Comparison of Simultaneous Multiband Whole Brain Imaging with Multiplexed-EPI

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Introduction EPI is generally used in neurosciences for which the speed of whole brain imaging can be an important factor. Recently, the use of simultaneous slice acquisition techniques in EPI have reduced the time of whole brain imaging [1, 2]. The use of two different techniques, simultaneous image refocusing (SIR) and simultaneous slice excitation with multiband rf pulses (MB) which uses phased array coils to separate the simultaneously recorded slices [2], have together led to a resurgence of development and applications. We recently demonstrated the combination of SIR and MB, referred to as Multiplexed-EPI [3], to achieve higher accelerations, up to 12 images recorded in each echo train, where the number of simultaneous images in the echo train equals M = SIR x MB. The minimum TR to image the whole brain is then the echo train time (ETT) times the number of echo trains required for sufficient slice coverage of the entire brain. Here we compare different multiplexed acquisitions with M ranging from 6 to 48 images per echo train using different combinations of SIR and MB.

Methods Multiplexed-EPI (M-EPI) images were acquired using a 32 channel phased array coil on a 3 T scanner (Siemens Trio) on 3 subjects. The sequence was implemented with controlled aliasing to improve MB slice separation [4,5,6]. To maximize image signal when using higher MB accelerations, dephasing effects of the controlled aliasing process were minimized at k_0 in the echo train [7]. Oblique axial images were acquired with the following parameters - matrix 80 × 80, 2.4mm x 2.4mm, slice thickness/3mm, TR/500ms, TE/30 ms (lengthened to TE/36ms in SIR-3), flip angle 30°, partial Fourier:6/8 controlled aliasing shift = 1/3 FOV, excitation sinc pulse/ 5.2 ms, reconstruction kernel size = 7 (slice unaliasing) and no in-plane accelerations. Scans were repeated with in-plane R=2 and no partial Fourier.

The ETT was 66 ms, 86ms, and 102ms for SIR factor of 1, 2, and 3 with echo spacings of 0.63, 1.02, 1.42 (ms), respectively. The ETT was independent of MB factor. MB acceleration factors of 6, 8, 10, 12, and 16 were evaluated. The whole brain was scanned in each acquisition, using fewer echo trains with larger M factor, down to two echo trains with M factor =18 or greater, and one echo train (single shot) with M =36 or greater.

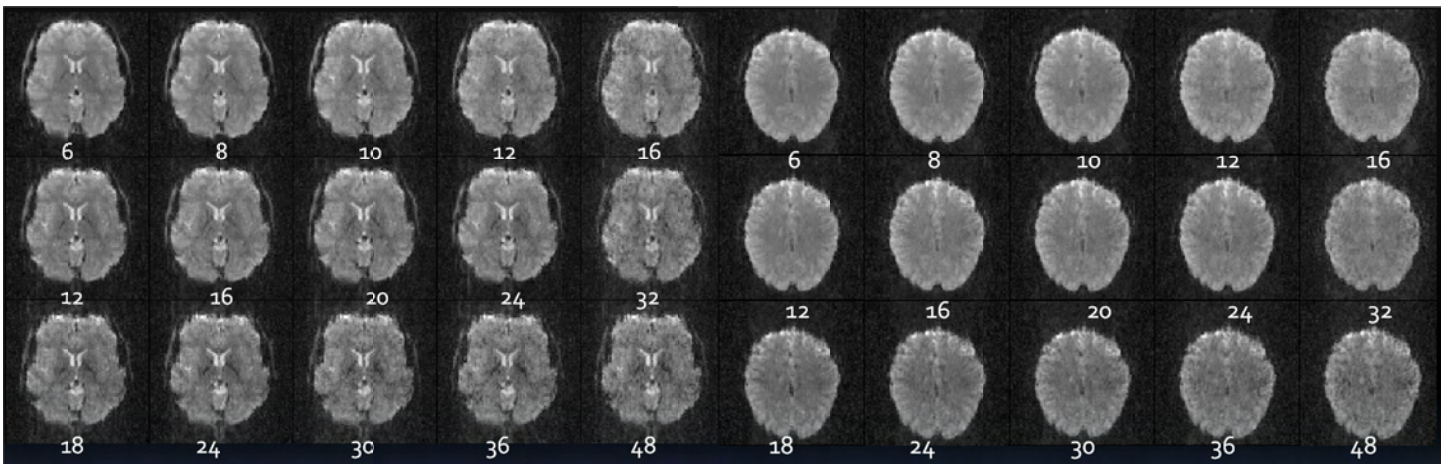

Figure 1. Comparison of different accelerations (M) number of simultaneous slices per echo train using combinations of MB (6,8,10,12, 16) in columns (left to right), and SIR (1,2,3) in rows (top to bottom). Two slices of whole brain scan are shown.

Results and Discussion Figure 1 shows comparisons at two slice levels of the whole brain scans. Some general differences are observable. There was a progressive reduction of image quality with higher MB and higher SIR factors especially above MB=12 and above SIR=2. The worsening g-factor of the higher MB factor is affected by limitations of the 32 channel coil. This might be improved at higher fields or with higher arrays such as 64 channel coils. The SIR3 has noticeably increased distortions due to greater echo spacing and signal loss from longer TE (36ms vs 30ms) which contribute to the reduced image quality. These issues may be partially mitigated with ramp sampling and faster gradient switching possible with higher amplitude and higher slew rate head gradient inserts. Figure 2 shows results with in-plane Grappa=2 along the phase encode, halving the echo train length. This gave poor results above MB12 and with SIR3 (not shown). The slice acceleration factors reached a maximum M=48 and appeared to show the largest degradative change above M=24. While TR was held constant at 500ms for image quality comparisons, a minimum TR of 176ms is possible using two echo trains M=16 or higher (SIR2 x MB8) using Ernst flip angle to reduce SAR, or whole brain coverage using a single echo train in 80 – 100ms with M=32 or higher but with greater sacrifice in image quality. Increased slice cross-talk (signal leakage) occurring with higher M factor will likely ultimately limit fMRI experiments, no less brain imaging in general, and needs to be further evaluated [8]. In conclusion, high speed whole brain imaging can be achieved with multiplexed-EPI in one to three echo trains with dependent trade-offs in image quality.

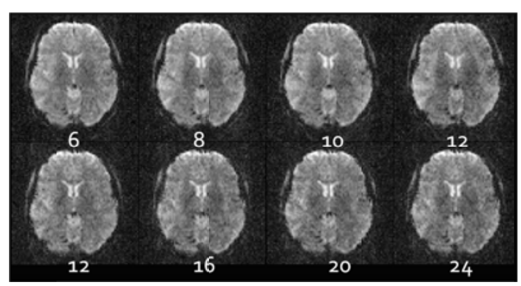

Figure 2. Comparison of accelerations (M) with Grappa/2. (format is same as in Fig.1)

References [1] Larkman, et al. *J.Mag.Res.Imag.* 13:313-317, 2001 [2] Moeller, et al. *Magn. Reson. Med.* 63:1144–53, 2010 [3] Feinberg, et al. PLoS ONE, 5(12):e15710, 2010, [4] Breuer, et al. *Magn. Reson. Med*. 53:684–91, 2005 [5] Nunes, et al. ISMRM 2006 [6] Setsompop, et al. *Magn. Reson. Med*. 2011 in press [7] Xu, et al *ISMRM 2012* [8] Moeller et al *ISMRM 2012*.

Acknowledgements Funded by NIH grants NIH Human Connectome Project (U54MH091657), R44 NS073417, P41 RR008079, and P40 NS057091.