MRI Quantification of Liver Proton Density Fat Fraction during Free Breathing using a Motion-Insensitive Single-Shot 2D Technique

Pooler BD[1], Ruby JA[1], Hernando D[1],
Shimakawa A[2], Reeder SB[1]

[1]University of Wisconsin, Madison, WI
[2]Global MR Applications and Workflow, GE Healthcare

Background

- Chemical shift encoded (CSE-MRI) techniques can accurately measure liver proton density fat fraction (PDFF) as a quantitative biomarker of liver fat content.
- Currently available CSE-MRI techniques require a breath hold during acquisition to avoid motion-related artifacts.
- This leads to image degradation and inaccurate PDFF measurements when patients can’t hold their breath.

Purpose

- Demonstrate the feasibility of a “single-shot” sequential 2D CSE-MRI technique for motion-insensitive quantification of liver PDFF.

Methods

- IRB-approved, HIPAA-compliant.
- Patients underwent CSE-MRI using three different techniques to measure liver PDFF:
  - 3D acquisition (3D).
  - 2D interleaved acquisition (2D int).
  - 2D sequential acquisition (2D seq).
- All techniques acquired during breath hold (BH) and free breathing (FB), for a total of six scans per patient.

Methods

- Imaging was performed at 1.5T (MR450w v25.0, GE Healthcare, Waukesha, WI) using a phased-array torso coil.

- CSE-MRI acquisition parameters were identical between corresponding BH and FB acquisitions, and were corrected for all relevant cofounding factors, including R2* decay, multi-peak fat, and phase errors.

Methods

CSE-MRI Parameters:

Parameter	3D	2D int	2D seq
Field of view	44 x 36 cm	44 x 36 cm	44 x 36 cm
Slice thickness	8 mm (32 slices)	8mm/2mm gap	8mm/2 mm gap
Matrix size	224 x 160	192 x 144	128 x 100
TR	16.3 ms	300 ms	10.2 ms
TE1/ΔTE	1.1 ms/2.0 ms	1.3 ms/2.0 ms	1.1 ms/1.5 ms
Flip angle	5°	20°	5°
Echo train length	6 (single train)	6 (single train)	6 (single train)
Receiver bandwidth	±111 kHz	±62.5 kHz	±62.5 kHz
Parallel imaging R	2.5	N/A	N/A
Scan time	20 s	23 s	20 s

MRS Parameters:

Parameter	MRS value
Voxel size	20 mm^3
TR	3.5 s
TE1/ΔTE	10.0 ms/5.0 ms
Readout points	2048
Bandwidth	5.0 kHz
Mixing time	5 ms

Methods

- Analysis of PDFF maps performed on a standalone workstation (OsiriX, Pixemo SARL, Geneva, Switzerland).
- Circular 3 cm^2 ROI's were placed centrally in each of the nine Couinaud liver segments and were averaged to estimate overall liver PDFF.
- Multi-echo T2 corrected single-voxel STEAM MR spectroscopy (MRS) PDFF measurements also acquired for comparison.

Methods

- Data analysis:
  - Bland-Altman analysis comparing FB versus BH acquistions.
  - Correlation plots comparing CSE-MRI and MRS.

Results

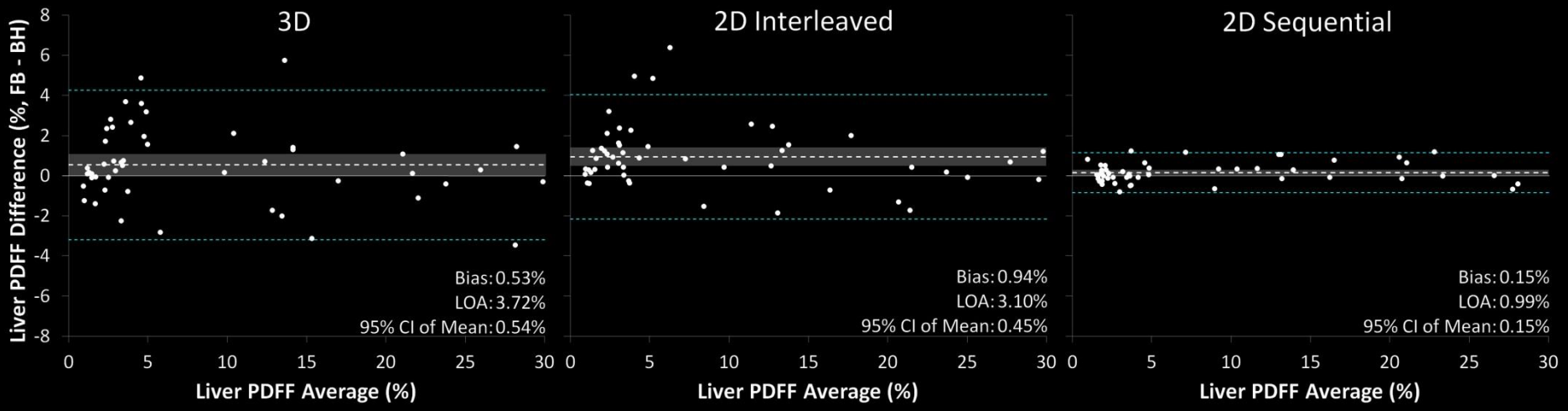
- 50 patients recruited.
  - 27 women, 23 men.
  - Mean age 57.2 ± 12.1 years, range 23-81 years.

