High-Speed Spectroscopic Imaging at 4T for R_2* Measurement of Individual Spectral Components

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Introduction

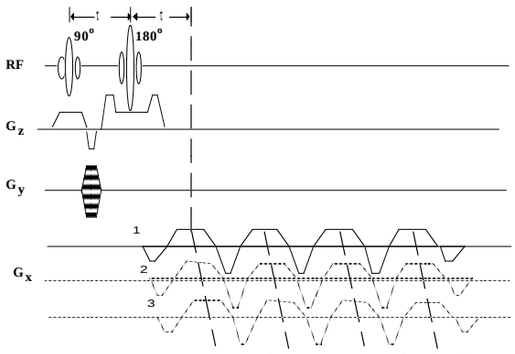


Fig. 1: IMA-GESFIDE pulse sequence for high-speed SI.

Measurement of R_2* for characterizing cancellous bone is typically done by fitting the gradient echo amplitudes to some model for signal decay. This approach faces two problems: (a) it assumes that relaxation of all spectral components is governed by the same time constant, which is not necessarily correct; (b) at field strengths >>1.5T R_2* of cancellous bone marrow protons become extremely short (~5-10ms) (1), which complicates measurement since the interferogram cannot be sampled with sufficient precision. Both problems can be remedied by spectroscopic approaches (e.g. (2)). However, since cancellous bone density depends on anatomic location and the location of greatest sensitivity to bone loss is not known *a priori*, spectroscopic imaging is preferable to single voxel approaches. During recent years several embodiments of high-speed SI techniques, based on an idea by Mansfield (3), and first realized by Matsui et al. (4), have been described (e.g. (5) and refs.). The method relies on a train of gradient echoes, which are modulated by chemical shift. An additional Fourier transformation along the time axis then yields the spectrum at each spatial location. Here we explore an implementation of the method at 4T, using multiple interleaved gradient-echo trains as a means for spectroscopic bandwidth expansion.

Methods

The pulse sequence consists of a 90°-180° pulse pair, followed by a train of 16 equal-polarity gradient echoes, with the first one coinciding with the spin echo (Fig. 1). In order to increase the spectral bandwidth (i.e. the reciprocal of the effective inter-echo time), multiple interleaves, offset in time, were used. The pulse sequence, which is a derivative of the IMA-GESFIDE technique (6), was implemented in the EPIC pulse sequence programming environment (version 5.7) for imaging at 170MHz (GE Signa™ 4T). Data was collected with a SE pulse 2τ=9.2ms, TR=500ms, scan time=6.48mins, 128x128 matrix. Typically, six 16-echo interleaves were collected at a sampling frequency bandwidth (BW) of ±32kHz, resulting in 96 echoes, with an effective echo spacing of 1ms (i.e. corresponding to 1 kHz spectral BW, and spectroscopic sampling time of 100ms=nominal spectral resolution ~10Hz). Raw data were processed in IDL. A 2D FFT was performed to create images, which were ordered in time. Single voxel time series data then yielded FID's which, after zero filling to 128, produced spectra for each image pixel. Absorption-mode spectra were acquired in an oil phantom and in the calcaneus of a volunteer at 1.8x1.8x10mm^3 voxel size.

Results

Fig. 2b shows a 170MHz spectrum of a vegetable oil phantom, obtained with the SI technique of Fig. 1, along with a single voxel spectrum (Fig. 2a). All pertinent resonances of the typical fatty acid triglyceride spectrum are clearly visible in both spectra, except for some spectral broadening in b, caused by the much shorter spectroscopic sampling time. Fig. 3 displays a sagittal image through the foot of a 30-year old male subject, together with spectra representing anatomic regions of different trabecular density with R_2* following the order: subtalar > tuber calcanei >cavum calcanei.

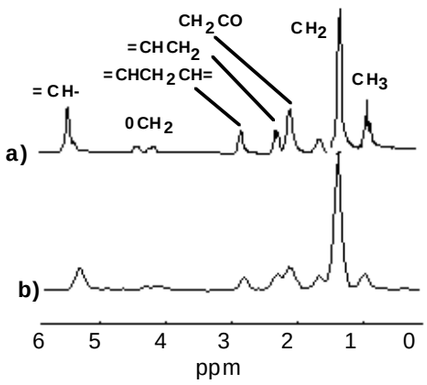
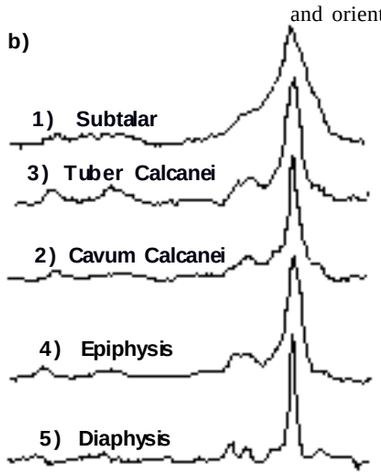


Fig. 2: 170MHz localized spectra of vegetable oil phantom obtained by PRESS (a) and high-speed SI pulse sequence (b).



Fig. 3: a) Localizer image with ROI's of single-voxel (1.8x1.8x10mm^3) spectra (b) showing the expected differences in line width at the three anatomic locations due to differences in trabecular density and orientation (1).



Conclusions

The SI technique of Matsui et al. (4), with multiple interleaves for bandwidth expansion, represents a viable alternative for rapid high-resolution R_2* mapping of individual spectral components. It has the well known limitations, requiring trade-off between spectral bandwidth and resolution. In the current embodiment, 1kHz spectral width covers 6ppm at 170MHz and the 100ms echotrain reduces spectral resolution to 10 Hz.

References

1. H. K. Song, et al., *J. Magn. Reson. Imaging* **7**, 382 (1997).
2. F. Schick, *Progr NMR Spectroscopy* **29**, 169 (1996).
3. P. Mansfield, *Magn. Reson. Med.* **1**, 370 (1984).
4. S. Matsui, et al., *J. Am. Chem Soc.* **107**, 2817 (1985).
5. S. Posse, et al., *Magn Reson Med* **33**, 34 (1995).
6. F. W. Wehrli, et al., *J Magn Reson* **131**, 61 (1998).