ACCELERATING MR DIFFUSION TENSOR IMAGING VIA REDUCED ENCODING PROJECTION RECONSTRUCTION

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1. INTRODUCTION

Diffusion tensor imaging (DTI) is a promising tool for characterizing microstructures of ordered tissues. Practical applications of DTI have been hampered by the low SNR and spatial and temporal resolutions. K-space sharing with constrained reconstruction has been shown effective for accelerating DTI, though the implementation was based on rectilinear k-space sampling [1]. Radial sampling of k-space, or projection reconstruction (PR) imaging [2], may be advantageous due to the intrinsic oversampling and averaging of central k-space and isotropic trajectories for symmetrical reduced encoding. In this study, a novel radial mask filtering is applied to select for spatial frequency information in the reconstruction of diffusion-weighted images (DWI) so that less of the low spatial frequency than the outer k-space reference data (b0 image) are incorporated. To minimize the magnitude and phase discontinuities between the b0 and DWI data, a zeroth-order correction is employed as well. The performance of filtered reduced encoding projection reconstruction (FREPR) is evaluated in terms of DWI differences and deviations in fiber orientation from the full-encoded datasets, both in simulation and experiment, and against rectilinear k-space sharing method (i.e., keyhole).

2. METHODS

A reduced-encoded DTI dataset consists of a full-encoded reference image (b0 image) and a series of reduced-encoded DWI (RE-DWI). RE-DWI data refer to the central k-space of the full DWI data for rectilinear sampling or angularly undersampled k-space for radial sampling. The RE-DWI data are combined with the b0 data to reconstruct full size DWI. Radial mask filtering is employed in the radial sampled k-space, which is a high-pass filter H (ranges 0-1) applied along the radial k-space lines of the b0 data (Fig 2) and a corresponding low-pass filter $m-(m-1)\times H$ applied along the RE-DWI k-space, where m is the reduced encoding ratio. A baseline correction is applied on the b0 data before combing with the RE-DWI data to ensure zeroth-order magnitude and phase continuity, which is realized by multiplication with a complex scalar factor. In computer simulation, reduced-encoded DWI were reconstructed via each reduced encoding scheme (uncorrected and corrected keyhole, uncorrected and corrected FREPR with different kinds of radial filters) and compared to the full-encoded DWI. In experimental verification reduced encoding schemes at 1:2 and 1:4 reduced encoding were applied on the rectilinear or radial sampled raw data as described early. The normalized RMS difference and the fiber deviation-angle map were used to quantify difference between full-encoded and reduced encoded images/datasets.

3. RESULTS AND DISCUSSION

Results in Fig 1 indicate that the zeroth-order correction is necessary for improving reduced encoding performance both in rectilinear and radial sampling. This is especially important for applications like DTI because the large intensity differences between the reference and reduced-encoded data will incur high-pass filtering effect distortion. Fig 2 shows that radial filtering is a key feature for FREPR, which takes advantage of the unique pattern of radial k-space. The best performance is achieved with the filter (f), which is consistent with the radial sampling k-space property for the 1:2 RE-DWI data with central half k-space fully sampled and outer half k-space sampling density decreased gradually. In Figs 1-3, error distribution reveals that most errors resulted from the keyhole method concentrate on the edges with ringing artifact (Fig 3 b), but errors from FREPR distribute more uniformly throughout the whole image. This is consistent with the k-space property of the rectilinear and radial sampling, which also suggests inherently advantage for fiber mapping because the background information is usually discarded in DTI. PR imaging is additionally advantageous for *in vivo* imaging in that it is relatively insensitive to motion [2]. FREPR method does not necessarily limit to DTI, showing potentials for helping improve time efficiency of other PR-based MR imaging techniques, for example, MR cardiac cine, contrast MRI and IMRI.

