Further investigation on the SNR and de-blurring effect of the weighting window on PROPELLER EPI reconstruction

F-N. Wang[1], T-C. Chuang[2], T-Y. Huang[3], N-K. Chen[4], H-W. Chung[2], and K. K. Kwong[5]

[1]Institute of Brain Science, National Yang-Ming University, Taipei, Taiwan, [2]Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan, [3]Department of Electrical Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan, [4]Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts, United States, [5]MGH/MIT/HMS Athinoula A. Martinos Center for Biomedical imaging, Massachusetts General Hospital, Charlestown, Massachusetts, United States

Purpose

Due to the long echo train length of an EPI read out, the susceptibility-induced off-resonance effects can lead to prominent geometrical distortions along the phase encoding direction. Although such distortion could be substantially corrected by combining blades with rotational phase encoding directions with PROPELLER technique, image blurring will take place to a certain extent, especially at the air-tissue interface [1]. Previous studies have shown the de-blurring effect of using an exponential weighting scheme in PROPELLER EPI image reconstructions.[2] In this study, we use Monte Carlo simulations to further investigate the complicated nonlinear process of image reconstruction quantitatively. Using computer simulations, images with random Gaussian noises were simulated for PROPELLER data, which were reconstructed using different schemes to cover the k space. In simulations, the signal strength was calculated from the minimal TE allowed in different blade widths, and the noise level was calculated from the standard deviation with ROIs. The edge profiles of air-tissue interface were extracted to quantify the blurring effect.

Materials and Methods

Two simulation schemes were performed. In the first part of simulations, images consisted of random Gaussian noise (zero mean and unit variance) were generated in the k space with the image matrix of 128x128. The simulated blades had 8, 16, 24, 32, 48, or 64 phase encoding lines requiring 26, 13, 9, 7, 5, or 4 rotating blades to cover the k space, respectively. After combining blades to reconstruct a PROPELLER EPI image, a ROI of 10x10 pixels around the image center was selected to measure the standard deviation of image intensity. The average of the standard deviations over 100 iterations was used to as the noise level in the SNR calculation, where signal level was estimated from T2 = 100 ms and a minimal TE allowed in the a spin echo EPI blade. Different weighting constant (k=0, 0.01, 0.1, 0.5) were utilized in reconstructing blades using the weighting function: $s = \exp(-ky)$, where the s denotes the weighted data, and y represented the distance from the central line of the blade along the phase encoding direction. (Fig.1) In the second part of simulations, a circular phantom with radius of 24 pixels was simulated with contaminating random noise described above. After distorted the image using synthetic rotated field maps with monotonic decreasing field along the phase encoding direction of each blade to generate a 3-pixel displacement at the boundary of the phantom in the phase encoding direction, the k-space data were re-sampled to simulate the acquisition of PROPELLER blades of 32 phase encoding lines. The width from the edge to the half maximum intensity was measured to quantify the blurring effect on the air-tissue interface.

Results

Figure 2 shows the SNR as a function of number of phase encoding lines in each blade. It is noted that the SNR increased with less phase encoding lines in each blade, due to a shorter TE and more signal averages around the k space center. Compared to non-weighting (k=0), the SNR decreased to 0.5%, 3.8%, and 16.9% using an exponential window with k = 0.01, 0.1, and 0.5, respectively (blade size 128 frequency encoding x32 phase encoding). Figure 3 shows the profiles at the simulated tissue-air interface from the reconstructed PROPELLER EPI images. While combining blades without off-resonance induced geometrical distortion, the simulated edge profile (red dash line) is close to the ideal phantom edge (solid black lines). The width at half maximum at edge became as large as 1.91 pixels when we distorted the blade image, but substantially reduced to 0.86 pixel when k = 0.5, which indicates a de-blurred result.

Discussion and Conclusion

In this study, we demonstrate that an exponential weighting can successfully decrease the image blurring caused by combining distorted EPI blades in PROPELLER. However, using a large exponential weighting constant can reduce the SNR. We show that a windowing parameter k ~.1 can de-blur the reconstruction considerably without substantial SNR degradation. Although the real field map in actual PROPELLER acquisitions can be more complicated than our simulated monotonic decreasing fields, we found that the exponential weighting scheme is a potential method to alleviate the image blurring [2].

References

1.Wang FN, et al., MRM ,2005 54:1432-40. 2.Chuang TC, et al. ISMRM ,2006.

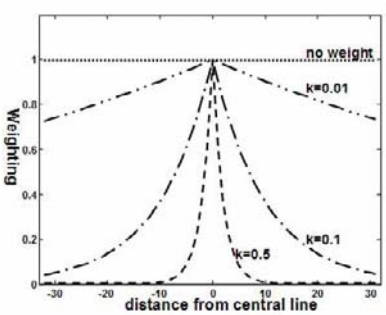

Fig.1 Weighting windows with different exponential constants. Note that the central line is highly weighted using a high k value.

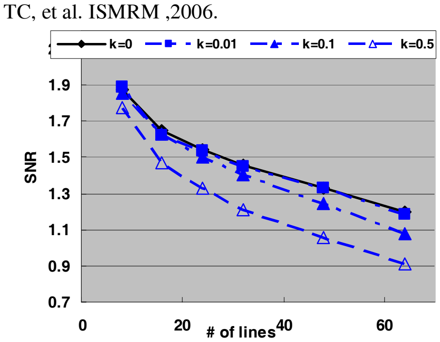

Fig.2 SNR as a function of number of phase encoding lines in one blade. More blades are acquired to cover whole k space with small blade size. The SNR increases when the center of k space was highly averaged. Note that the SNR was reduced when using a higher k value and a larger blade.

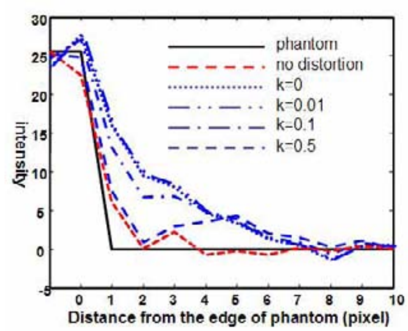

Fig.3. Edge profiles of simulated phantom. Noted that the profile of using a high k value is close to the profile without distortion.