Dependence of PDFF Measurement Accuracy on Location, Resolution, and Field Strength

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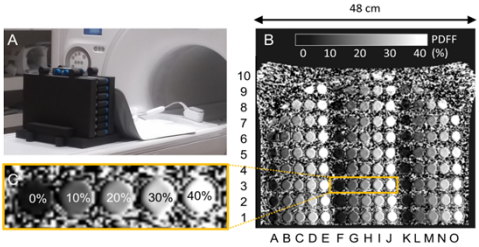
Background

Accurate quantification of PDFF in the liver is essential for clinical care of patients with fatty liver disease which is recognized as a global epidemic.[1] CSE-MRI is the state-of-the-art MRI method for noninvasive quantification of PDFF.[2] Previous results showed that PDFF bias increases with distance from isocenter with bias increasing steeply over 18cm in-plane and over 10cm in the z-direction.[3] However, this study tested a limited number of z-offsets at 3.0T only. For clinical use, the maximum distance from isocenter in all directions at which PDFF measurements are still accurate needs still to be determined.

Purpose

The purpose of this work was to determine the spatial dependence of PDFF measurements at both 1.5T and 3.0T.



D	1.5 T	3.0 T
FOV (cm)	48.0x38.4	46.0 x 36.8
TR (ms)	10.8-14.6	5.3-7.5
TE (ms) / ETL / number of echos	minimum / 6 / 6	minimum / 3 / 6
Voxel size (mm³)	1.7x1.7x6.4 (high) 1.8x2.0x8.0 (mid) 2.5x2.5x10 (low)	1.3x1.6x6.4 1.8x2.0x8.0 (mid) 2.5x2.5x10 (low)
Flip Angle (°)	5	3-4
Bandwidth (Hz)	83.33	142.86

Figure 1: *A+B) 26 phantoms were stacked into a foam sleeve to fill most of the bore covering 48x38cm. C) Each phantom contained 5 vials with predefined PDFF values of 0%, 10%, 20%, 30%, and 40%. D) Acquisition parameters.*

Methods

26 sets of commercially available vials-only pocket PDFF phantoms (Phantom Pack, Calimetrix, Madison, WI) were stacked to fill the bore. Each pocket phantom set contains 5 vials with 0%,10%,20%,30%, and 40% PDFF concentration, respectively, resulting in 130 vials total (Fig.1). Acquisitions were performed on clinical MRI systems (3.0T SIGNA Premier; 1.5T SIGNA Artist, GE Healthcare, WI, USA) using a 30-channel anterior array receiver coil and a commercial CSE-MRI method (IDEAL IQ, GE Healthcare) for PDFF quantification with 3 different spatial resolutions (Fig.1D). Acquisitions were repeated with 9 different z-direction offsets (0cm, ±10cm, ±13cm, ±15cm, ±20cm). To avoid fat/water swaps, confounder-corrected PDFF maps were reconstructed using a magnitude-based reconstruction where the iterative parameter estimation algorithm is initialized with the initial assumption that PDFF=0%.

The confounding effects of T2* decay, spectral complexity of fat and temperature were also corrected. ROIs were placed in the center of all vials using OsiriX (Pixmeo, Switzerland). Absolute bias between the vendor provided true PDFF and the measured PDFF for each ROI were calculated for each vial. Bias between vendor-provided and measured PDFF values was evaluated separately for distance from isocenter in xy-plane, offset from isocenter in z-direction, and absolute difference in x-y-z direction. This was done at both 1.5T and 3.0T and for different spatial resolution, respectively. PDFF bias was plotted as a function of distance from isocenter in-plane, along the z axis and distance in all directions.

Results

PDFF measurement bias increased with increasing in-plane distance from isocenter with a steep increase at 20cm (Fig.2). At a cutoff of ≤20cm distance from isocenter in the xy-plane, bias at 1.5T (3.0T) was ≤3.0% in 97% (97%) of vials and ≤2.5% in 93% (94%). PDFF measurement bias increased with increasing offset in z-direction with a steep increase at 20cm (Fig.3).

