Comparison of applying 1D phase and 2D phase N/2 ghost correction prior to PROPELLER-EPI reconstruction

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Introduction

The PROPELLER-EPI (periodically rotated overlapping parallel lines with enhanced reconstruction using EPI as signal readout) has been shown useful for diffusion applications with reduced geometric distortion [1]. PROPELLER-EPI consists of EPI signal readout with alternative echoes, thereby the phase inconsistencies between odd and even echoes generate N/2 ghost artifact [2] in each rotating blade as well as conventional EPI imaging. The typical N/2 ghost correction method is to acquire reference scan for estimating the phase difference between odd and even echoes along readout direction, and then applies 1D phase correction to image data for eliminating N/2 ghost [2]. This 1D correction method fails in oblique scan because the phase inconsistencies between odd and even echoes are not only along the readout direction, it also occurs along phase direction. The oblique ghost is mainly induced from eddy current effects or anisotropic gradient delays of two or three concurrent gradients used for oblique scan [3]. A 2D phase correction method can overcome this problem by modifying the reference scan and considering the phase inconsistencies along both readout and phase directions [4]. In this work, we compare the quality of reconstructed PROPELLER-EPI images by applying 1D phase and 2D phase N/2 ghost correction prior to PROPELLER-EPI reconstruction.

Material and method

In the theory of 2D phase correction, Eq.(1) shows a spatial phase difference [4] between images separately reconstructed from odd and even echoes, and this phase difference can be measured using double FOV reference scan. In contrast to reference scan for 1D correction acquired by switching off phase blip gradient, the double FOV reference scan consists of using half area of blip gradient for imaging. Thus, there is no overlapping between object and N/2 ghost in double FOV reference image, then we can easily zero out the ghost and estimate ψ0(x, y). After the estimation of ψ0(x, y), it will be interpolated to a full sized object in y direction, and shifted FOV/2 to create another phase difference map ψ1(x, y). Consequently, the corrected image without ghost can be calculated from Eq.(2) [4]. To improve the correction efficiency, the 1D correction parameters can be simultaneously calculated from the double FOV reference data, then removes the large echo shift along x direction before estimating phase difference ψ0(x, y) [4]. The phantom images were acquired using PROPELLER-EPI technique on a 1.5T MRI scanner (Signa HD, GE): FOV 20x20cm, blade size 32*128 (ETL=32), rotating angle 15°, NEX 1, TE 76.8ms, TR 4000ms, slice thickness 5mm without gap, 12 blades for 180° k-space coverage. The double FOV reference scan was acquired for each blade with half area of phase blip gradient.

$$\Psi_0(x,y) = angle(F_{odd}(S)\cdot F^{*}_{even}(S)) \quad \text{Eq.(1)}, \qquad F(s) = \frac{\exp(-i\Psi_1(x,y))\cdot F_{odd}(s) + F_{even}(s)}{\exp(-i\Psi_1(x,y)) + \exp(-i\Psi_0(x,y))} \quad \text{Eq.(2)}$$

Results

The low-resolution images of each blade respectively applied 1D correction and 2D correction are shown in Fig. 1. The results of 1D correction showed the failures in N/2 ghost correction of several oblique blades (upper red frame in Fig. 1). The results of 2D correction showed a great reduction of oblique ghost than 1D correction method (lower red frame in Fig. 1). Figs. a & b showed the PROPELLER-EPI images reconstructed from 1D correction blades and 2D correction blades. A percentage signal difference map calculated by subtracting Fig. 1a from Fig. 1b is shown in Fig. c.