- Mean liver PDFF:
  - 8.8 ± 8.7% by MRS (range 0.6 – 28.5%).
  -

3D BH	3D FB	2D int BH	2D int FB	2D seq BH	2D seq FB
8.8%	8.3%	8.9%	8.9%	8.3%	8.0%

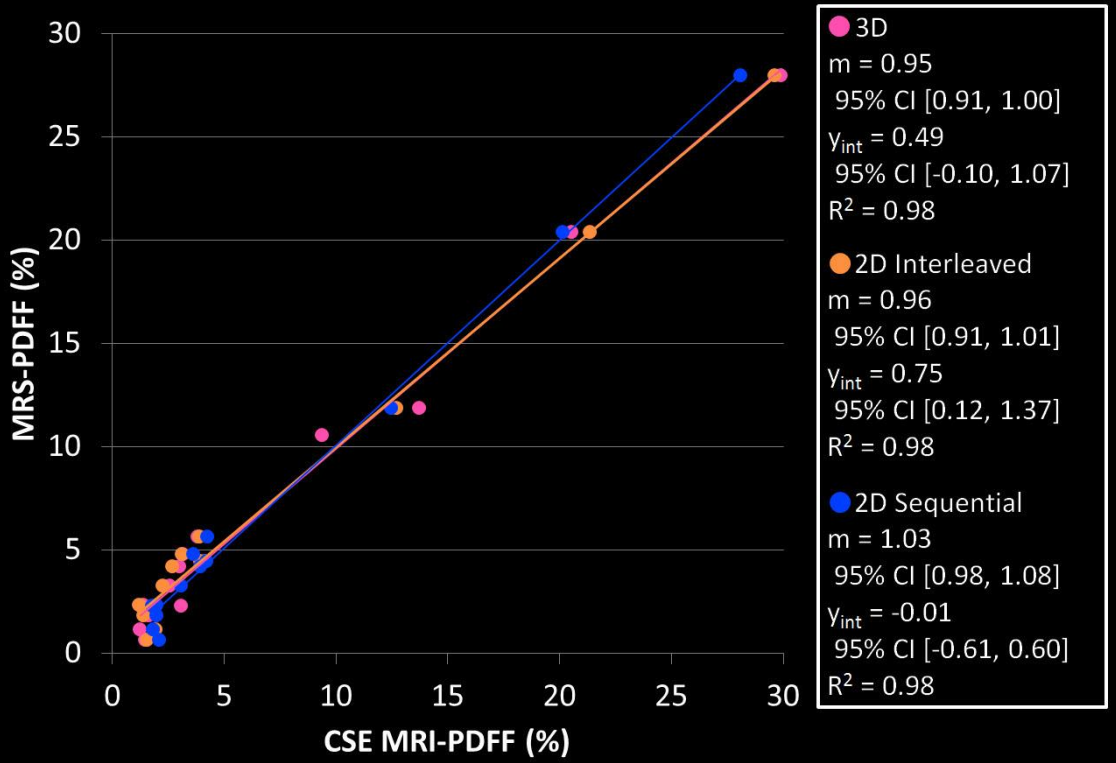
  - No significant difference among CSE-MRI acquistions (*P*=0.99) or between any CSE-MRI acquisition and MRS (*P*=0.67-0.99).

