Combination of VAT and Z-shimming in Echo Planar Imaging for Distortion Correction and Signal Recovery

Sinyeob Ahn[1], and Xiaoping Hu[1]
[1]*Biomedical Engineering, Georgia Institute of Technology/Emory University, Atlanta, GA, United States*

INTRODUCTION

Geometric distortion and signal loss are detrimental artifacts caused by field inhomogeneity in gradient-echo EPI (GE-EPI). One well-known approach to recover signal is to apply z-shimming along the slice-selection (SS) direction, assuming a linear variation of field across the slice [1]. Recently, view angle tilting (VAT), which has been used for various applications to correct distortion in the readout (RO) direction in conventional spin-echo (SE) imaging [2], has been applied to SE-EPI for correcting in-plane distortion in the phase-encoding (PE) direction [3]. Although VAT has the capability of correcting distortion, it does not intrinsically recover signal loss caused by field inhomogeneity in the SS direction in GE-EPI. Considering the fact that GE-EPI is widely used for various applications, particularly functional MRI, it would be valuable if distortion correction and signal recovery are both achieved. Hence, in this study, VAT technique is implemented in combination with z-shimming in GE-EPI to address both artifacts and evaluated.

METHODS AND MATERIALS

EPI VAT utilizes the addition of VAT gradient pulse blips along the SS direction, applied concurrently with PE gradient pulse blips, producing an additional phase [3]. This phase offsets phase errors caused by field inhomogeneity and chemical shift. To achieve a complete (theoretical) distortion correction, one needs to apply a VAT pulse blip given by $G_{vat}=G_z T_{esp}/t_b$, where G_z is the SS gradient pulse, T_{esp} is echo spacing, and t_b is the rise time of the pulse blip. View tilting angle, θ, is determined by $\tan(\theta)=G_{vat}/G_y=G_z T_{esp}/(G_y t_b)$. To make VAT practical for EPI, VAT was combined with parallel imaging (R=3) and a relatively low excitation RF pulse bandwidth (200 Hz). The sequence diagram in Fig. 1 shows the combination of VAT with z-shimming in GE-EPI. All experiments were performed on a 3 T scanner (TRIO, Siemens Medical Solutions, Malvern, PA) using a body coil for transmission and a 12-channel head coil for signal reception. To determine the optimal z-shimming value, pre-scan was run with -210 μT/m ~ 210 μT/m in steps of 15 μT/m. GE-EPI was performed with TE/TR=30/2000 ms, 3.2x3.2x5 mm resolution, 25 contiguous slices, 2520 Hz/pixel receiver bandwidth, GRAPPA (R=3) and VAT ($\theta=54.3^0$) for human in vivo imaging.

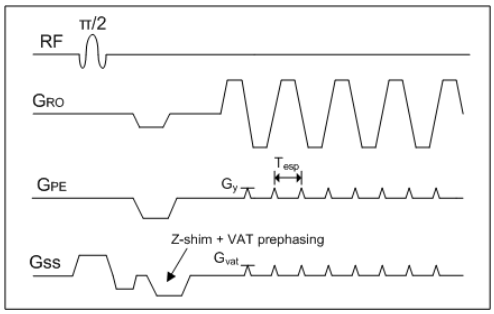

Fig. 1. Sequence diagram

RESULTS AND DISCUSSIONS

Results are presented in Figs. 2 and 3, where GE-EPI with parallel imaging and GE-EPI with parallel imaging and VAT are referred to R3 and R3-VAT, respectively. Red contour obtained from conventional SE imaging is overlaid onto each EPI image to aid in the visualization of distortion and signal loss. Fig. 2 shows a slice containing frontal region of human brain. In the region indicated by the yellow rectangle, R3 images (Fig. 2b~d) show in-plane distortion and signal modulation effects (erroneous signal pile-up due to distortion) which were not corrected by z-shimming. R3-VAT (Fig. 2e) shows similar signal void in the frontal region although the in-plane distortion was corrected. The addition of z-shimming recovers the signal in this distortion-corrected region (Fig. 2g: z-shimming gradient: -90 μT/m). In the circled area in Fig. 3, distortion correction by VAT (Fig. 3c) seems to make the region darker because it stretched the area in inferior orbito-frontal (OF) region. However, the signal in this region was recovered by z-shimming at the distortion-corrected region (Fig. 3d). In conclusion, the combination of VAT with z-shimming is capable of both distortion correction and signal recovery in GE-EPI. It has a value for addressing both artifacts, especially with new advances in parallel imaging.

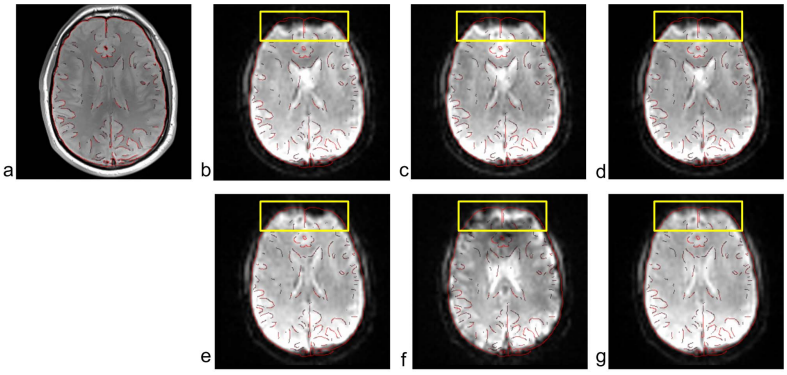

Fig. 2. Images of frontal region of human brain acquired by using GE-EPI with parallel imaging (R=3) and with (bottom row) and without (top row) VAT. Images without z-shimming (b,e) and with z-shimming (c,f) and combined images (d,g).

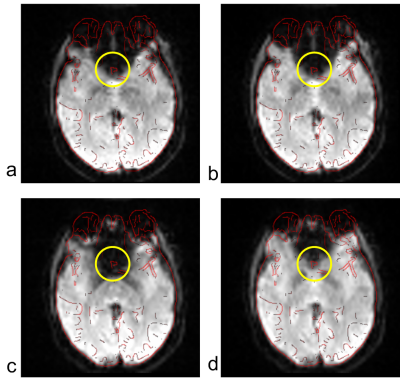

Fig. 3. Images of inferior OF region of human brain acquired by using GE-EPI with parallel imaging (R=3) and with (bottom row) and without (top row) VAT. Images without z-shimming (a,c) and combined images (b,d).

REFERENCES

[1] MRM 2004;51:212-216. [2] Med Phys 1988;15(1):7-11. [3] ISMRM 2011 Proceedings, p. 2699.