Discussion & Conclusion

PROPELLER-EPI reconstruction method has ability to overcome the imperfect ghost correction of each blade. There is no visual difference between PROPELLER-EPI reconstructed from 1D and 2D correction blades, and the quantitative signal difference within the object is lower than 10% between two PROPELLER-EPI images. The signal difference mainly appears along the direction with remaining ghost of using 1D correction method. It demonstrates that the remaining ghosts affect the signal intensity of reconstructed image a little. Although 2D correction shows a great reduction of oblique ghost, the computational processing is complex than 1D correction and the margin of ψ0(x, y) always not easy to determine on the low resolution images of each blade. In addition, the acquisition time of reference scan used for 1D and 2D correction is equal, and double FOV reference data also can be used to only perform 1D correction, which is easy to implement. Thus, the double FOV reference scan can be substituted the conventional 1D correction reference scan in PROPELLER-EPI acquisition, which offers a choice of applying 1D or 2D correction prior to PROPELLER-EPI reconstruction. Furthermore, the 2D correction may be useful to improve the image quality of each blade for applying additional post-processing prior to PROPELLER-EPI reconstruction such as geometric distortion correction.

Reference

[1] Wang FN, et al, MRM, 54:1232 (2005). [2] Bruder H, et al, MRM, 21:311 (1992). [3] Reeder SB, et al, MRM, 41:87 (1999). [4] Yuval Zur, US patent 7375519.

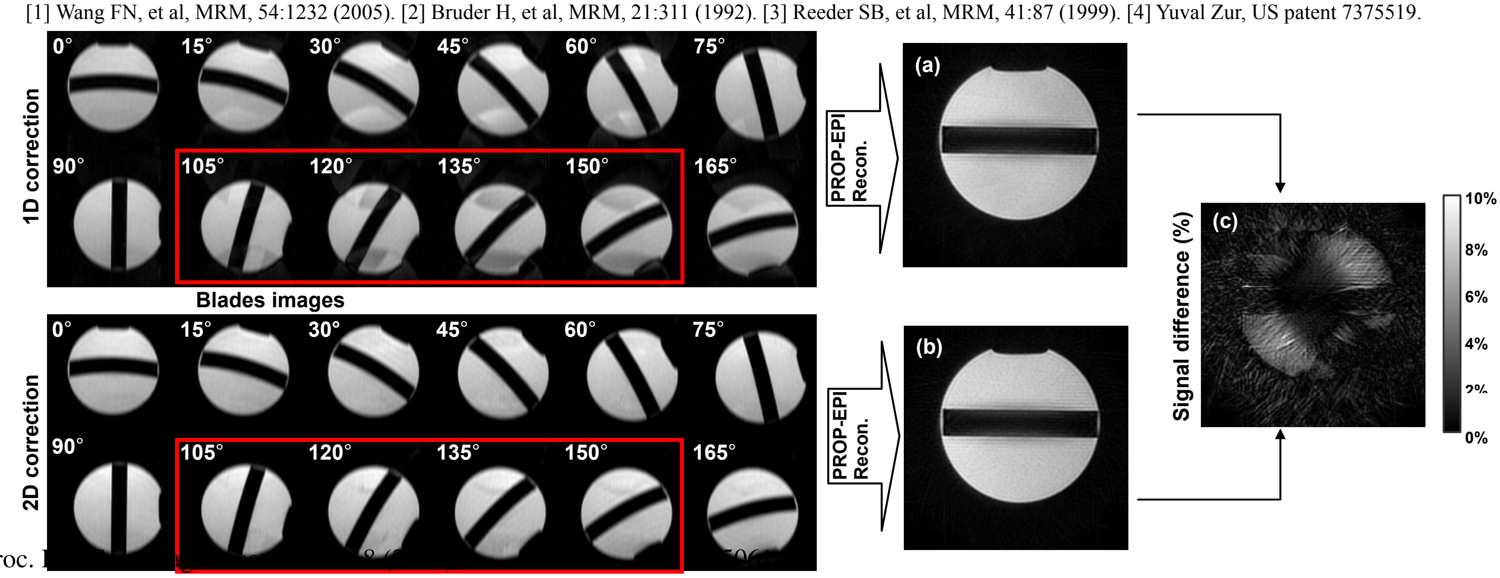

Fig. 1. The PROPELLER-EPI images reconstructed from 1D and 2D correction blade (a & b). (c) showing the signal difference between two PROPELLER-EPI images.