Breath-Hold High Resolution Spectroscopic Imaging of the Liver Using Rosette Trajectories

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Introduction:

Nonalcoholic fatty liver disease (NAFLD) affects an estimated 14% to 30% of the general population in the United States, with an important number of these patients progressing to nonalcoholic steatohepatitis (NASH), cirrhosis or die of liver failure [5]. The earliest manifestation of NAFLD/NASH is hepatic steatosis (fatty infiltration of the liver) and regrettably, the utility of liver biopsy is very limited. MRI techniques based on a two-point [4] or multi-point [5] Dixon method were demonstrated for fat-water separation and fat fraction quantification in liver. However, FT based techniques are much more susceptible to even minimal amounts of motion compared to methods using center-out k-space trajectories. We propose the use of Rosette Spectroscopic Imaging (RSI) for fat-water separation in liver.

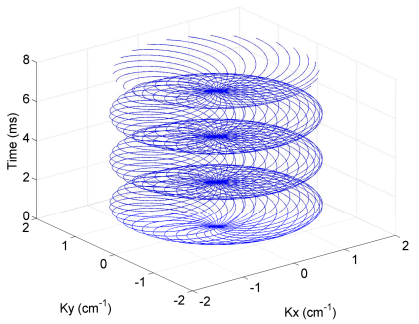

Figure 1: *Rosette Trajectories used for data acquisition (k_{max}=1.67cm^{-1},f_1=215Hz,f_2=230Hz). Every 7th trajectory shown.*

Theory:

Rosette Trajectories were first demonstrated for selective spectroscopic imaging by Noll [1]. They consist of a radial oscillation with frequency f_1, which rotates at the same time with angular frequency f_2 in kx-ky space, and are mathematically described by:

$$\vec{k} = k_x + i \cdot k_y = k_{\max} \cdot \sin(2\pi f_1 t) \cdot e^{i \cdot 2\pi f_2 t}$$

We showed [2] that, by fully encoding all spatial/spectral frequencies, the off-resonance signal that is present in the on-resonance slices as background noise [1] can be removed and the highest SNR sensitivity for these trajectories can be achieved [2,3]. Analytical relations based on hardware constraints, desired spatial resolution and spectral bandwidth were derived for all trajectory parameters, number of excitations and gridding precompensation weights [2]. This efficient encoding scheme can achieve a sensitivity of up to 14% greater than the gold standard Free Induction Decay Chemical Shift Imaging (FIDCSI) experiment with square k-space support [2,3]. In Fig. 1, Rosette trajectories used for data acquisition are depicted in k-t space.

Methods: Experiments were carried out on a whole body 1.5T General Electric scanner, using the built in body coil. K-space rosette trajectories were designed for a FOV=48cm, matrix size Nx=Ny=160 (for an in-plane resolution of 3x3mm^2) and a spectral bandwidth $\Delta\delta = 430Hz$. One axial slice was collected from the liver of a healthy volunteer (slice thickness was 5mm). Readout trajectory length was T_{read}=65ms resulting in a spectral resolution of 15.3Hz ($N_\delta = 28$ spectral slices). At the end of the readout, trajectories were rewound to the center of K-space (while simultaneously the waveform gradients were brought to zero). Each readout was followed by a spoiler gradient to dephase the remaining transversal magnetization. The number of shots used was N_{sh}=196 and the repetition time was T_R=100ms, with no averages (NEX=1). Total scan time, including the equilibrium excitations (dda=4), was 20seconds. Complex data points were collected every 8us (acquisition bandwidth BW=+/-62.5kHz). Raw data was reconstructed on a two-fold oversampled grid using a Kaiser-Bessel kernel and no spatial or temporal filters were applied.

Results: A number of $N_\delta = 28$ spectral images were reconstructed, with a corresponding 15.3Hz separation in frequency between them. The sum of the images corresponding to the water and respectively fat resonances are shown in Fig. 2.

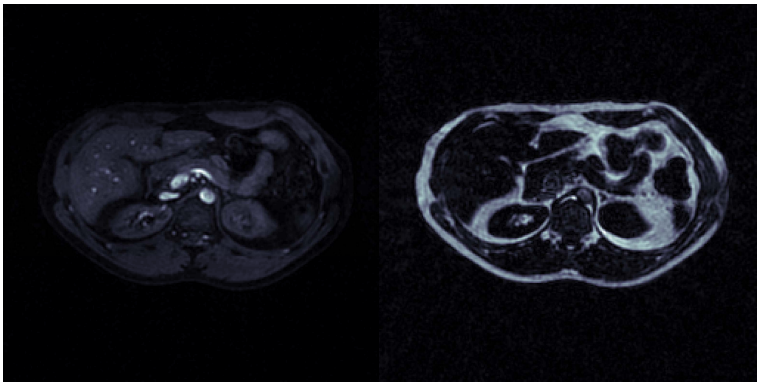

Figure 2: *Liver RSI: Left –Sum of images around the Water resonance. Right- Sum of images around the Fat resonance*

Discussion and Conclusions: We demonstrated very good water-fat separation in liver can be achieved using RSI, making this encoding approach a suitable candidate to obtaining high quality images needed for reliable fat-water fraction quantification. The Rosette trajectories are robust to motion and have great SNR efficiency [3]. A B_0 map can be derived by time segmenting the acquired data [2,7], to correct for field inhomogeneities without need for a separate acquisition. Unlike the two-point [4] or multi-point [5] Dixon that resolves only fat and water, using RSI, it may be feasible to resolve simultaneously all spectral peaks in liver (thus, separate the unsaturated lipids at 5.35ppm from water at 4.65ppm). A higher field strength for the experiment (greater peak separation) or/and using a slightly longer readout (increased spectral resolution) may be needed. A small flip angle (approx equal to Ernst angle), as demonstrated in [5] for IDEAL-SPGR, can be used to minimize the noise bias on fat-water fraction quantification. While T_2^*effect may have to be accounted for [5], the longer repetition time used for RSI compared to IDEAL-SPGR, allows for a greater Ernst angle and therefore greater signal, thus further minimization of the noise bias. An optimized dual-flip angle approach [6] can be used as in [5], to eliminate T_1 bias. As was demonstrated in [5], the fat-fraction quantification is robust to B_1 inhomogeneities for a dual-flip method. A navigator could be implemented to collect multiple slices for liver volumetric spectroscopic imaging.

References: [1] Noll, IEEE Trans Med Imag, **16(4)**, 372, '97. [2] Schirda, Univ. of Pittsburgh, PhD Disertation'07. [3] Schirda et al., Non-Cartesian Workshop, Sedona AZ, '07 [4] Ma, MRM, **52**, 415, '04.[5] Liu et al.., MRM, **58**, 354, '07. [6] Deoni et al.., MRM, **49**, 515, '03. [7] Noll et al., IEEE Trans Med Imag, **10(4)**, 629, '91.