Results



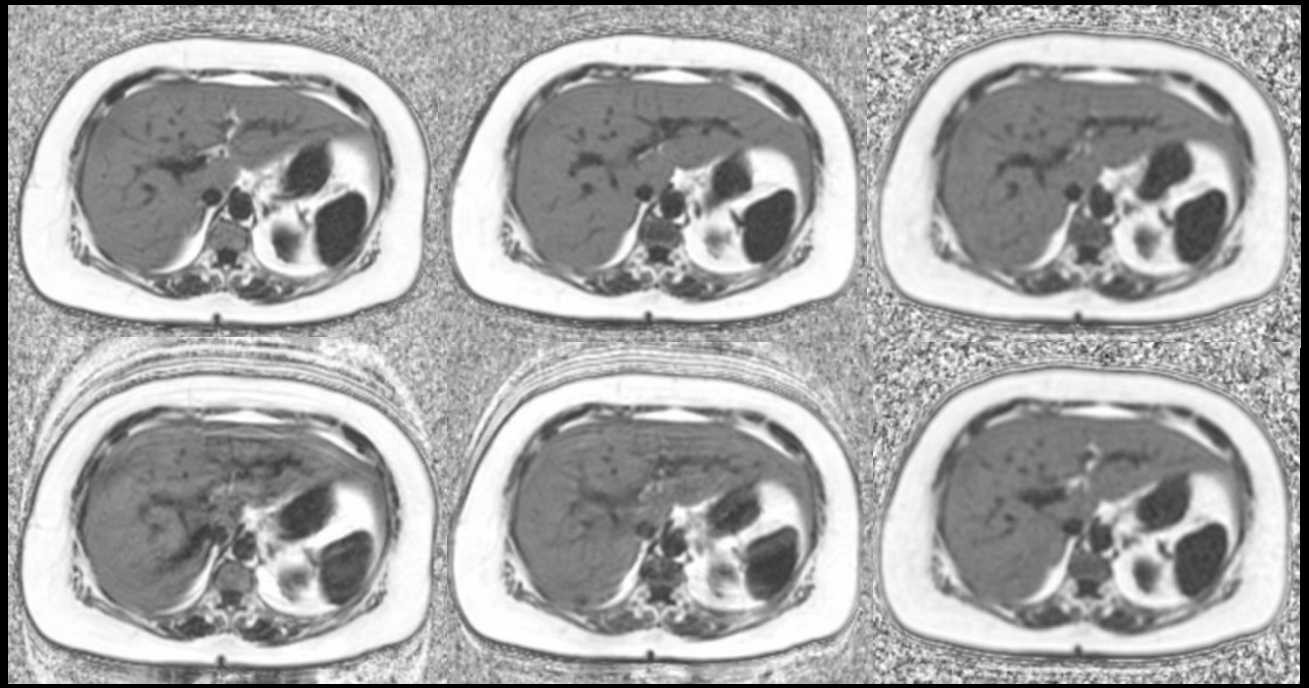
- Bland-Altman analysis shows minimal variability between FB and BH for 2D seq CSE-MRI [*right*] when compared to 3D [*left*] and 2D int [*center*], reflecting insensitivity to motion artifact.
- Note the relative lack of bias as well as narrow LOA and 95% CI of the mean for 2D seq.

Results



- Correlation plots of PDFF values from MRS and CSE-MRI during breath hold show excellent correlation and good agreement with MRS.

Results



- Representative PDFF maps from a 54-year-old female with hepatic steatosis illustrate the relative insensitivity to motion seen with the 2D seq acquisition compared with 3D and 2D int.
- Note the lack of background ghosting artifact with 2D seq, even during FB.

Limitations

- Relatively low signal-to-noise ratio for 2D sequential acquisition may limit broader application beyond quantification of fat fraction.

Conclusion

- CSE-MRI can be successfully used to measure liver PDFF during free breathing using a motion-insensitive, “single-shot” sequential 2D technique.
- This technique permits the accurate quantification of liver fat content without the need for the patient to suspend respiration.

Thank you!

- The authors would like to thank GE Healthcare for their continued institutional support and collaborative efforts.

- This study was supported in part by NIH grants R01-DK083380, R01-DK088925, R01-DK100651, and K24-DK102595.