Improvement of Diffusion Weighted Images with Reduced-View Radial Acquisitions

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INTRODUCTION

Diffusion imaging techniques using radial trajectories have been presented including the radial turbo-spin-echo (rTSE) and highly constrained backprojection (HYPR) sequences, which reduce not only the imaging time but also image distortions (1, 2). Here, we propose a method to further improve the image quality by estimating the missing information from the projection data acquired with a reduced number of projection views.

METHODS

Projection Data Regeneration: In order to reduce the data acquisition time in projection reconstruction (PR) methods, the proposed PR method acquires data from a reduced number (n) of projection views for diffusion weighted (DW) images which is less than the number (N) required by the Nyquist rate while acquiring full-view (N) projection data for the non-DW image. It can be performed with any kind of sequences having radial trajectories. Using the reduced projection data ($n<N$), images can be formed using the inverse radon transform (*IRT*), and the projection data can be calculated again using *RT* to generate N views. ***Projection Data Interpolation:*** The roughly calculated (N-n)-view projection data can be supplemented with the high frequency terms of the reference non-DW projection dataset with full (N) projection views because they share a similar high-frequency information. An optimal cutoff frequency ω_c of 0.4π for low and high frequency filters in human brain images is determined using the previously suggested method (3). The low-pass filter (H_{LPF}) and high-pass filter (H_{HPF}) for interpolation of the (N-n) projections are then designed as follows: For $\omega<\pi/5$, $H_{LPF}(\omega) = 1$ and $H_{HPF}(\omega) = 0$. For $\pi/5<\omega<3\pi/5$, $H_{LPF}(\omega) = (1+\cos(5(\omega-\pi/5)/2))/2$ and $H_{HPF}(\omega) = (1-\cos(5(\omega-\pi/5)/2))/2$. For $3\pi/5\leq\omega$, $H_{LPF}(\omega) = 0$ and $H_{HPF}(\omega) = 1$. By using these filters, the calculated DW MR signals and the acquired non-DW MR signals of the corresponding views are interpolated in the frequency domain. The composite signals are then transformed to the composite projection data by *1D-FT*. Combining the composite projection data with the originally acquired projection data produces a full-view DW projection data. In the end, a DW image is reconstructed by filtered backprojection. ***Data Acquisition:*** The proposed method was verified with a simple radial spin-echo diffusion-weighted-imaging (rSE-DWI) sequence on a 3.0T MRI system using a birdcage RF head coil for both the RF pulse excitation and signal detection. Imaging parameters were as follows: diffusion directions=(0,0,0), (0,1,-1), (1,1,0), (0,1,1), (1,0,1), (1,1,0), and (1,-1,0). δ=28ms, Δ=54.8ms, G=1.4Gauss/cm, b=1000s/mm^2, slice thk=4mm, TR/TE = 2000/100ms. 256 points were acquired for each projection to produce images with a 256×256 matrix size and a FOV of 220×220 mm^2. The acquisition time for each reduced number of view imaging (n=90 projection views) was 3min., whereas 6min. for full view imaging (N=180 projection views).

RESULTS

Computer Simulations: 180-view (N) and 90-view (n) projection data were acquired by *RT* from a simulated diffusion-weighted Shepp-Logan phantom image. Fig.1 shows the cutview-intensity of different images along the same positions marked by the solid and dotted lines in the phantom image. The proposed method improves image details which are in coherence with the original image from 180-view DW projection data. Fig.2 shows the images reconstructed from projection views with $n=N/3$ and $n=N/4$ views. By calculating RMSE between these images and the original phantom image shown in Fig.2a, the amount of image improvement can be quantitatively assessed. The RMSE between Fig.2a and Figs.2b through 2g were 0.0260, 0.0144, 0.0431 0.0375, 0.0595, and 0.0413, respectively. ***In vivo experiments:*** For human *in-vivo* studies, 180-view (N), 90-, 60-, 45-view DW projection data, and 180-view (N) non-DW projection data were acquired. In Fig.3, images show two different axial slices of a brain, reconstructed by applying the proposed method to reduced view datasets along with images reconstructed directly from the acquired 180-view DW projection data (bottom). The proposed method improves the image quality and more than 1/2 reduction is especially effective when applied to higher axial slices. The fractional anisotropy (FA, Fig.4) and directional anisotropy (DA, Fig.5) maps were calculated from images using 90-view, the estimated 180-view and the original 180-view projection data. The proposed method produced a more salient FA map (middle), closer to the original FA (right), than those reconstructed conventionally using the projection data with a reduced number of views (left). DA maps of three different image sets are illustrated using the conventional RGB colormap to show similar results as obtained from the FA maps.

