Homodyne Reconstruction of Partial Fourier Readout-Segmented EPI for Diffusion Imaging

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Introduction

Readout-segmented EPI (RS-EPI) with GRAPPA parallel imaging, 2D navigator correction and navigator-based re-acquisition has been used to acquire high resolution diffusion-weighted images with reduced susceptibility artifact and blurring from T2* signal decay compared to single shot EPI (ssEPI) [1-3]. However, for RS-EPI to be used in a clinical setting the scan time must be reduced further to be more comparable with current ssEPI protocols. This study demonstrates that the number of segments can be reduced to 6/11 without significantly compromising image quality by reconstructing missing k-space data with partial Fourier techniques. Homodyne partial Fourier reconstruction [4] versus full k-space acquisition was investigated and image quality and signal-to-noise ratio (SNR) comparisons are presented.

Methods

The double echo sequence [1] collects an imaging and navigator echo after each modified Stejskal-Tanner diffusion preparation**,** which uses the full time between the two RF pulses for diffusion gradients. Both echoes sample contiguous k_x points and have 2X GRAPPA acceleration in k_y. Successive imaging echoes are at different offsets in k_x to cover the full extent of k-space, whereas the navigator echo is always the central segment.

Data were acquired from healthy volunteers using a 3T Siemens Verio scanner under an approved technical development ethics protocol. 12- and 32-channel head coils were used to acquire DWI protocols. Imaging parameters: matrix=256 x 256; FOV=220mm; voxel size=0.9mm x 0.9mm x 4.0mm; slices=19; readout segments=11 (for full k-space, segments were omitted from reconstruction for partial k-space comparison); GRAPPA R=2; TR=5410ms; TE1/TE2=65ms/113ms; echo spacing=320µs. DWI protocol: 1 image at b=0 and 3 directions at b=1000s/mm^2; scan time: 5:04mins. GRAPPA auto calibration scans were acquired for each slice and Nyquist ghost correction data were acquired for each slice and echo.

Data were reconstructed offline in Matlab (The Mathworks, Inc). All segments were re-gridded to fit a sinusoidal readout gradient waveform, Nyquist ghost phase corrected and missing lines were reconstructed with a GRAPPA algorithm. 2D navigator phase correction for each slice was carried out by zero filling all segments to 256 k_x columns; Fourier transforming to image space; selecting the navigator with the least motion corruption (judged by the parameter distribution width - a measure of the spread of points in k-space); and phase correcting all imaging segments relative to this. Motion-induced phase correction was not applied to b=0 data. The segments were then concatenated in k_x after discarding the 8 overlapping columns at each edge of the segments. These extra k_x points were acquired in order to be able to account for minor k-space shifts caused by motion.

Partial Fourier reconstruction was performed using a homodyne correction algorithm [4] from 6/11 segments. The reduced k-space matrix for each channel was multiplied by the homodyne weighting function and the result was Fourier transformed to the image domain. The channel images were phase corrected using phase from a low-resolution image and the real parts combined to form the final image. The mean SNR was calculated in all slices using the mean signal in a ROI in the sub-cortical white matter versus the standard deviation of the noise in a background ROI.

Results

Comparison of full and reduced segment-set trace weighted images with b=1000s/mm^2 from the 12-channel coil are shown in figure 1, b=0 images from the 32-channel coil in figure 2 and a SNR comparison is shown in table 1. Image quality is good for homodyne reconstruction despite an expected loss of ~20% in SNR.

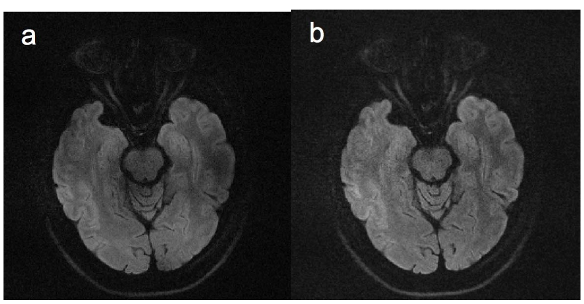

Figure 1: Comparison of 12-channel coil trace-weighted images with b=1000s/mm^2 for full k-space (**a**) and homodyne reconstruction using 6/11 segments (**b**)

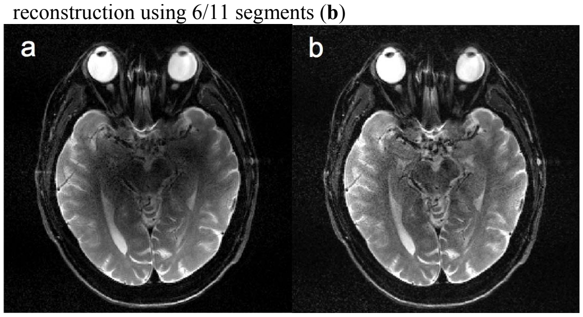

Figure 2: Comparison of 32-channel coil b=0 images for full k-space (**a**) and homodyne reconstruction using 6/11 segments (**b**)

Reconstruction	**12-channel SNR**		**32-channel SNR**	
	b=0	TrW	b=0	TrW
Full k-space	29(3)	17(3)	33(3)	27(2)
Homodyne	23(2)	14(3)	26(4)	22(1)

Table 1: Comparison of SNR in full k-space and homodyne reconstructions in b=0 and trace-weighted images with b=1000s/mm^2 using 12- and 32-channel head coils.

Discussion

In this study we have shown that acquiring a reduced number of segments in combination with homodyne reconstruction can reduce DWI scan time by 40% while maintaining acceptable image quality. The reduced acquisition times could also allow high-resolution tractography in a clinically realistic time frame, and is the aim of ongoing work.

References

[1] Porter et al. MRM 62: 468-75 (2009); [2] Robson et al. MRM 38:82-88 (1997); [3] Miller et al. MRM 50:343-353 (2003); [4] Noll et al. IEEE TMI 10:154-64 (1991)