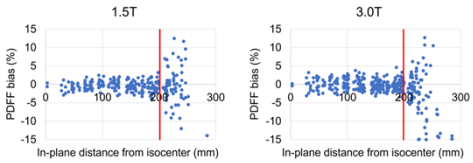


Figure 2: *In-plane, at 0 offset along the z-direction, PDFF bias increases sharply at a 200 mm in-plane (x-y-/axial plane) distance from the isocenter at both 1.5T and 3.0T.*

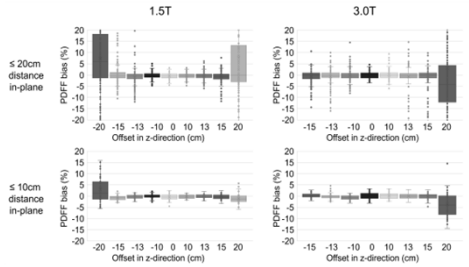


Figure 3: *Bias in the z-direction is low up to a distance of a ≤15cm offset. The bias is lower if only vials within a distance of ≤10cm from the isocenter in plane at a mid-resolution are considered compared to a distance of ≤20cm from the isocenter in plane.*

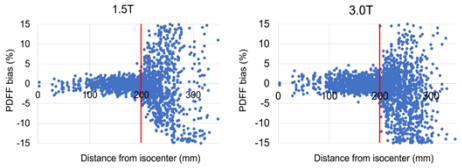


Figure 4: *Bias was low within 200 mm distance (left of the red line) from the isocenter in both in-plane and z-direction. There was a steep increase at 200mm with clinically relevant bias.*

At ≤15cm offset and within a radius of 10cm around isocenter in xy-plane, bias at 1.5T (3.0T) was ≤3.0% in 99% (100%) of vials and ≤2.5% in 96% (99%). At a distance ≤20cm from isocenter in x-y-z direction, bias at 1.5T (3.0T) was ≤3.0% in 99% (98%) of vials and ≤2.5% in 97% (95%; Fig.4). The cutoff of ≤20cm was independent of spatial resolution and field strength (Fig.5&6).

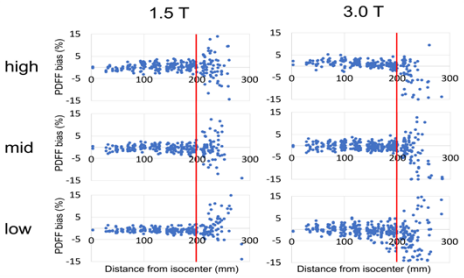


Figure 5: *Spatial resolution of the acquired PDFF maps did not affect the cutoff value of a 200mm distance from isocenter in-plane.*

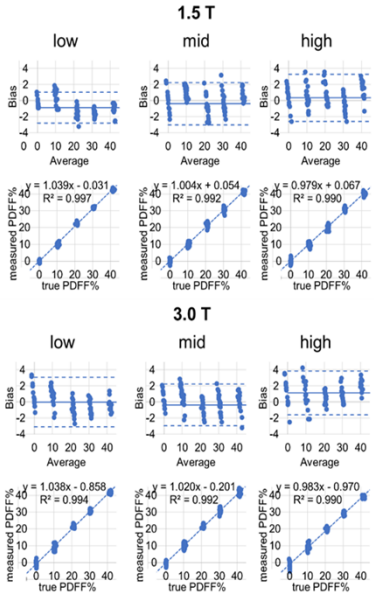


Figure 6: *The Bland-Altman plots show a smaller bias with narrower limits of agreements (LoA) in the low and mid resolution compared to the higher resolution (upper row). The measured PDFF values were highly correlated to the true PDFF values for all resolutions and field strengths, as seen in the linear regression (lower row).*

Conclusion

Bias in CSE-MRI-based PDFF measurements is low when performed in areas less than 20 cm from magnet isocenter. This is relevant for prescribing clinical PDFF measurements and for the positioning of pocket phantoms as quality assurance tools.

References

[1]Younossi ZM et al. (2016). Global epidemiology of nonalcoholic fatty liver disease-Meta-analytic assessment of prevalence, incidence, and outcomes. *Hepatology*, 64:73-84.

[2]Caussy, C., Reeder, S. B., Sirlin, C. B., & Loomba, R. (2018). Noninvasive, quantitative assessment of liver fat by MRI-PDFF as an endpoint in Nash Trials. *Hepatology*, 68(2), 763–772.

[3]Panagiotopoulos N, Oechtering TH, Rutkowski D, Brittain J, Hernando D, Reeder SB (2021). Spatial Dependence of PDFF Measurement Bias using Chemical Shift Encoded MRI. *ISMRM*, Poster presentation #3868

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