Pre-Scan with Half-Sized Phase Encoding Blips Reducing Ghost and Slice Leakage Artifacts in Dual-Band EPI

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•Target audience: Physicists or neuroscientists with an interest in multiband echo planar imaging (EPI), especially for small-animal studies

•Purpose:

One of the most important issues in EPI with multi-band excitation[1-4] is inter-slice leakage artifacts[5], which should be emphasized especially in the use of animal MRI scanners equipped with relatively few (i.e., 4-channels) receiver coil elements. The purpose of this study was to reduce ghost artifacts due to phase correction error and to reduce slice leakage artifacts in dual-band (DB) EPI, using pre-scans with a half-sized phase encoding (PE) blips technique.

•Methods:

An in-house made spherical phantom and *in vivo* rat brains were scanned using a custom single-shot DB 2D-EPI sequence with blipped-controlled aliasing[2,3, 5] (CAIPI) on a 7T animal scanner (BioSpec 70/20, Bruker, Germany) equipped with a 4-channel receiver coil. A total of 40 slices (20 excitations) were imaged for the phantom, and 60 slices (30 excitations) were imaged for the rat brain. DB excitation pulses were designed based on sinc functions with frequency offsets. Between-bands spacing were 10 mm for the phantom and 9.6 mm for the rats. Flip angle was 60°. TR/TE = 1000/19 ms for the phantom and 1174/14.56 ms for the rats. Voxel size was 0.4x0.4x0.5 mm for the phantom and 0.3x0.3x0.32 mm for the rats (to achieve near-isotropic voxel size). Encoding matrix size was 115x80 for the phantom and 96x56 for the rats. Pre-scans for DB EPI included a set of scans with no PE blips, with half-sized PE blips, and with full-sized PE blips. Using these EPI pre-scans with various sizes of PE blips, 2-D phase corrections[6] as well as the conventional 1-D phase corrections were performed for comparison. After the accurate phase correction in the image reconstruction process, a GRAPPA-like kernel method[5] was applied to separate the simultaneously acquired data from two slices into each slice data, according to the information of coil sensitivity profiles of multi-element array coils. The degree of slice leakage was evaluated by the L-factor[7].

•Results and Discussion:

EPI pre-scans with half-sized PE blips (doubling the field-of-view (FOV) in PE direction) were useful and effective in reducing ghost artifacts caused by phase correction errors in EPI. Remarkable ghosts were sometimes observed in the 1D-phase corrected pre-scan images (Fig. 1a), while they were almost eliminated in the 2D-phase corrected images (Fig. 1c). The EPI pre-scans with half-sized PE blips could avoid the partial overlap between two slices acquired simultaneously by DB excitations (Fig. 2a, 3a). Thanks to the overlapping-free reference images acquired using the single-band EPI pre-scan with half-sized PE blip, the coil sensitivity profile for each slice can be easily evaluated, and thus enabled the accurate slice separation in the reconstruction of DB EPI with CAIPI (Fig. 2b,c,d; 3a,b,c; 3f,g,h). For the *in vivo* rat brain scans, the mean L-factor was estimated to be less than 5%, which is within the acceptable level. In the estimation of slice-leakage artifacts, the simultaneously excited slices in the images scanned with full-sized PE blips (Fig. 3i-j) were partially overlapped with each other, while in the images scanned with half-sized PE blips (Fig. 3d,e) simultaneously excited slices were imaged separately (without overlapping each other). This indicates the advantage of the half-sized PE blips method in the signal leakage evaluation for each slice (Fig.3).

•Conclusion:

A half-sized PE blips technique in pre-scan EPI was proposed to achieve accurate phase correction in EPI and to reduce slice leakage in DB EPI with CAIPI, even in an animal MRI scanner equipped with relatively few receiver coil elements (in our case, 4-channels). This method would enable faster acquisition in EPI with efficient whole brain coverage for small animal brains, without sacrificing the spatial resolution especially in the slice encoding direction. The proposed method could potentially be applied for higher-resolution functional, diffusion, and perfusion MRI studies in small animals.

•References: 1. Larkman et al, J Magn Reson Imaging (2001), 2. Nunes et al, ISMRM (2006), 3. Breuer et al, Magn Reson Med (2005), 4. Moeller et al, Magn Reson Med (2010), 5. Setsompop et al, Magn Reson Med (2012), 6. Zur, Magn Reson Med (2011), 7. Moeller et al, ISMRM (2012).

Fig.1. Comparative results between the conventional 1D-phase correction (a) and the 2D-phase correction (c) for the same measurement of single-band EPI pre-scan with half-sized PE blips (only a representative slice is presented (reconstructed from pre-combined 4th channel signals)). The localized ghost artifacts caused by the phase correction error in EPI can be observed in (a). The 2D phase-corrected image (c) is ghost-free, which was calculated using the phase difference map (b) between the odd- and even-lines images.

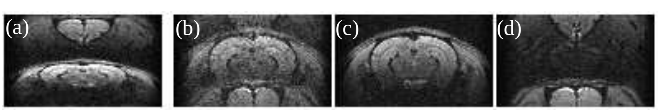

Fig. 2. *In vivo* rat brain images acquired using blipped-CAIPI DB EPI with half-sized PE blips (as pre-scans, no overlap between the two slices) (a), and with full-sized PE blips (partial overlap between the two slices) (b). The results of the slice separation from (b) are presented for the proximal slice in (c) and for the distal slice in (d). In slice separation, information about coil sensitivity profile for each slice was obtained from (a) as well as from (b), in order to achieve more accurate slice separation from (b) into (c) and (d).

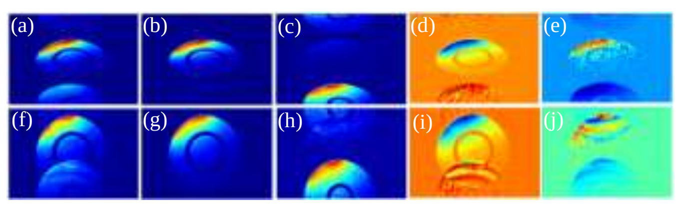

Fig. 3. Phantom images acquired by blipped-CAIPI (FOV_y/2 shift) DB EPI with half-sized PE blips (upper row) and with full-sized PE blips (lower row). The results of the slice separation and leakage estimation between the simultaneously-acquired two slices are shown. From the phase-corrected DB EPI data (a, b), the proximal slice (b, g) and the distal slice (c, h) were separated according to the information about coil sensitivity profile for each slice. Leakage from the distal slice into the proximal slice were estimated as an image in (d, i), and leakage from the proximal slice into the distal slice were estimated as an image in (e, j). Scan with half-sized PE blips seems to have an advantage in estimating the coil sensitivity profile and evaluating the slice leakage.