Effect of Region-Of-Interest Selection On IVIM Analysis in the Liver

Juan A. Vasquez[1], Shengwen Deng[2], Geoffrey D. Clarke[1,2]

1Department of Radiology, 2Research Imaging Institute, UT Health Science San Antonio, 8403 Floyd Curl Drive, San Antonio TX, USA 78229.

Introduction

Non-alcoholic fatty liver disease (NAFLD) is a major public health issue affecting millions of people worldwide. Chronic NAFLD is defined by excess liver fat (hepatic steatosis) and can lead to the more profound disease state of non-alcoholic steatohepatitis (NASH), a comorbidity that causes hepatocyte insult leading to hepatic fibrosis.

Intravoxel Incoherent Motion (IVIM) is a diffusion weighted imaging (DWI) model which accounts for slow and fast diffusion compartments in tissue. Associations between histological features of NAFLD and IVIM parameters have been observed, however work on clinical implications is warranted.[1]

Purpose

In this study we investigate:

- The effects of region-of-interest selection ROI, including (Ri) and excluding (Re) vascular or biliary structures, on IVIM results
- Differences in IVIM parameters between normal and fatty liver subjects
- Correlation between diffusion parameters and liver fat status and stiffness

Methods

Twenty-one subjects were included in this study, with 8 patients presenting with steatosis determined by a hydrogen-1 magnetic resonance spectroscopy (^{1}H-MRS) liver fat fraction (PDFF) > 5%. ^{1}H-MRS and DWI protocols were performed on a 3T MRI system (TIM Trio, Siemens) with a 12-channel body matrix coil (Siemens) placed on the subjects abdomen. A single-voxel 1H-MRS STEAM sequence was used to obtain spectra using multiple TEs to correct for T_2 effects (vol=(20 cm)^3, TR=2000 ms, TE=20-35 ms, TM=10 ms, BW=1250 kHz, flip-angle=90°). DWI data were acquired using a gaited, diffusion-weighted sequence (EPI factor=121, and SPAIR; 7 b-values: 0, 50, 100, 150, 200, 400, and 1500 s/mm²). All subjects were also scanned with Fibroscan to acquire liver stiffness measurements (LSM). Diffusion parameters in the right hepatic lobe were compared. IVIM parameters were fit to Le Bihan's equation:[2]

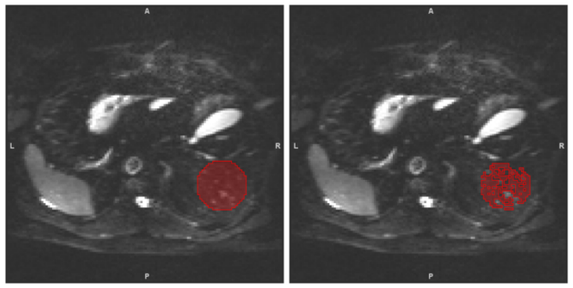
$$S_b/S_0 = f \exp(-b\ p) + (1-f)\exp(-b\ d),$$

where S_b/S_0 is the signal ratio for different gradient (b) values, f is the fraction of fast diffusion, p is fast diffusion, and d is slow diffusion (true diffusion coefficient). The shifted apparent diffusion coefficient (sADC) was also calculated using b=150,1500. Fitting was performed using the Levenberg-Marquardt least squares optimization algorithm. Fitting and statistical analysis was done in R with significance level at 0.05.