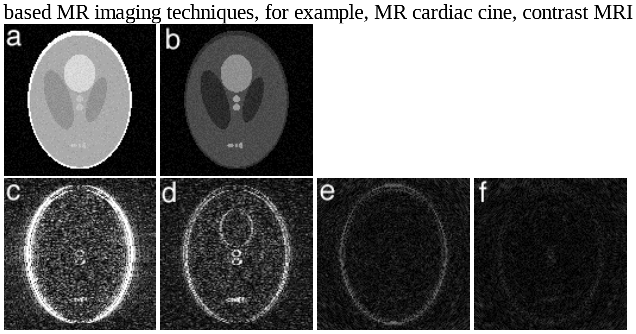

Fig 1. Effect of correction.
Fully encoded (a) b0 image and (b) target DW image. Difference image between the full-encoded and the reduced-encoded DWI reconstructed by (c) uncorrected keyhole, (d) corrected keyhole, (e) uncorrected FREPR, and (f) corrected FREPR. The difference images have been scaled ×10 times for better visualization. The respective normalized RMS differences were (c) 27.8%, (d) 12.1%, (e) 4.71% and (f) 2.92%.

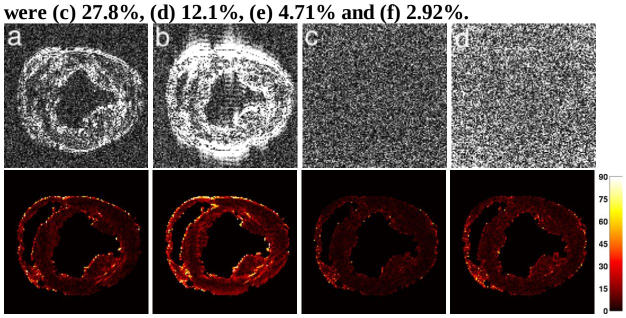

Fig 3. Comparison of FREPR and keyhole at 1:2 and 1:4 reduced encoding ratios.
Top panel: Difference image between the full-encoded and the reduced-encoded DWI reconstructed by (a) keyhole at reduced encoding ratio *m*=2 (i.e., 1:2 reduced encoding), (b) keyhole at *m*=4 (i.e., 1:4 reduced encoding), (c) FREPR at *m*=2, and (d) FREPR at *m*=4. Bottom panel: Fiber deviation-angle map corresponds to each RE-DTI scheme on the top panel.

4. REFERENCE

1. Hsu, E.W. and C.S. Henriquez, *Myocardial fiber orientation mapping using reduced encoding diffusion tensor imaging.* J Cardiovasc Magn Reson, 2001. **3**(4): p. 339-347.
2. Glover, G. and J. Pauly, *Projection reconstruction techniques for reduction of motion effects in MRI.* Magn Reson Med, 1992. **28**: p. 275-289.

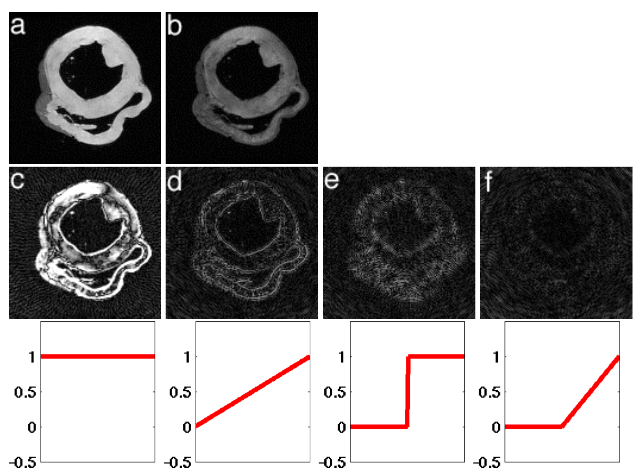

Fig 2. Effects of radial filters for FREPR.
Short-axis view of fully encoded (a) b0 image and (b) target DW image of a fixed sheep heart. Difference image between the full-encoded and the FREPR reconstructed DWI with (c) no filtering, (d) ram-lak filtering, (e) step filtering, and (f) step-triangular filtering. The difference images have been scaled ×25 times for better visualization. The respective normalized RMS differences were (c) 10.3%, (d) 2.77%, (e) 2.73% and (f) 1.79%. The corresponding filters *H* are displayed in the bottom panel with zero frequency at the leftmost end.