Correcting the Influence of Iron on Steatosis Measurements

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TARGET AUDIENCE This work will appeal to clinicians and researchers interested in liver steatosis.

PURPOSE To characterize the accuracy of 3D Dixon Vibe for measuring water and fat content of the liver on both 1.5T and 3.0T MR imagers and to understand the influence of heightened concentrations of iron on the accuracy. Additionally, we sought to explore methods of correcting for differences in T1 of the fat and water components.

METHODS We developed a phantom consisting of a collection of ten, 15 mL vials each containing 10 mL of hydrogel in which we embedded varying concentrations of iron oxide (ferumoxytol). Ferumoxytol is a MION with a particle size of 30 nm. We varied the iron concentration between 0 and 60 µg/gm wet weight. This concentration is approximately 1/20 than seen in the liver but because of the larger particle size, the effect on T2* is similar to what is seen in severe iron overload[1]. On top of the gel we added canola oil to simulate fat in the liver[2]. The phantom was imaged on both a 1.5T and a 3.0T imager (MAGNETOM Aera and Verio, Siemens Medical Systems). Both images and spectroscopic data were acquired on the phantom using prototype applications provided by the manufacturer. We placed the voxel of interest at the interface of the gel and oil to simulate a mixture of the two compounds. By shifting the slice position away from the interface, we could accurately vary the proportions of oil and water contained in the voxel. We acquired 3D Vibe images at three flip angles α={2°, 4°, 8°} and in each acquisition we extracted the total water, total fat and relative water and fat volumes. From the variation of the total water and total fat signal with flip angle we used linear regression in a plot of $S/\sin(\alpha)$ vs. $S\cdot\cot(\alpha)$ to find the slope =exp(-TR/T1) from which we estimated the T1 of the individual components.

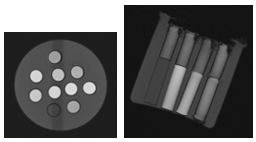

Figure 1. Cross sectional images of the phantom. The lower portion of each tube contains hydrogel with various concentrations of ferumoxytol. The upper portion contains vegetable oil.

RESULTS Cross sectional images of the phantom are shown in figure 1. The estimated water content varied linearly with slice position reaching 96±2% for all vials when the voxel was completely inside the gel. For voxel placements with a mixture of oil and water there was a greater variation in the estimated water content which increased at higher iron concentrations. Using the three Vibe volumes collected at different flip angles we calculated T1 for the fat and water components and derived correction factors λ_F and λ_W for fat and water respectively which took account of the signal saturation from incomplete magnetization recovery. The average T1 for the oil component was 240±30 ms while the T1 for the water component varied with a linear relationship between 1/T1 and the known iron concentration of the gel. The measured relaxivity of the ferumoxytol from this analysis was 8.2 L/s/mmol which is within a factor of 2 of values from the literature[3]. R2* derived from the Vibe images for each sample also varied linearly with iron concentration and were much higher for the measurements at 3.0T than at 1.5T. We corrected the individual estimates of water content as $\widehat{W} = W/[W+F(\lambda_w/\lambda_f)]$. Correcting the individual components for differences in T1 significantly improved the accuracy of the measured water content as shown in figure 2.

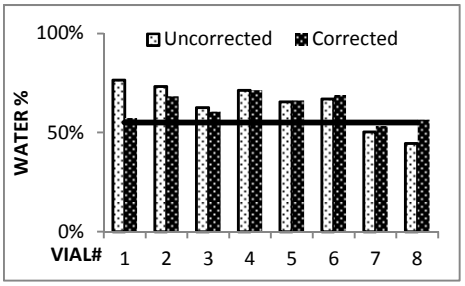

Figure 2. Plot of % water derived from Vibe results vs amount predicted from phantom. The expected value is shown by the solid line.

DISCUSSION Determining the fat content of the liver is an important measurement for characterizing NASH and NAFLD. Developing the most accurate steatosis quantitation method will be essential to justify replacement of liver biopsy. This work demonstrates the ability to estimate the fat content accurately using an imaging technique and we have demonstrated an important correction which can improve the accuracy of the measurements.

REFERENCES

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