DISCUSSION

By using the proposed method, image quality improvement can be achieved for a reduced set of radially acquired DW signals. By applying the proposed method to the data acquired from any kind of PR-DW sequences such as rSE, rTSE and HYPR, an additional improvement in image quality can be achieved while reducing the imaging time.

REFERENCES

(1)Seifert MH, et al. JMR 2000:144:243-254. (2) Mistretta CA, et al. MRM 2006:55:30-40 (3). Han YJ, et al., ISMRM 2007:1492.

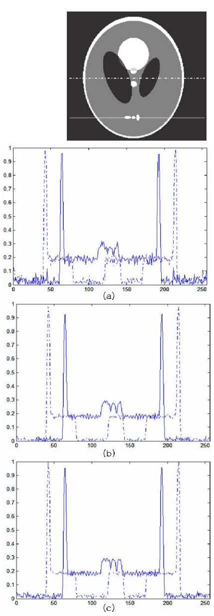

Fig.1 The intensity cutviews from the images of a) reduced 90-view, b) estimated 180-view, and c) original 180-view. Each position of the cutviews for solid and dotted lines are marked in the image, respectively.

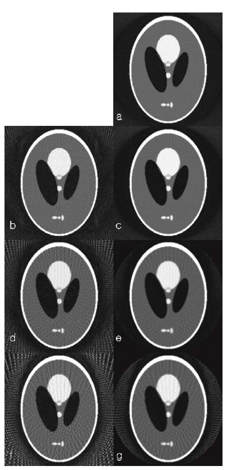

Fig 2 Shepp-Logan phantom images. a) original image. Images reconstructed using the acquired DW projection data with b) 90, d) 60, and f) 45 projection views and reconstructed using the 180-view of the proposed method from c) 90, e) 60, and g) 45.

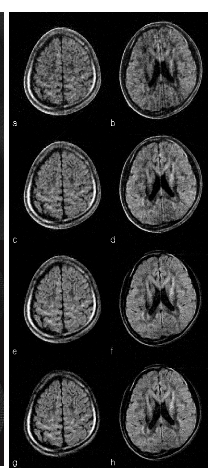

Fig.3 Images with different reduction factors for 2 slices. Images generated by applying the proposed method to the acquired a),b) 45-view, c),d) 60-view, e),f) 90-view projection data, and g),h) the acquired 180-view. projection data.

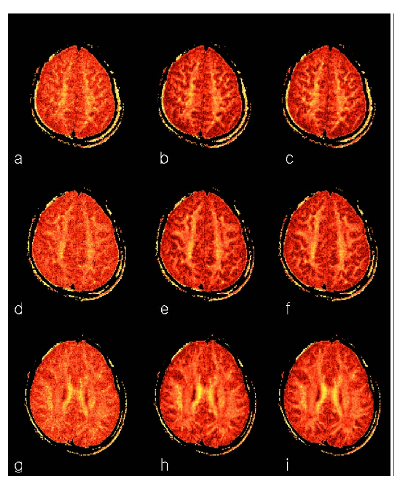

Fig.4 FA calculated from the DWIs. 90-view (left), proposed 180-view (middle), the acquired 180-view (right).

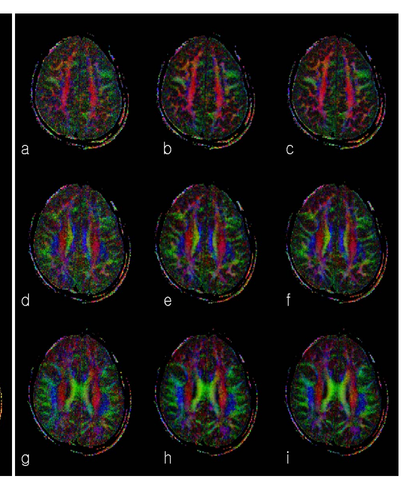

Fig.5 DA calculated from the DWIs in a conventional RGB colormap. 90-view (left), proposed 180-view (middle), and the acquired 180-view (right).