MR imaging for quantitative measurement and display of hepatic fat fraction: A potential replacement for liver biopsy

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Abstract: Non-alcoholic fatty liver disease is a common condition that may progress to cirrhosis. Liver biopsy is the only means of diagnosing this condition. Biopsy is an invasive procedure that carries potential risks. We propose a fast, non-invasive MR imaging method to accurately quantify and display the fat fraction in the liver. This method addresses the ambiguities associated with the dominant species, and the effects of NMR relaxation on the signal intensity.

Introduction: Non-alcoholic fatty liver disease (NAFLD) includes a spectrum of clinicopathological conditions ranging from simple steatosis through steatohepatitis to cirrhosis. The diagnosis of NAFLD is often delayed compared with other chronic liver disease, because it requires a liver biopsy, which is an invasive procedure associated with significant morbidity, and rarely mortality. Simple in-phase/out-of-phase comparison does not address the ambiguities associated with the dominant species and relaxation times.

Purpose: To develop a fast and efficient method to acquire and display quantitative maps of the fat content of the liver.

Materials and Methods: Imaging of the liver is performed using a breath-held dual-echo spoiled gradient-echo sequence acquired at 70º then 20º flip angles, to provide high resolution anatomical images, and resolve the ambiguity related to whether fat or water is the dominant species. With rare exception, fat exhibits shorter native T1 when compared to water in other soft tissues. This fact allows us to determine whether fat is the minority or the majority constituent simply by changing the T1-weighting. Inspection of Figure 1 indicates the apparent fat content will almost always increase as one increases T1-weighting when fat is the minority component. The dual flip algorithm identifies the dominant species based on the increase or decrease in the apparent fat fraction with change in T1W, as seen in figure 1. A third dual-echo gradient echo breath-held sequence with two in-phase TE values (4.5 and 18 msec) is also acquired to calculate T2*. Software was developed to reconstruct hepatic fat fraction maps for each slice through the scanned anatomy, and display the percentage of hepatic fat in color maps for subsequent quantitative VOI analysis.

Results: Fat fraction maps were generated for a phantom containing equal volumes of water and mineral oil. A single oblique slice was obtained across an oil-water interface with a continuum transition from pure water to pure oil. Fat fraction maps show that the algorithm successfully adds significant dynamic range above and below 50% (fig 2). This method was successfully applied for patients with suspected fatty infiltration of the liver (fig 3).

Conclusion: A phantom study and initial clinical experience shows the proposed method to be fast, clinically practical, and has the potential to reliably quantify hepatic fat fraction.

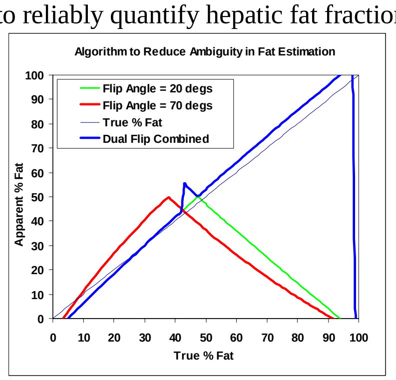

Figure 1 Algorithm to determine whether the fat fraction is the dominant species by a combination of two flip angles. Algorithm accurately distinguishes above from below 50% conditions aside from minor error near around 45-55%

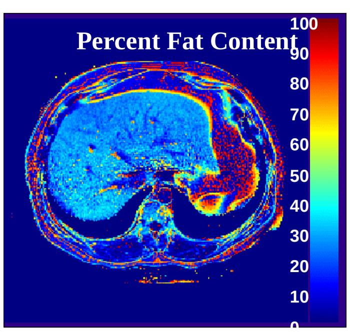

Figure 3. Demonstration of hepatic fat fraction map in a patient with approximately 30% fatty infiltration

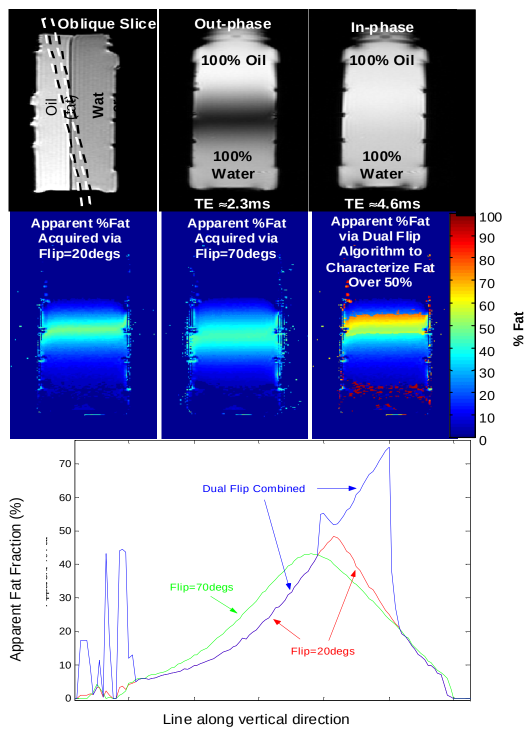

Figure 2. Oil/water phantom results. Quantitative maps of the fat fraction at low T1W (left) and high T1W (middle). Results of algorithm to remove ambiguity at about 50% level (right).Significant increase in dynamic range above 50% is achieved. Vertical line through the three images which demonstrates general agreement with simulation is shown graphically below the images