Characterization of Diffuse Liver Disease Using the T2 of the Water Component and Fat Fraction

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Introduction: Chronic liver disease due to Hepatitis B/C infection or non-alcoholic steatohepatitis (NASH) is a major health problem. The first manifestation of chronic liver disease is liver inflammation, which can progress to fibrosis which in turn can lead to cirrhosis and liver cancer. The diagnosis of these pathologies requires a liver biopsy which is an invasive procedure with associated morbidity and cost and subject to sampling errors. Non-invasive imaging techniques including Magnetic Resonance Elastography and Diffusion Weighted MRI have been sought as a non-invasive alternative for the diagnosis of chroniv liver disease (1,2). One of the drawbacks of these techniques is that the presence of fat (typically found in the liver) is a confounding factor in the determination of parameters that otherwise can be associated with inflammation and fibrosis.

Our group developed a novel radial gradient and spin-echo (RADGRASE) method which provides T2 and fat-water mapping with the advantage that the T2 estimation is independent of the presence of fat (3). The method is fast (data for T2 and fat-water mapping are acquired in a breath hold) and it provides high spatial resolution and motion insensitivity. Initial results in a limited number of patients with proven biopsy (n=4) showed that T2 histogram parameters (mean and variance) correlated with degree of disease (inflammation and fibrosis) determined by biopsy (4). In this work we extend the study to a set of 22 subjects and use the T2 of the water component (T2w) and fat fraction (FF) to characterized liver disease.

Technique: The RADGRASE method consists of four gradient echoes collected at each SE period (as shown in Figure 1A). For each E_n within an SE period the same k-space line is acquired thus, multiple images at different times from the SE point are obtained. These images are used for obtaining the initial estimates for fat and water using the iterative algorithm IDEAL (Fig. 1B) (5). For T2 estimation we use the echo closest to the SE point and an echo sharing algorithm to obtain images at each TE (Fig. 1C).

If a voxel contains fat and water, the signal intensity in the TE images is modeled by: $\left|S(TE_{eff})\right| = \left| I_w e^{-\frac{TE_{eff}}{T2w}} + I_f e^{-\frac{TE_{eff}}{T2f}} e^{iC_s\Delta_n} \right|$ [1].

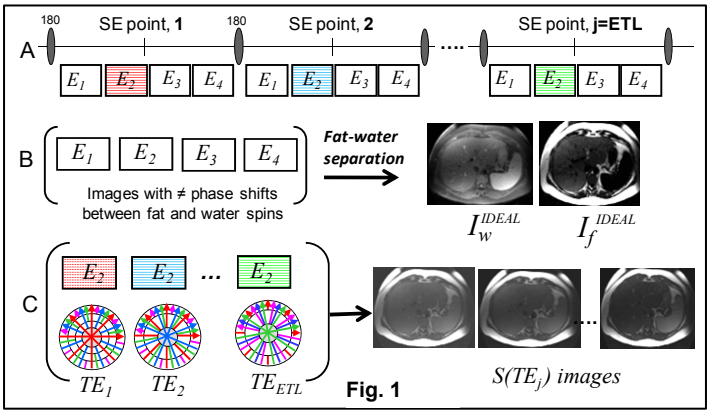

Fig. 1

In Eq. 1, I_w and I_f are the water and fat estimates and $T2_f$ is the T2 of fat. C_s is the chemical shift between fat and water and Δ_n is the time shift of the echo (used for T2 estimation) relative to the SE point. Both C_s and Δ_n are known quantities. $T2_f$ is treated as a known constant in Eq. 1. In vivo $T2_f$ is estimated for each subject using the average T_2 value from regions in the body that contain mostly fat (e.g. the subcutaneous fat layer) using the single exponential decay model. The initial estimates for I_w and I_f come from the IDEAL estimation.

Methods: Data for subjects (n=18) who had liver biopsies within a week of the MRI scan were acquired on a 1.5T GE Signa NV-CV/i scanner. Data were also acquired in normal controls (4). Data acquired on a breath hold (18 s) with BW=±125 kHz, ETL=12, matrix size=256×192, TR=1s, NEX=1, FOV= 48 cm, slice thickness= 8 mm. The time shifts Δ_n corresponded to fat-water phase shifts of (-5π/2, -π/6, π/2, 7π/6).

The T2w histograms were generated from all slices imaged (8-10 slices) from a segmented region containing just the liver. Blood vessels within the liver were automatically segmented out by applying a threshold to the signal intensity in the water image.

Results: Figure 2 summarizes the T2w mean and variance for a total of 22 subjects. For easier data interpretatin we also show Fig. 2B which is the projection of the data in A onto the diagonal. Figs 2A-B show that: Patients with normal Bx fall within the range of controls and are perfectly separated from patients with abnormal Bx. Patients with red symbols, who have fibrosis scores F≥2 and treatment was recommended, separate from all other subjects. The three patients with yellow symbols only have mild inflammation (I=1) and no or mild fibrosis (F=0 or 1). These subjects are between normals and the subjects recommended for treatment; this shows the potential of the method to identify subjects at early stages of disease.

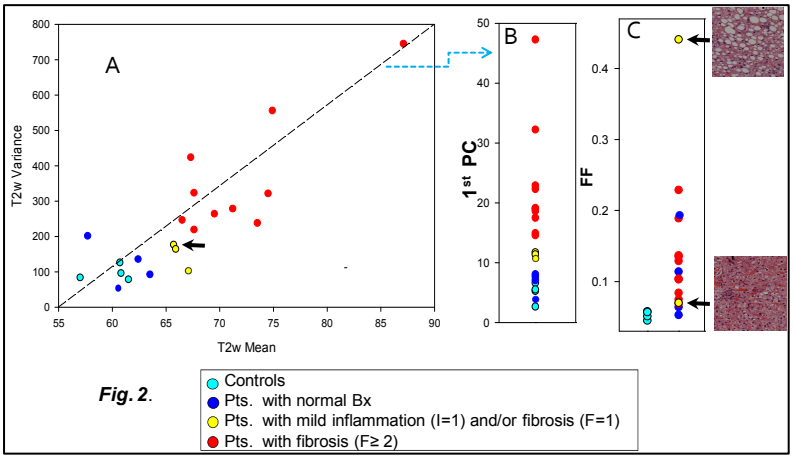

Fig. 2.

The FF plot (Fig. 2C) shows that the FF of patients ranges from 0.053 (normal values) to 0.44 (steatosis) regardless of fibrosis scores. It is important to note that the two subjects with yellow symbols with almost identical T2w statistics (black arrows in Fig. 2A) had the same scores for inflammation (I=1) and fibrosis (F=0) but very different FF. One has normal FF and the other has steatosis as indicated by our technique and the Bx slides. This supports the claim that in our technique T2w is independent of FF.

Conclusion: A RADGRASE method where the T2 of the water component is determined independently of the fat component was evaluated in patients suspected of liver disease. Results indicate that $T2_w$ mean and variance in the liver increases with disease severity as identified by biopsy. The method is fast and may result in a valuable clinical tool for the non-invasive imaging of the liver.

References: (1) Wang Y, AJR 2011; 196:553–561, (2) Talwalkar JA, Hepatology 2008; 47: 332. (3) Li Z, MRM 61:1415, 2009. (4) Altbach MI, ISMRM 18, 261, 2010. (5) Reeder SB et al MRM 51:35, 2004.