Improved Sensitivity in ^{19}F Cellular Imaging using Nonconvex Compressed Sensing

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Introduction

Great progress has been accomplished in the field of ^{19}F-marked stem cell tracking [1], nonetheless ^{19}F imaging suffers from low signal intensities and, thus, long data acquisition times due to averaging. The distribution of the ^{19}F signal is sparse in the image domain. To exploit the inherent sparsity of these datasets, one can use Compressed Sensing (CS) [3]. CS allows the reconstruction of sparse undersampled datasets and is becoming increasingly popular in the field of MRI since many MR applications exhibit sparsity (e.g. angiography). Classical Chemical Shift Imaging (CSI) offers the possibility to image multi-resonant ^{19}F compounds. Furthermore, classical CSI is a purely phase encoded technique; therefore, random sampling can be applied, being optimal for the CS reconstruction due to the incoherent undersampling artifacts. In this work we demonstrate the potential of Nonconvex CS [4] in cellular imaging using ^{19}F CSI. Although CS applied to CSI has been presented recently [5], this study is the first one where CS exploits solely the sparsity in image space and not in the spectral dimension. Initial results from retrospectively undersampled phantom and *in vivo* experiments are presented.

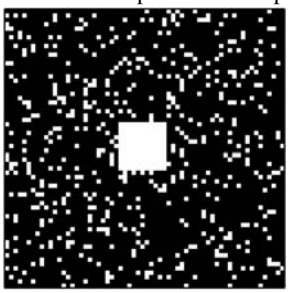

Figure 1: Sampling Pattern

Materials and methods

A phantom of six tubes filled with perfluoro-15-crown-5-ether (PF15C) emulsion (Celsense Inc., Pittsburgh, PA, USA) was imaged using a CSI sequence: Bruker BioSpec 7 T (Bruker Biospin GmbH, Rheinstetten, Germany), 64x64, FOV 40x40mm^2, TR=17 ms, 38.55 Hz/Px, 6 averages. For the *in vivo* experiments a PF15C emulsion was injected into the tail vein of a male C57/BL6 mouse with focal cerebral ischemia; measurement parameters of the CSI sequence: Bruker BioSpec 7 T, 48x48, FOV 30x30mm^2, TR=24 ms, 25 Hz/Px, 65 averages. To mimic accelerated imaging, the datasets (phantom and *in vivo*) were retrospectively undersampled using a random pattern with a dense sampling region in the center of k-space (see Figure 1). For the phantom experiments, 618 out of 4096 phase encoding steps were used for reconstruction, for the *in vivo* experiments 382 out of 2304 points were used. The data were CS reconstructed point-by-point along the spectral dimension according to [4,6].

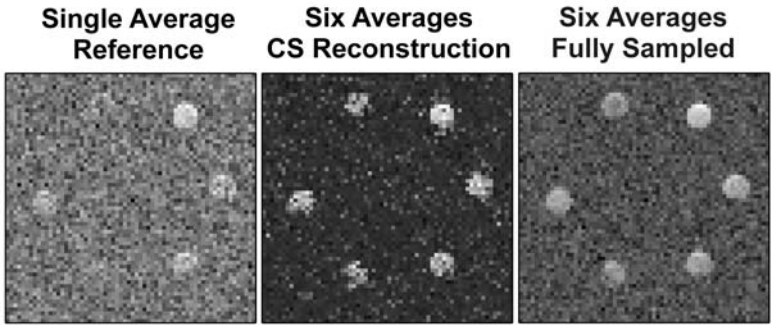

Figure 2: Results from the phantom experiments (single spectral point). The acquisition time for the right image was six times longer than for the other images

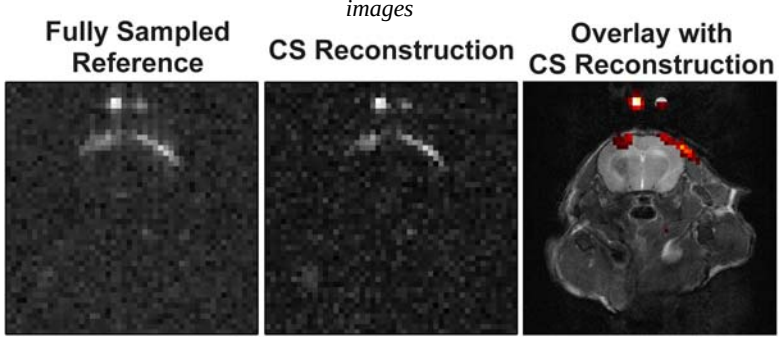

Figure 3: Results from the in vivo *experiments. The CS reconstruction used approximately a sixth of the data of the reference; thus, the measurement time would have been reduced by a factor of approximately six*

Results

In Figure 2, the reconstructed undersampled phantom chemical shift image is compared to fully sampled single-average and six-times-averaged datasets. The acquisition of the undersampled six-times-averaged data would have taken approximately as long as the fully sampled single-average dataset. The CS reconstruction offers the same sensitivity as the six-times-averaged reference but in a sixth of the measurement time. Figure 3 shows the reconstructed undersampled *in vivo* data in comparison with the fully sampled image. Again, when using a CS reconstruction, it is possible to obtain almost the same information content by collecting only a sixth of all phase encoding steps in ^{19}F CSI.

Discussion

CS offers the possibility to dramatically reduce the number of phase encoding steps in CSI while preserving the spectral information. This is important in the case of multi-resonant ^{19}F compounds. The gain in imaging time can be invested into more averages to improve k-space SNR, to increase the resolution, or to speed up the entire imaging process. The accelerated data acquisition is especially beneficial for *in vivo* experiments because of the limited measurement time. Furthermore, 3D CSI experiments might become feasible. The apparently improved SNR of the CS reconstructions is due to the CS algorithm, which alters the noise statistics. Improved k-space SNR by averaging helps emphasize the ^{19}F signal against the noise level, leading to better CS reconstructions with apparently improved SNR. These results may appear paradox, however, they are due to the more efficient use of available information during the CS reconstruction process and need further investigation. In conclusion, the proposed method shows promise in terms of imaging speed and sensitivity for CSI experiments.

Acknowledgements

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