Simultaneous Multislice Readout-Segmented Diffusion-Weighted EPI with Blipped-Controlled Aliasing

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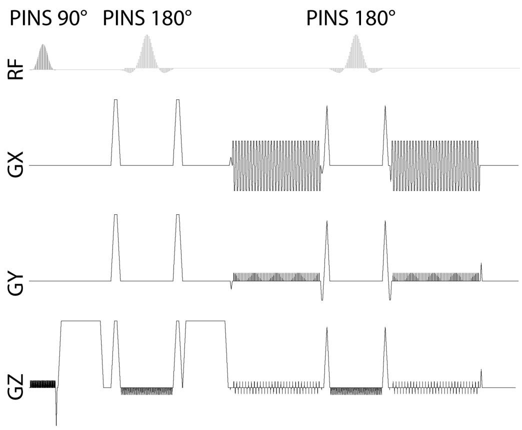

Fig. 1: *Pulse timing diagram of the multi-band RS-EPI trajectory. The multiband data is acquired using a PINS 90° and 180° pulse which selects two slices simultaneously. In RS-EPI each imaging blind is accompanied by a navigator blind in order to perform a phase correction between diffusion-weighted blinds. Note that the calibration scan used to perform the slice-grappa reconstruction is acquired using a pins 90° and standard 180° sinc pulse which selects one slice only.*

TARGET AUDIENCE: For those interested in reducing distortion and reducing scan time in diffusion-weighted imaging.

INTRODUCTION: Readout-segmented EPI (RS-EPI) is a promising candidate for reducing distortion in diffusion-weighted (DW)-EPI while being robust to motion-induced phase errors. However, the requirement of several adjacent segments (or 'blinds') in RS-EPI can make the scan time can prohibitively long, particularly for thin slices which require a large number of slices to achieve full brain coverage. A promising approach for reducing scan time is to use multi-band acquisitions – which make diffusion imaging with full brain coverage faster and more SNR-efficient by simultaneously acquiring multiple slices with limited g-factor penalty [1]. In this work, we reduce the minimum TR in RS-EPI with the use a simultaneous multislice acquisition using PINS multiband pulses [2] coupled with blipped-controlled aliasing [1].

METHODS: ***Acquisition –*** A multiband RS-EPI scan was performed on a healthy volunteer using a 3T GE system (GE 750) and a 32-channel head coil. Two slices separated by 8 cm were excited simultaneously using PINS excitation and refocusing pulses [1]. The PINS pulses are essentially a series of hard pulses spaced by 1/Δ in k-space, that excite and refocus a set of slices separated by a distance Δ. Here the separation of 8 cm was designed such that only 2 slices were excited in the z-FOV at once. Inherent fat suppression was achieved by using positive slice select gradients and negative refocusing slice gradients such that the bands of fat selected and refocused moved in opposing directions in z and thus did not intersect (Fig 1). For RS-EPI the navigator echo was acquired after a second 180° PINS refocusing pulse with negative polarity (Fig 1). Gz-blips were applied during the imaging and navigator readouts to shift the slices by FOV/2 and better exploit the coil sensitivity [1]. The following scan parameters were used for multiband RS-EPI: Stejskal Tanner diffusion preparation with *xyz* encoding (b = 1000 s/mm^2), one b=0, matrix size = 128^2, TR = 4s, 5 blinds of width 64, TE_1 /TE_2 = 63ms/110ms, FOV = 24cm, slthck/gap = 5 mm/0mm, and a scan time of 1:20min. For the slice-grappa calibration a b=0 scan (of the center blind only) was acquired by replacing the PINS 180° pulses with standard sinc pulses. EPI multiband (and calibration) data were acquired at the same target resolution. ***Reconstruction –*** The center imaging blind from the b=0 calibration and multiband image underwent FOV/2 ghost parameter estimation (image entropy-based approach) – followed by application of ghost parameters to all acquired blinds. The multiband imaging and navigator blinds were then unaliased using the calibration scan with a slice-grappa approach [1]. For RS-EPI, the imaging blinds were individually phase corrected (using the navigator blind) and were gridded together to form the final image.

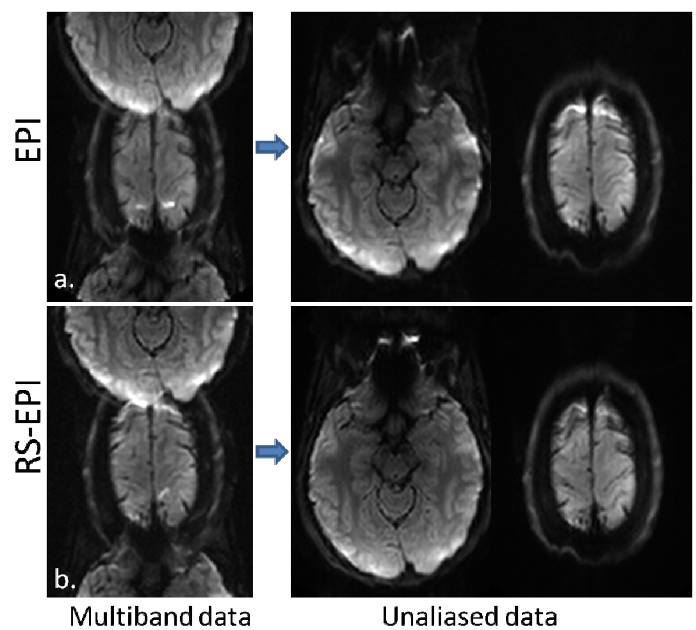

Fig. 2: *Comparison of (a) EPI and (b) RS-EPI simultaneous multislice isoDWI data acquired with fat-suppressive PINS pulses.*

RESULTS: Fig. 2 shows multiband EPI and RS-EPI DWI data acquired on a volunteer. As expected, RS-EPI DWI images show better geometric fidelity than EPI. Note that the simultaneously excited slices appear in the same image (Fig 2 left column) with one slice aliased to FOV/2 due to the alternating blips in z. After the slice GRAPPA reconstruction (Fig 2 right column) both slices appear unaliased effectively providing the acceleration factor of 2.

DISCUSSION AND CONCLUSION: One of the biggest concerns about the application of RS-EPI to DWI/DTI is the scan time, particularly for high-resolution applications which require a large number of slices and thus a long TR. One can get an extra ~2-fold acceleration of the imaging sequence with the use of simultaneous multislice approaches, and here we demonstrate that it is feasible to combine RS-EPI with this approach. Further scan efficiency was achieved by shifting the fat slice in opposite directions during the excitation and refocusing steps – removing the need for an upfront chemical saturation pulse. Further acceleration in RS-EPI can be achieved with the use of homodyne reconstruction in the kx-direction [3]. Here we show that one can accelerate RS-EPI DWI scans with the use of a fat-suppressive blipped-controlled multislice approach.

References: [1] K Setsompop, et al. MRM 2012;67:1210–1224. MRM 68:441–451 (2012) [2] DG Norris et al, MRM, 66:1234-1240, 2011. [3] R Frost et al, MRM, 68:441–451 (2012). **Acknowledgements:** NIH (2R01 EB00271108-A1 , 5RO1 EB008706, 5R01 EB01165402-02), the Center of Advanced MR Technology at Stanford (P41 EB015891), Lucas Foundation, Oak Foundation.