THEORETICAL AND EXPERIMENTAL BENEFITS OF MULTI-BAND (MB) EPI FOR PCASL BRAIN IMAGING

Xiufeng Li[1], Dingxin Wang[2], Steen Moeller[1], Kamil Ugurbil[1], and Gregory Metzger[1]

[1]*Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States,* [2]*Siemens Medical Solutions USA Inc, Minneapolis, MN, United States*

Target audience: Arterial spin labeling researchers, neuroimaging scientists and clinicians

Purpose:

Multi-Band (MB) imaging[1-5], a method reducing MRI time with increased spatial or temporal resolution, recently, has been demonstrated[6] and later compared to single-shot 3D GRASE[7] for brain perfusion imaging using FAIR[8]. These recent work[6-7] on MB ASL imaging found that the differences between single-band (SB) and MB EPI in ASL are small, in fact, essentially negating the practicality of using MB imaging for ASL. In addition, confounding effect from the acquisition and reconstruction are detrimental for reliable perfusion quantification, including and not limited to EPI ghosting, g-factor or noise amplification from accelerated acquisitions with multichannel arrays[9], residual ghosting and signal leakage from signal separation in MB[10-11], which has not been thoroughly investigated in those previous work. Furthermore, when evaluating imaging methods for ASL, SNR efficiency is paramount for ASL, and should be one important metric under consideration.

Therefore, to achieve improved insight into the potential benefits of MB EPI for ASL imaging, both systematic experiments and theoretical simulations were performed by using pseudo-continuous arterial spin labeling (pCASL), which provides much higher labeling efficiency than FAIR used in previous studies[8-9], and our comprehensive evaluation results are reported here.

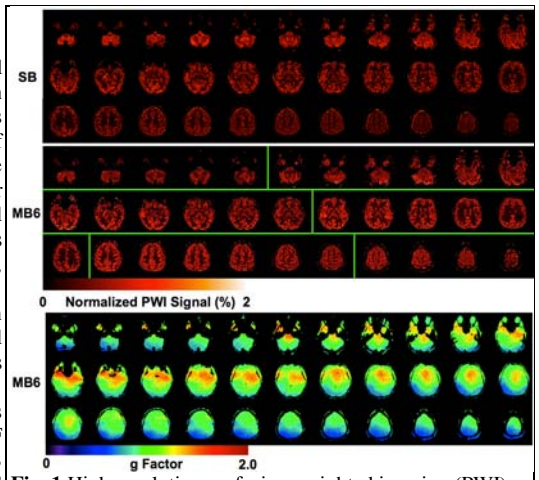

Fig. 1 High-resolution perfusion-weighted imaging (PWI) maps for SB and MB6, and g-factor map from one subject. Thirty-three out of total 36 slices are presented with MB 6 slice groups indicated in green lines on PWI maps.

Methods: Brain perfusion imaging studies were performed on a TIM Trio 3T scanner (Siemens Healthcare, Erlangen, Germany) by using a 32-channel head coil as a receiver and the body coil for RF transmission. Healthy volunteers provided written consent to participate in an IRB approved study. MB EPI utilized the blip-CAIPI[5] with a slice GRAPPA kernel size of 5 and RF phase optimization for reduced peak RF power[14]. High-resolution perfusion imaging (2.5x2.5x3.0 (20% slice gap) mm^3 and 36 slices) used the same 1.5 s labeling time, ~1.1 s delay time for SB and 1.6 s[15] for MB6 and optimal MRI parameters for each acquisition (minimal TR, TE, delay time, etc). With these parameters, the delay time between the two acquisitions are the same for slice 13. Within each ASL series scan, 200 noise images were collected after ASL image acquisition for thermal noise and g-factor estimations. Theoretical simulation used CBF estimations from both SB and MB studies using the standard single-blood compartment model[16]. To evaluate the signal contamination due to imperfect MB slice un-aliasing, a measurement was performed in which a single slice from *N* simultaneously acquired slices had its RF turned off during excitation thus allowing the contamination from the *N-1* slices on the N^{th} slice to be determined. The contamination for all slices in the imaging volume was measured, and the ratio of leakage contamination to the perfusion signal is assessed.

