Improvement in multi-slice 2D SENSE-MR Spectroscopic Imaging at 3T using frequency-modulated refocusing pulses

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Introduction

Multi-slice, sensitivity-encoded (SENSE) MR Spectroscopic Imaging (MRSI) of the human brain at 3T offers reduced scan time and increased signal-to-noise ratios (SNR) compared to conventional MRSI techniques at 1.5T [1, 2]. However, chemical shift artifacts are increased at 3T, and full SNR improvements are only attained if efficient RF pulses are available for excitation and refocusing. Since phased-array (SENSE) receiver coils are typically used in combination with a body transmit coil (which has a relatively weak B_1 field), these effects are magnified at 3T. This abstract demonstrates reduced chemical shift displacement artifact and improved SNR in multi-slice 2D SENSE-MRSI at 3T using high-bandwidth frequency-modulated (FM) refocusing pulses.

Material and Methods

2D SENSE-MRSI was performed on a Philips Intera 3T system with a six channel SENSE receive head coil. RF pulses were transmitted on the body coil which has a maximum RF field of 14 mT (≈ 600 Hz). A 3-slice (15 mm), spin-echo circularly-encoded 2D-MRSI pulse sequence with dual hyperbolic secant water/lipid suppression [3] and outer-volume suppression, covering from the basal ganglia to the centrum semiovale, was collected (TR/TE 2500/144 msec, FOV 220x110 mm, matrix size 40x20, SENSE factor 2, scan time 25 minutes) [4]. Nominal voxel size was 1.5x0.55x0.55 cm = 0.45 cm^3. Prior to MRSI, field homogeneity was optimized using high order shimming. After MRSI, additional rapid gradient echo MRI scans were recorded to calculate the coil sensitivity matrix. Multi-channel time-domain MRSI data was combined and un-folded using a SENSE algorithm, as described previously[1].

Two acquisitions were performed in an adult volunteer, one with conventional sinc-Gauss slice selective refocusing pulses of bandwidth 600 Hz, and another with numerically optimized FM refocusing pulses ("fmref07") [5] (Figure 1) of bandwidth 2.2 kHz.

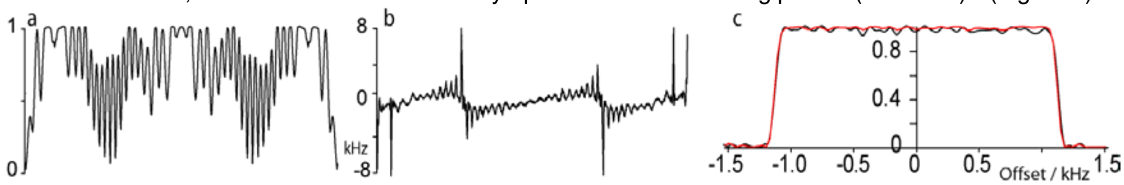

Figure 1. (a) Amplitude, (b) frequency modulation and (c) refocusing profile (red – theoretical, black - experimental) for a 17 msec fmref07 pulse.

Results

High resolution SENSE-MRSI data was obtained in both acquisitions. Using the high bandwidth FM pulses, the chemical shift displacement between Cho and NAA images was 1 mm, while with the SG pulses it was 4 mm. The difference in slice location between NAA and Cho images in the SG acquisition can be visually appreciated in Figure 2. In addition to the reduced chemical shift displacement artifact, SNR was also improved in the high bandwidth FM acquisition, because of the improved slice refocusing profile of the FM pulses: SNR for slice 3 (above the ventricles), defined as NAA peak height/2*rms noise voltage, was 33.4±4.8 for conventional SG pulses, and 38.4±4.2 for high bandwidth FM pulses, an improvement of 15%. RF power deposition was significantly higher for the FM pulses, which limited the minimum TR that could be used to avoid exceeding the allowed specific absorption rate (SAR).

(a) (b)

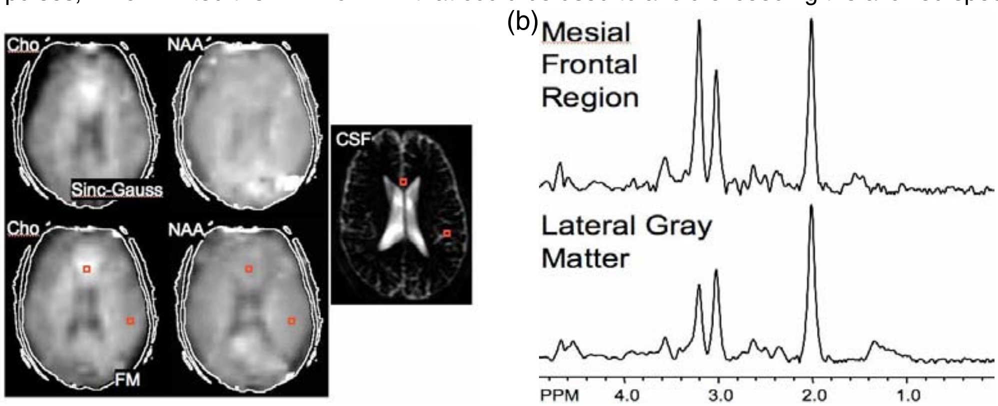

Figure 2. (a) Metabolic Images of Cho and NAA with SG (top) and FM (bottom) refocusing pulses, respectively. The depiction of the ventricular system is much clearer on the FM NAA image, and spatially more similar to the CSF localizer image, than in the SG NAA image.
(b) selected SENSE-MRSI spectra from 0.45 cm^3 voxels (locations indicated in Fig 2a) using FM-refocusing pulses.

Discussion

MRSI at 3T is expected to show improvements in SNR and resolution compared to 1.5T [6], however these improvements may not be fully realized if protocols are not adapted for optimal use at the higher field. Chemical shift artifacts are increased at 3T compared to 1.5T, and it is also more difficult to obtain efficient excitation and refocusing slice selective pulses at higher field. The data presented here shows that high-resolution SENSE MRSI (0.45 cm^3 voxel size) is significantly improved in terms of SNR, and reduced chemical shift displacement artifact, by using high bandwidth FM RF pulses.

References

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Supported by NIH P41 RR15241 and Philips Medical Systems.