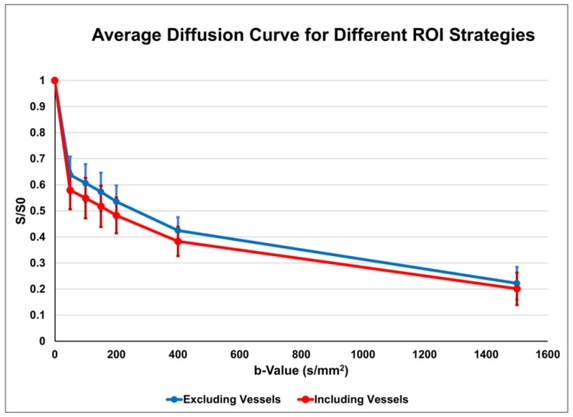
Results

Parameters	N (n = 13)	F (n = 8)
Age (y)	63.7 ± 8.4	55.1 ± 14.1
Sex (M/F)	7/6	5/3
BMI (kg/m^2)	32.2 ± 5.4	33.6 ± 6.3
PDFF (%)	1.5 ± 0.7	8.9 ± 5.6
LSM (kPa)	6.7 ± 3.1	7.6 ± 1.8
fe (%)	38.6 ± 7.2	40.0 ± 8.4
pe (x10^{-3} mm^2/s)	48.0 ± 23.5	43.1 ± 20.5
de (x10^{-3} mm^2/s)	0.75 ± 0.19	0.67 ± 0.20
sADCe (x10^{-3} mm^2/s)	0.99 ± 0.24	0.89 ± 0.27
fi (%)	43.7 ± 7.8	46.6 ± 5.7
pi (x10^{-3} mm^2/s)	51.0 ± 15.7	45.3 ± 17.9
di (x10^{-3} mm^2/s)	0.78 ± 0.22	0.69 ± 0.21
sADCi (x10^{-3} mm^2/s)	1.00 ± 0.25	0.88 ± 0.26

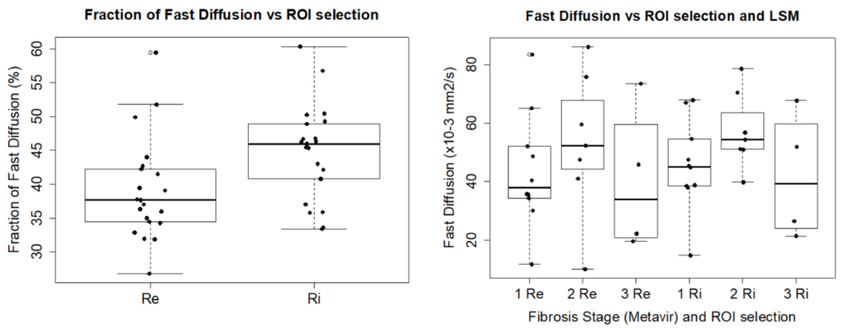
- LSM measurements were higher in NAFLD subjects; IVIM parameter estimates for normal subjects was higher in p, d, and sADC compared to NAFLD subjects for Re and Ri
- The fraction of fast diffusion was the only IVIM parameter estimate that was elevated in NAFLD patients for Re and Ri



- The ROIs used in this analysis are shown in red; Re is shown on the left and Ri on the right; Ri are created by using a histogram to exclude high and low signal vessel structures found on the b0 image



- Average diffusion curves were significantly different between ROIs including (red) and excluding vessels (blue) and biliary structures with p<0.001



- The boxplot on the left shows the distrbution for estimates of f using Re and Ri (39.2 ± 7.5% vs 44.8 ± 7.1%, p<0.001)
- The boxplot on the right shows how f varies with different of METAVIR stage, there were no significant differences between stages
- Diffusion had a slight significant difference between Re and Ri (0.72 ± 0.19 x10^{-3} mm^2/s vs 0.74 ± 0.21 x10^{-3} mm^2/s, p<0.05)

Summary

- ROI selection strategy has a significant effects on the estimates of f and d
- The average diffusion curves were significaly different, with ROIs including vessles having lower signal ratios for all non-zero b-values
- IVIM coefficents except for f were decreased in subjects with NAFLD regardless of ROI strategy

Conclusion

The present study demonstrates that including vascular and biliary structures in the ROI being analyzed had a significant effect on estimates of the f and d. Estimates of f using Ri were higher while d were lower, this is likely due to the increased fast diffusion in the vessels. These results are in agreement with the two-compartment model proposed by Le Bihan. No correlation could be found between IVIM parameters and level of liver stiffness. However, this is likely due to the small sample size comprising the group with a METAVIR score of 3. Future work will continue to investigate the clinical implications of IVIM.

References

1. Manning P, et al. Liver histology and diffusion-weighted MRI in children with nonalcoholic fatty liver disease. J Magn Reson Imaging. 2017.
2. Le Bihan D, et al. Separation of diffusion and perfusion in intravoxel incoherent motion MR imaging. Radiology. 1988;.