Fast Chemical Shift Imaging by Online Optimal Sparse k-space Acquisition And Projection Onto Convex Set Reconstruction

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Introduction

Long acquisition time, low resolution, and voxel contamination are some of the major difficulties in the application of in vivo chemical shift imaging (CSI). To overcome these difficulties, an on-line k-space optimization method, based on sequential forward array selection of k-space (SFAS), was developed on a 4T Varian whole body system to reduce acquisition time without sacrificing spatial resolution in CSI. In-house software was developed to process and reconstruct chemical shift images using the projection onto convex set approach. Phantom and in vivo studies conducted on the 4T scanner showed that good quality CSI was obtainable with 80% reduction of data acquisition time using this approach.

Method

In our application, the region of interest (ROI) was identified using T1 weighted scout images. A 2D CSI was obtained at the selected ROI using the LASER technique [1]. Adiabatic pulses were used to suppress water signals and to refocus metabolic signals in the ROI. A region of support (ROS) was able to be created from the same ROI. The localized ROS is the basis for the optimization of sparse k-space acquisition using SFAS [2], which doesn't reduce the spatial resolution but can minimize noise amplification in reconstructed CSIs. A 50 Hz convolution difference and 6Hz Gaussian broadening was used before Fourier transform to get k-space spectra. Spatial domain spectra were reconstructed using the projection onto convex set method after getting k-space spectra. Metabolic images are generated from registered peak frequency of each chemical species.

Result

Results from phantom and in vivo experiments using this approach are shown here.

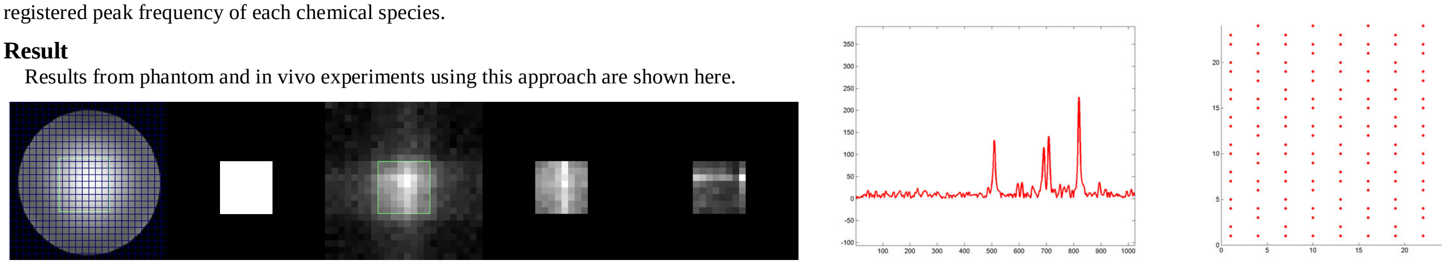


Fig 1a 1b 1c 1d 1e 1f 1g

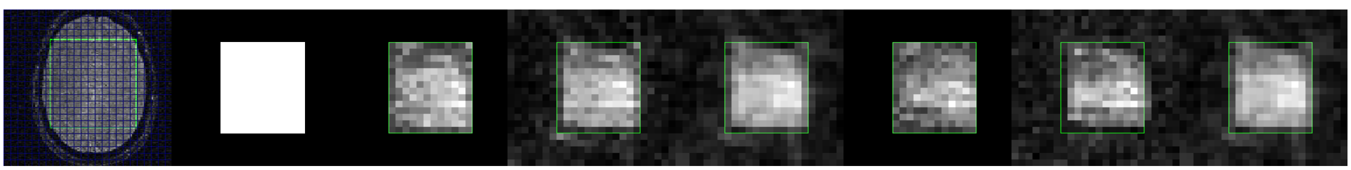
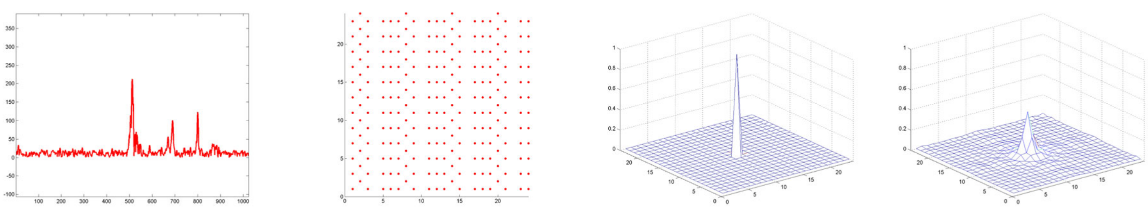


Fig 2a 2b 2c 2d 2e 2f 2g 2h



2i 2j 2k 2l

Figure 1 shows a phantom study. Fig. 1a shows a scout image with ROI. Fig. 1b shows ROS from the ROI. Fig. 1c shows the reconstructed NAA image with a full 24 x 24 k-space data set and acquisition time of 19 minutes. Fig. 1d shows the reconstructed NAA image with only 128 sparse k-space locations optimized with online SFAS. It takes only 4 minutes, i.e., approximately 22% of the time for full k-space acquisition. But, an impulse point spread function (PSF) from the 128 optimized phase encoding steps in Fig. 1g guarantees that the image in Fig. 1d has the same resolution as in Fig. 1c. Figure 1e shows the reconstructed image from an arbitrary 128 phase encoding steps, which shows that the arbitrary acquisition caused singularity. Figure 1f shows the spectrum of voxel at (13, 13) in Fig. 1d. Figure 1g shows the 128 optimized k-space locations from the ROS. The nonuniform acquisition pattern breaks the Nyquist barrier.

Figure 2 is an in vivo study. Figure 2a is a scout image with ROI. Fig. 2b shows the ROS image from the ROI. Figs. 2c and 2f show the reconstructed NAA and Creatine images from the 240 optimized k-space locations. The impulse PSF shown in Fig. 2k from the 240 optimized k-space locations (shown in Fig. 2j) guarantees that Figs. 2c and 2f are obtained with 59% reduction in acquisition time but have retained the same resolution as Figs. 2d and 2g with standard full k-space acquisition. Figures 2d and 2g show the reconstructed NAA and Creatine images, respectively, from full k-space data (24x24 data matrix). Figures 2e and 2h show the reconstructed NAA and Creatine images, respectively, from central k-space with 249 data points, i.e., 43% of full k-space, which show blur artifacts and voxel contaminations due to the broad PSF shown in Fig. 2l. The spectrum at voxel (15,16) reconstructed from the optimized data set with projection onto convex set is shown in Fig 2i. Fig. 2j shows the optimized k-space locations (with 240 data points) from the ROS in Fig. 2b. Fig. 2k shows the impulse PSF obtained from the optimized k-space locations in Fig. 2j. Figure 2l shows the PSF from the central k-space locations with broad central lobe and side lobes causing blur and voxel contamination in reconstructed images.

Discussion

We demonstrated that the proposed online optimization of sparse k-space acquisition using the SFAS scheme is able to produce chemical shift images with 22% and 41% of data acquisition time without losing spatial resolution for phantom and in vivo experiments, respectively, comparing them with the full k-space acquisition. The required acquisition time using the online SFAS depends on the ratio of the ROI size to the field of view dimension. Thus, the smaller the ROI to FOV ratio has chosen, the less acquisition time required.

References

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2. Gao Y and Reeves SJ, IEEE Trans Med Img, 20:868, 2001.