Results and Discussion: High-resolution perfusion-weighted images from both SB and MB6 and measured g-factor map are presented in Figure 1. The measured group means of slice-wise g-factor, CBF and SNR efficiency from simulation and experiments are presented in Figure 2. Both theoretical simulation and experimental measurements indicated that MB EPI could particularly benefit high-resolution whole brain ASL imaging in terms of SNR efficiency. The obvious PWI signal modulation between bands of the MB acquisition are addressed when the single compartment model is used to calculate CBF. The time required to cover all slices of the high resolution SB acquisition was more than 1.5 s, resulting in both dramatically decreased SNR and underestimated CBF as the slice dependent delay increased compared to MB, even after correcting for T_1. Simulation with CBF measurement from SB gave even larger CBF underestimations in the superior brain region compared to real measurements (not shown), indicating that MB can better support the standard single compartment ASL model.

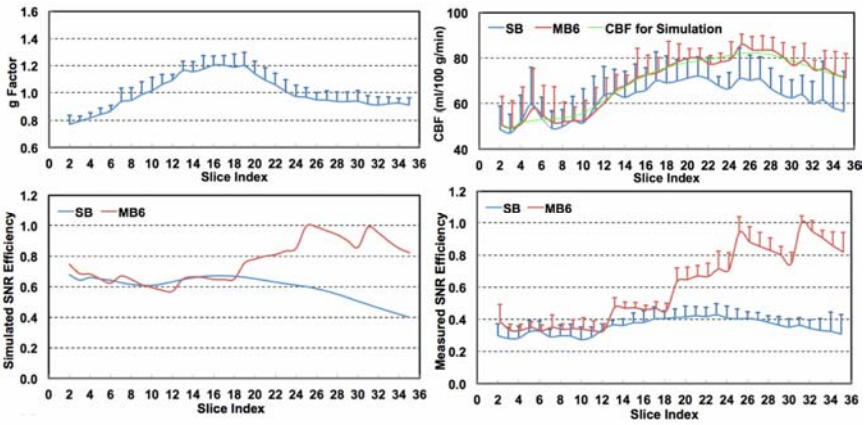

Fig. 2 Group means (N=5) of g-factor, CBF, simulated and measured perfusion SNR efficiency for grey matter. Across-slice CBF values for theoretical simulation are indicated in green.

For matching timing parameters and coverage, similar to previous studies, the differences in CBF estimation between SB and MB acquisitions is minimal. We have verified this in an array of low resolution studies with varying MB factors (data not shown). While this is an interesting finding it represents an unrealistic acquisition strategy as typically whole brain coverage is desired. The results shown here go beyond the previous analysis of MB ASL where simple correlations with SB acquisitions were shown. By exploring the slice dependent impact of g-factors, leakage contamination and T1 dependent signal loss a tremendous advantage is realized in SNR efficiency mostly benefitting superior regions of the brain where long effective delay times plague SB acquisitions. The advantage only grows with increasing resolution and in turn addresses a major barrier to traditional ASL acquisition strategies in achieving high resolution whole brain coverage.

Conclusions: MB EPI can greatly benefits high-resolution whole brain ASL perfusion imaging with respect to both SNR efficiency and CBF quantification.

Acknowledgements: P41 EB015894, U54 MH091657, P30 NS076408, P41 RR008079 and S10 RR026783.

References: 1. Larkman, et al. JMRI 2001. **2.** Breuer et al. MRM 2005. **3.** Nunes et al. ISMRM 2006: 293. **4.** Moeller et al. MRM 2010. **5.** Setsompop et al. MRM 2012. **6.** Kim et al. MRM 2013. **7.** Feinberg et al. MRM 2013. **8.** Kim et al. MRM 1995. **9.** Robson et al. MRM 2008. **10.** Moeller et al. ISMRM 2012: 519. **11.** Cauley et al. ISMRM 2012: 2543. **12.** Wu et al. MRM 2007. **13.** Dai et al. RM 2008. **14.** Wong ISMRM 2012:2209. **15.** Dai et al. MRM 2012. **16.** Wang et al. MRM 2003.