PROPELLER EPI Using Asymmetric Blades: A Preliminary Study on Point Spread Function

F-N. Wang[1], T-C. Chuang[2], and T-Y. Huang[3]

[1]Biomedical Engineering and Environmental Sciences, National Tsing Hua University, Hsinchu, Taiwan, Taiwan, [2]Electrical Engineering, National Taiwan University, Taipei, Taiwan, Taiwan, [3]Electrical Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan, Taiwan

Purpose

Several methods were proposed to reduce the susceptibility-induced blurring effect of long-axis PROPELLER (LAP) EPI. [1,2] Skare et al. suggested using an alternative short-axis PROPELLER (SAP) EPI to reduce the geometric distortion by shortening the echo spacing. In order to achieve comparable SNR, which is an advantage of LAP by reducing TE, half Fourier blades was implemented in SAP method. In this study, we applied analogous concept to LAP by using asymmetric numbers of phase encoding (PE) lines between two sides of k space center. Point spread functions (PSF) of LAP EPI with symmetric and asymmetric blades are investigated to characterize their blurring effect.

Materials and Methods

PSF of symmetric and asymmetric blades are simulated first. Full 128x128 k space points are combined by blades with 32 PE lines using either original symmetric layout (Fig.1a) or an asymmetric design with 12 PE lines shifted to another side (Fig.1b). 14 blades are simulated with inter-blade rotational angle as 26 degree. The echo spacing of the EPI readout is set as 1ms, and T2* is assumed to 40ms. A substantial off-resonance frequency presumed to 35 Hz to generate a 4.5 pixel displacement along PE direction of each blade. In the following in vivo experiment on a 3T MRI scanner (Siemens Allegra), blades of full k space (i.e. a 128x128 matrix) are acquired on a volunteer using Spin Echo EPI with the same rotation angle as previous simulation, and TE/TR are set to 65/1500ms. Both symmetric and asymmetric 128x32 blades are extracted from identical full k space blades. LAP EPI images are then combined with an exponential weighting constant of 0.1. [2] The differences of two schemes are illustrated by subtracting the combined images.

Results

In Fig2, PSFs are showed, where the PSF of asymmetric blade is noted with lower side peaks than original symmetric blade method under the simulated off resonance. A combined LAP EPI image with asymmetric blades is showed in Fig3a. Difference ratio map is also showed in Fig.3b, where the intensity showing how much proportion is reduced in asymmetric blades combined image. Note that the difference proportion at interfaces around tissues with high intensities, such as brain tissues and eyeballs, is negative at high intensity side while positive at low intensity side. Therefore, sharper step functions on tissue interfaces of asymmetric blades combined image, as a result of more focused PSF, well demonstrate the de-blurring effect.

Discussion and Conclusion

By simulation of PSF and combing in vivo data, we find that asymmetric blades could reduce image blurring considerably in LAP EPI. It is supposed fewer data with off-resonance induced phases are included when combining asymmetric blades in k space. In addition, one may consider the SNR could be downgraded since fewer central k space lines are acquired in each blade. By shifting PE lines to another side, the TE of EPI can be shortened. For example, a shift of 12 lines under the assumptions of our simulations can roughly reduce TE with 24 ms for spin echo EPI or 12 ms for gradient echo EPI. Therefore, SNR could be compensated or optimized with shift PE lines. This technique could possibly be advantageous for implementing LAP on large matrix size or imaging short T2* tissues using gradient echo EPI blades with very short TE.

References

1. Wang FN, et al., MRM ,2005 54:1432-40. 2.Chuang TC, et al. ISMRM, 2006. 3.Skare S et al., MRM 2006 55:1298-207.

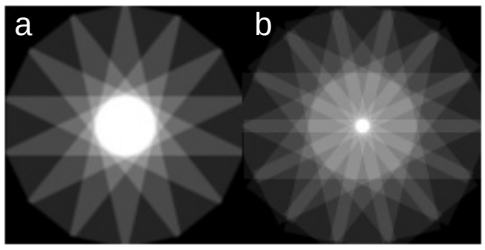

Fig.1 Density maps of original PROPELLER with symmetric blades (1a) and asymmetric blades (1b). The intensity denotes the number of overlapped blades on each point of k space.

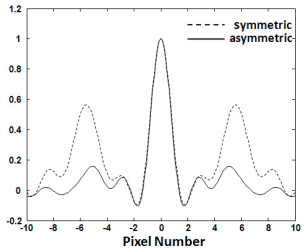

Fig.2 Point Spread Functions of LAP EPI under off-resonance frequency is showed. Note that the PSF of asymmetric blades combined image has much lower side peaks.

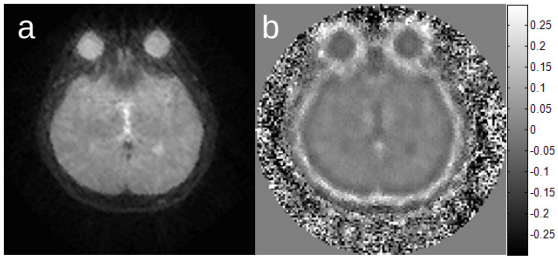

Fig.3 A combined LAP brain image using asymmetric blades is showed in 3a. Image using symmetric blades is subtract by image using asymmetric blade with the same number of PE lines and then divided by original intensity to show the difference ratio in 3b. Note the negative ratios at high intensity side and positive ratios at low intensity side imply a sharper step function when using asymmetric blades.