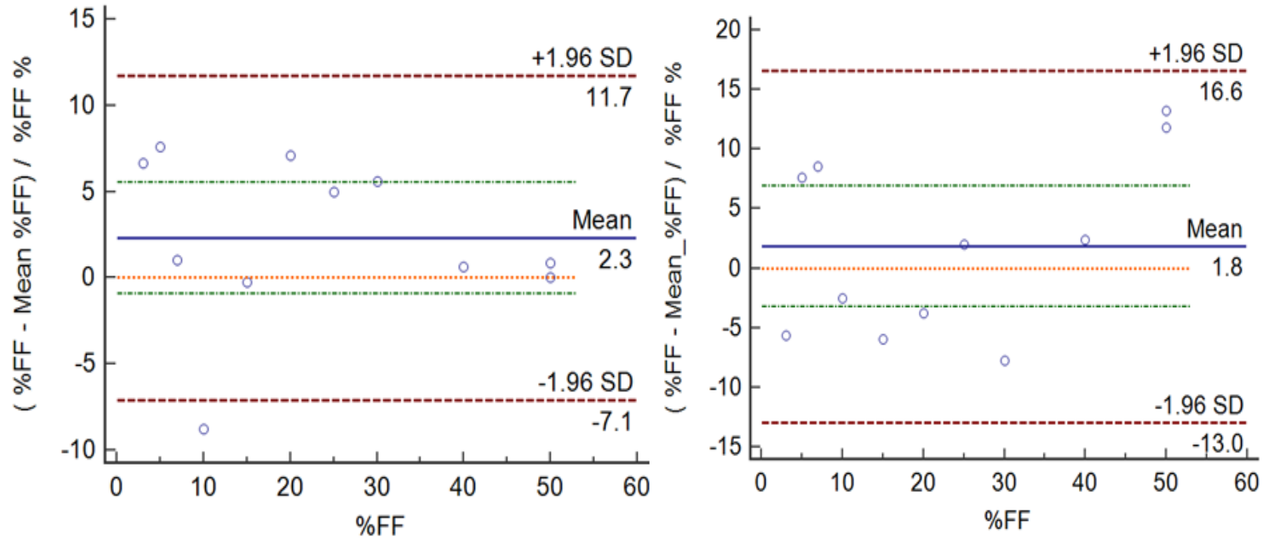

Figure 4. Different Bland-Altman (BA) plots: (a) BA between the LP-1 and the FFMRI phantom and (b) BA between the LP-2 and the FFMRI phantom.

4. Conclusions

- %FF measurements were aligned with the reference values of the phantom materials in both protocols (LP1, LP2)

- TESLA QMRI Utilities-X, already embedded into existing PACS/Workstation system, can serve as a fast and convenient tool for %FF measurements, eliminating the need for external software.

- LP-1 as compared to LP-2, was faster for both phantom scan and post processing times

- FF-MRI phantom proved to be a great means for simulating %FF values

- A multicenter, multivendor study would be of particular interest and importance for broader validation.

5. References

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