Accelerated Imaging of Hyperpolarized Carbon-13 Compounds

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INTRODUCTION

The long scan time characteristic of traditional chemical shift imaging sequences (CSI) is a major limitation for metabolic imaging of hyperpolarized compounds [1]. In this work, the ability to accelerate the spatial encoding process during a CSI scan of hyperpolarized compounds is demonstrated in vivo through parallel imaging [2,3]. A hardware set up designed to acquire ^{13}C signal data from multiple receivers simultaneously is presented here. Four preamplifiers, four gain blocks, a transmit coil and a four-channel rat coil were built for single channel excitation and simultaneous multi-channel detection of signals from ^{13}C nuclei. The ability to perform parallel imaging is demonstrated *in vivo*. The CSI data from the accelerated scans is reconstructed using self-calibrated SENSE [2], by using coil sensitivity maps obtained from lower resolution datasets reconstructed from the central region of k-space.

MATERIALS AND METHODS

A four-channel rat coil (shown in fig.1a) was built by placing individual coils around a cylindrical plexi-glass tube of 5cm diameter and 8cm length. Spatial overlapping decoupled neighboring coils. Coils facing each other were decoupled by the use of low input impedance, ^{13}C tuned preamplifiers. To compensate for system noise, 20dB gain stages were introduced into each channel of the receive chain, at the output of the preamplifiers. A single loop transmit coil of dimensions 12cm× 12cm (shown in fig.1b) was also constructed and securely attached underneath the receive coils. For shimming and anatomical localization of the region of interest in *in vivo* exams, this entire ^{13}C transmit receive setup was operated within a standard proton head coil (fig. 1c). The integration of the hardware setup with scanner electronics ensured that the ^{13}C transmit/receiver chain functioned like a conventional multi-channel proton system, except at a different frequency.

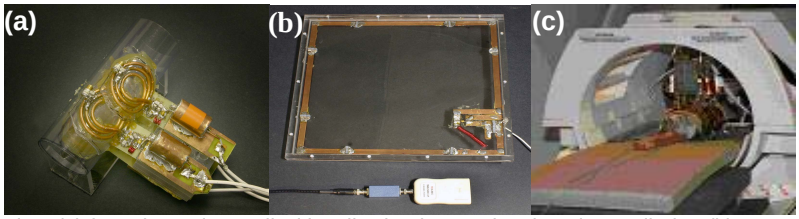

Fig.1 (a) four channel rat coil with coils clued around a plex-glass cylinder. (b) A single loop transmit coil tuned to ^{13}C frequency and connected to a broad band Rf amplifier. (c) Animal placed inside the ^{13}C transmit/receive set up which is operated inside a standard proton head coil.

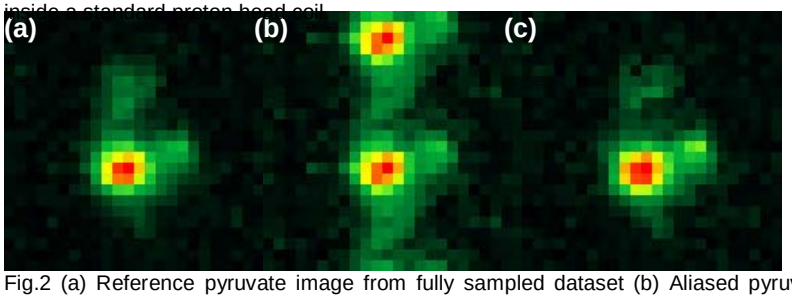

Fig.2 (a) Reference pyruvate image from fully sampled dataset (b) Aliased pyruvate image from artificially undersampled dataset. (c) The unaliased pyruvate image from the reconstructed dataset.

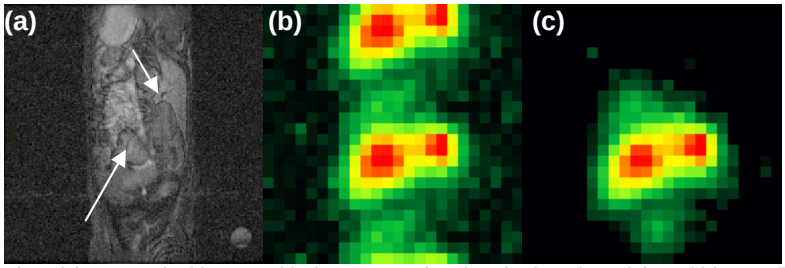

Fig.3 (a) Anatomical image with the arrows showing the location of the 2 kidneys. (b) Accelerated ^{13}C pyruvate image with aliasing visible. (c) Reconstructed unaliased image.

RESULTS AND DISCUSSION

All experiments were conducted on a commercial GE 1.5T scanner, and data reconstruction was implemented in MATLAB 6 (Natick, MA, USA) on a 1 GHz Intel PC processor. The signal was encoded with a FID CSI sequence with 24x24 spatial encodings, FOV=12cm, slice thickness=20mm, BW=5kHz, 256 spectral points and TR=80msec. For the first experiment, a fully sampled reference dataset was acquired and artificially undersampled by a factor of 2. Sensitivity maps were generated form the central 16x16 data FIDCSI points, and used to correct the artificial under-sampling. The results of this process are shown in fig.2. A standard FIDCSI sequence was then modified to allow the acquisition of accelerated scans, by undersampling the outer half of k-space of one or two dimensions. The center half of k-space was maintained fully sampled, to allow the generation of the coil sensitivity maps. Two accelerated hyperpolarized ^{13}C datasets were acquired; a higher flip angle was used in this case to account for the fewer number of phase encodes that were collected, and optimize SNR [4]. An acceleration factor of 1.5 was used here because of the geometry and small number of channels available. These two datasets were reconstructed, while successfully removing the aliasing, to demonstrate true parallel imaging capability. The results from one of the accelerated datasets are shown in fig.3. Note the high signal intensity of the two kidneys.

CONCLUSIONS

A multi-channel ^{13}C specific system was developed and used successfully with parallel imaging to accelerate CSI *in vivo* scans. All scans acquired multi-spectral data and we performed multi-spectral SENSE reconstruction by applying the algorithm on pyruvate, lactate and alanine chemical species though we have shown only pyruvate images due to limited abstract space. Future work will focus on quantification of image SNR, which, different than in conventional parallel imaging, should increase by decreasing scan time. The additional signal gain from shorter scan times can be used to increase spatial/spectral resolution of the acquired datasets.

REFERENCES

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