Compressed Sensing in Diffusion-Weighted Radial-FSE

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Introduction

Radial fast spin-echo (Radial-FSE) methods have been used to produce high-resolution diffusion-weighted images that are insensitive to motion and/or magnetic field inhomogeneity [1,2]. However, one of the drawbacks of radial-FSE is the long acquisition time, compared to single shot echo planar imaging, required for high resolution images with sufficient signal to noise ratio (SNR). Recently, Compressed Sensing (CS) theory [3,4] has been developed for MRI applications and has been demonstrated in MRI data acquired on radial trajectories [5-8]. The CS reconstruction of undersampled radial data has been shown to dramatically reduce streaking artifacts, compared to filtered backprojection or regridding reconstruction. In the present work, we have applied CS reconstruction to diffusion-weighted radial-FSE datasets to evaluate the utility of CS methods to enable faster acquisition of diffusion-weighted radial-FSE data.

Methods

DW Radial-FSE datasets were acquired using a previously published sequence [1] where diffusion–weighting is cycled through four different diffusion directions each TR period: XYZ, -XYZ, X-YZ, -X-YZ. Using full gradient strength on all three axes simultaneously allows maximal b values to be obtained in the shortest possible TE. By selecting the proper view ordering, effects of T2 decay within the echo train can be minimized [2] and radial lines with diffusion-weighting in a particular direction are equally distributed throughout the 2Π radians of Fourier space [1]. To evaluate CS reconstruction on undersampled DW radial-FSE datasets, reconstructions were carried out on subsets of data from a full radial dataset consisting of 256 equally spaced radial lines with 256 sample points each, collected with an echo train length, ETL = 4. Images were reconstructed using 256, 128, 64 and 32 lines of data, corresponding to increases in speed of 1, 2, 4 and 8 respectively. CS reconstructions were carried out using wavelet sparsity (Daubechies-6) as well as total variation regularization.

Results

Radial-FSE images obtained using non-uniform FFT (NUFFT, essentially regridding) and CS reconstructions from a cancer patient are shown in Fig. 1. When 256 views are included in the reconstruction, both techniques yield images that are free of visible streaking artifacts. When the degree of undersampling increases, the NUFFT reconstruction demonstrates the expected decrease in SNR and increase in streaking artifacts from azimuthally undersampled radial data. In contrast, the CS reconstructions with 128 and 64 views maintain high SNR, spatial resolution and exhibit few streaking artifacts. Histograms of a large ROI (tumor and surrounding tissue) from ADC maps produced using b = 0 and 1000 s/mm^2 images are shown in Fig. 2. As can be seen, the standard deviation of values in the ADC histogram obtained from NUFFT maps increase with undersampling (mean ±s.d. = 1.484 ±0.424, 1.582 ±0.576, 1.606 ±0.757, 1.621 ±0.919 for 256, 128, 64 and 32 view datasets, respectively), as does their mean value and shape. In contrast, the mean value, standard deviation and shape of the ADC histograms obtained from progressively undersampled CS reconstructions do not change significantly (mean ±s.d. = 1.489 ± 0.397, 1.523 ±0.394, 1.506 ±0.364, 1.478 ±0.362).

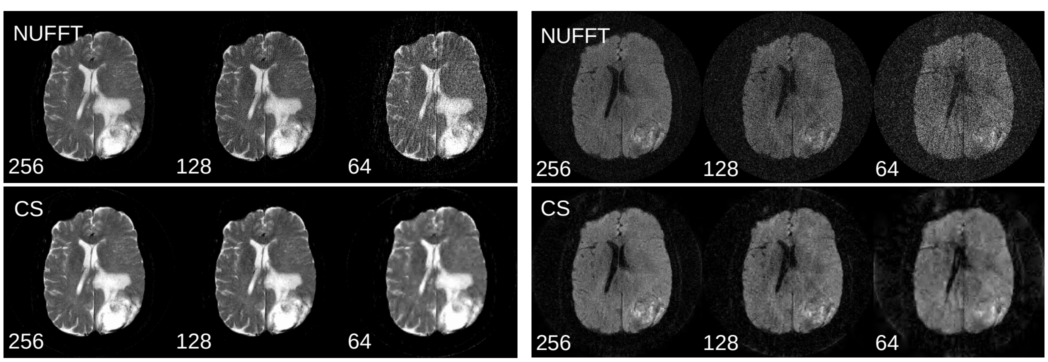

Fig. 1 Non-diffusion weighted (left) and diffusion-weighted (right, b= 1000 s/mm^2) radial-FSE images reconstructed from progressively undersampled data reconstructed with non-uniform FFT (NUFFT) and compressed sensing (CS) reconstructions. Numbers in the figure correspond to the number of radial views included in the reconstruction.

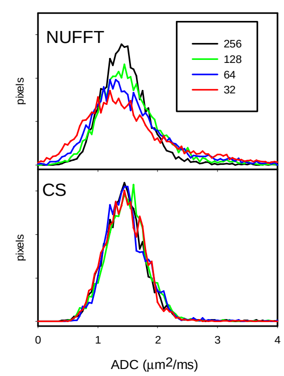

Fig. 2 Histograms from ADC maps produced with NUFFT and CS reconstructions from sub-sampled radial datasets (legend indicates view #)

Conclusion

With compressed sensing reconstruction, diffusion-weighted radial-FSE images can be reconstructed from highly undersampled data without introducing severe streaking artifacts or considerable reductions in SNR. This can dramatically increase the speed of multi-shot radial-FSE acquisition and its clinical utility. Furthermore, quantitative ADC values and histogram properties are maintained with undersampled CS reconstruction much more so than with regridding reconstruction.

References: [1] Sarlls, *et al.*, *MRM* (2005). [2] Theilmann, *et al.*, *MRM*, 51, 768-774 (2004) [3] Candes et al. IEEE Trans. on Inform. Theory. 2006. [4] Donoho DL, IEEE Trans. on Inform. Theory. 2006. [5] Chang TC et al. Proc. ISMRM (2006) [6] Bilgin et al. Proc ISMRM (2007). [7] Block KT et al. Proc. ISMRM (2007). [8] Chang TC et al. Proc. ISMRM (2007)

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