Fast and high resolution MRSI without aliasing using online SFAS and multiple regions of support

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Introduction

When localized magnetic resonance spectroscopic imaging (MRSI) is performed, unperfected signal saturation outside the region of interest (ROI) is typically encountered. This undesired signal can cause aliasing and signal contamination if fast high resolution MRSI is conducted by simply reducing FOV (i.e. Zoom MRSI). Alternatively, one can use the sequential forward array selection (SFAS) method to obtain the same resolution MRSI with the same or less data acquisition time required by the Zoom MRSI method [1]. In this work, we demonstrate that online SFAS can not only provide high resolution MRSI with less data acquisition time but also eliminate the aliasing unsaturated signal.

Methods

The ROI of the spectroscopic imaging slice was planned on a T1 weighted scout image (data matrix = 256x256, FOV 256cm^2). The MRSI was conducted by using a 3D localized adiabatic spin echo refocusing (LASER) sequence with two dimensions of phase encoding [2]. Water suppression was provided by an initial broadband semi-selective excitation pulse and frequency selective DANTE pulse applied to the water resonance. The data were acquired with a reduced number of nonuniform phase encodes using the online SFAS over an FOV of 256x256mm resulting in an acquisition time of 8 minutes (TR/TE of 2000/75 ms) and a nominal voxel size of 0.64cc (thk=1 cm). Free induction decay data were processed with 6 Hz line broadening, 50Hz convolution difference, and 1D FFT. The resulting spectra were processed by using projections onto convex sets reconstruction to generate MRSI [1].

Results

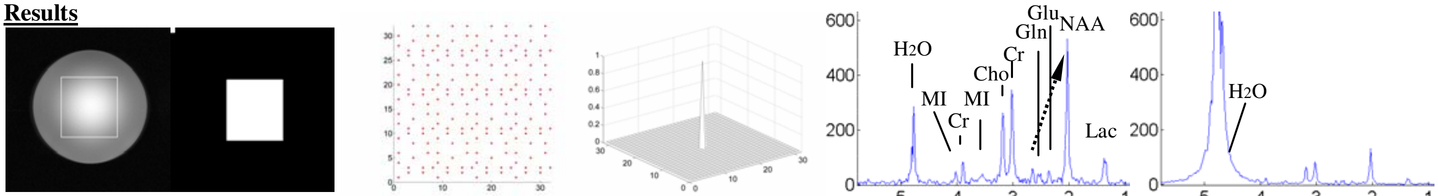

Figure 1.(a) (b) (c) (d) (e) (f)

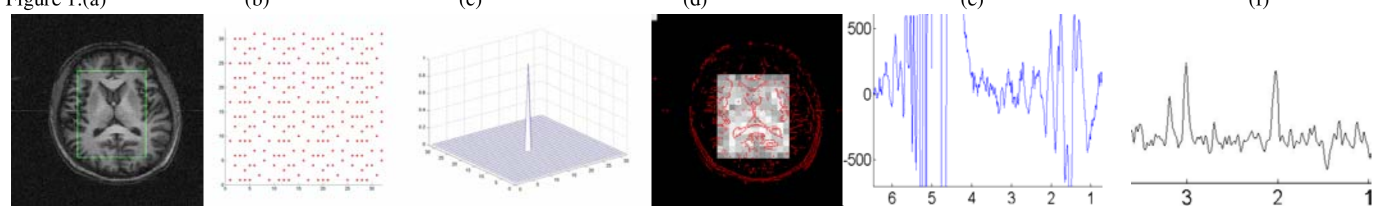

Figure 2(a) (b) (c) (d) (e) (f)

Results from an experiment using a standard Braino phantom are shown in Figure 1. Fig. 1a shows a 256x256 T1 scout image of the phantom with the white box indicating the ROI. Fig. 1b shows an ROS image (white regions) containing 137 pixels, which includes the ROI and one pixel in the upper left corner. Fig. 1c shows 256 nonuniform k-space sampling points optimized from 1024 complete k-space points, which were incorporated into the MRSI sequence for phase encoding. Fig. 1d shows the impulse point spread function (PSF) of the optimized k-space acquisition, which guarantees the minimum voxel contamination in the reconstructed MRSI. Fig. 1e shows a spectrum in the center of the reconstructed MRSI using the optimized nonuniform sparse k-space acquisition pattern as shown in Fig. 1c, which has no water aliasing signal. Fig. 1f shows a simulated spectrum at the same location of the MRSI reconstructed from 256 uniform k-space acquisitions using reduced FOV, which demonstrates significant aliased water signal in this voxel.

Shown in Figure 2 are *in vivo* results from a healthy subject. Fig. 2a shows a T1 scout image with the green box indicating the ROI. Fig. 2b shows 240 nonuniform sampling locations optimized from an ROS, which covers the ROI and one pixel from the upper left corner. Fig. 2c shows the impulse PSF, which resulted from the optimized k-space sample pattern in Fig. 2b. Fig. 2d shows the 32x32 Choline image reconstructed from the optimized 240 k-space acquisitions, which takes only 8 minutes instead of 34 minutes and shows good tissue contrast. Fig. 2e shows a spectrum at the upper left corner, which demonstrated unsaturated water and lipid signal shifted to the upper left corner when the receiver phase is alternated. Fig. 2f shows a spectrum from a predominant gray matter voxel in the ROI, which demonstrates no signal aliasing.

Discussions

For strong signals such as water and lipid, residual magnetization persisted from insufficient crushing gradients would normally appear at the center of the MRSI. However, when using phase alternation, it is shifted to the corner of the FOV. Since this signal cannot be avoided, it will be shifted into the center of the ROI when using the Zoom MRSI as well as the SFAS approach with an ROS that includes the ROI only. However, the aliased signal and the contamination can be eliminated in the high resolution MRSI using optimal nonuniform sparse phase encodings selected by SFAS based on an ROS including the isolated corner and the localized ROI. An impulse point spread function (PSF) from the optimal k-space acquisition guarantees the minimum voxel contamination.

Online SFAS is capable of modeling residual signals outside the ROI by including regions with significantly unsaturated water and lipid signals in the ROS, which can eliminate aliased signals from the ROI and minimize contamination to weak signals. The online SFAS is able to optimize nonuniform sparse phase encodings for multiple isolated ROS regions. Therefore, this can significantly reduce the MRSI acquisition time. Nonetheless, the impulse PSF from the optimal nonuniform k-space acquisitions guarantees the minimal voxel contamination. The online SFAS is an efficient approach for high resolution MRSI.

References

[1] Gao Y, et al., ISMRM 2005;13:284. [2]. Garwood M and DelaBarre L, J. Magn. Reson. 153, 155-177, 2001.