Quantifying hepatic lipid content and T2* decay using a single breath-hold multiecho sequence at 3 tesla.

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Introduction

Lipid quantification using gradient echo sequences relies on the chemical shift in resonant frequency between fat and water molecules. Currently-used dual echo techniques only allow a "fat index" to be derived based on the signal intensity change between images, and require a separate acquisition for T2* correction (1). However, the signal intensity variation in a multiecho acquisition would be expected to show a periodic oscillation of signal intensity between in-phase and out-of-phase echo times dependant on the tissue fat content, as well as the individual T2* decays of the fat and water components. Modeling of this variation in signal decay has the potential to allow measurement of the actual fat:water ratio.

Purpose

The aim of this study was to design and optimize a breath-hold in- and out-of-phase multiecho sequence suitable for quantifying liver fat fraction. A model was developed to derive the individual signal contributions from the fat and water components as a function of echo time. The sequence was tested in humans and compared to hepatic magnetic resonance spectroscopy (MRS).

Method

The MRI studies were performed on a 3.0 tesla Philips (Best, Netherlands) Intera system. Five patients suspected of steatosis (age 35 – 67 years; body mass index (BMI) 33 – 40 kg/m^2), and five healthy volunteers (age 32 – 44 years, BMI range 22 – 30 kg/m^2) were imaged. Multiecho imaging of an axial slice through the liver was performed with a breath-hold 7-echo spoiled gradient echo sequence with an acquisition time of 8 seconds. The multiecho sequence parameters were flip angle 20º, field of view 320mm, slice thickness 10mm, turbo field echo factor 6, matrix 126 x 128, acquired voxel size (mm) 2.5 x 2.5 x 10, TR 11 ms and 2 signal averages acquired. Echo times were chosen to reflect a fat-water chemical shift of 3.4ppm and were 1.15, 2.3, 3.45, 4.6, 5.75, 6.9 and 8.05 ms.

A comparison was made with point-resolved spectroscopy (PRESS) without water suppression of a 8ml volume of interest localized to the right lobe of the liver. The integrals under the lipid (1.3 ppm) and water (4.7 ppm) resonances, following T2 decay correction, were used to derive a fat fraction.

On the multiecho images a region of interest was placed over the right lobe of the liver, in the same location as the MRS voxel, to derive mean signal intensity. The variation in signal intensity was modeled with the following biexponential equation –

$$Signal\ Intensity = \sqrt{\left(S_w e^{-t/T2^*_w}\right)^2 + \left(S_f e^{-t/T2^*_f}\right)^2 + 2 \cdot S_w e^{-t/T2^*_w} \cdot S_f e^{-t/T2^*_f} \cdot \cos(\sigma \cdot \gamma \cdot 2\pi \cdot B_0 \cdot t)}$$

where S_w and S_f are the signal intensities in the oscillation due to water and fat, $T2^*_w$ and $T2^*_f$ their T2* decay constants and σ their chemical shift; t the time after excitation, f_0 the centre frequency (127 x 10^6 Hz at 3T), B_0 the static magnetic field strength (3T) and γ the gyromagnetic ratio (42.6 $MHzT^{-1}$). An iterative curve-fitting algorithm was used to derive S_w, S_f, $T2^*_w$ and $T2^*_f$, with the other values as knowns.

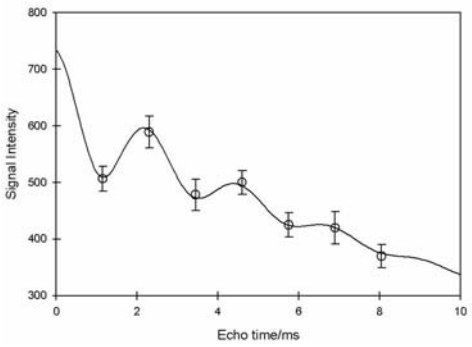

Figure 1 - A plot of mean signal intensity in a region of interest of a steatotic liver from a multiecho sequence, showing the biexponential model's best-fit curve.

Results

The multiecho sequence modeling converged on a fit for S_w and S_f in all cases, and also individual $T2^*_w$ and $T2^*_f$ components in those with steatosis (Figures 1 and 2). In the patient group the mean hepatic fat fraction was 15.2% ± 4.9; the mean water T2* 16.3 ± 3.8 ms, and the mean lipid T2* 9.9 ± 6.2 ms. In the volunteer group the mean hepatic fat fraction was 2.0% ± 0.8; the mean global T2* 21.9 ± 10 ms. Pearson's test indicated a highly significant correlation coefficient between multiecho and spectroscopic measurement of hepatic lipid ($y = 0.97x + 0.15$, $r^2 = 0.99$, $p<0.0001$).

Discussion

Non-alcoholic fatty liver disease (NAFLD) is seen in up to one third of the US population and is a spectrum of disease from uncomplicated steatosis to progressive steatohepatitis. Assessing the severity of fatty infiltration is important in risk stratification and monitoring response to therapy. A breath-hold multiecho technique offers a rapid quantification of tissue lipid content that correlates closely with that of proton spectroscopy. Unlike dual-echo approaches which derive a fat-index based on the signal intensity change, multiecho imaging allows the signal contributions from fat and water to be modeled. The multiecho model corrects for the effect of T2* decay in the fat and water compartments, and obviates the need for a separate T2* map to be acquired. The T2* decay constant will in part reflect the iron content of the liver although this has yet to be calibrated at 3.0 tesla field strength.

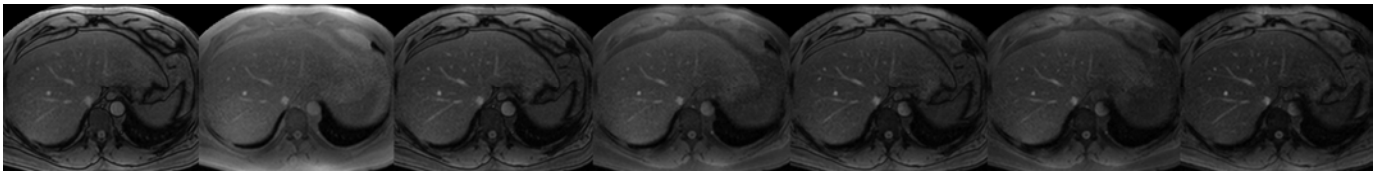

Figure 2 - A breath-hold multiecho acquisition of the liver with seven readouts at alternately out-of-phase and in-phase echo times

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Reference - Hussain HK et al, *Radiology* 2005; 237:1048-1055.