Optimised segmentation scheme for high-resolution multi-shot 3D-GRASE pCASL with improved point spread function

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Purpose. Pseudo-continuous arterial spin labelling 3DGRASE provides high signal-to-noise ratio (SNR) with uniform background suppression (BS) and inversion time in all slices [1-3]. Typical spatial resolution in ASL is around 4x4x6mm^3. Single shot 3DGRASE can provide higher spatial resolution and whole brain coverage but suffers from severe blurring in the partition/slice direction due to T2 decay if the echo train is excessively long. Multi-shot 3D-GRASE [4-6] has been proposed to reduce echo train duration and related blurring. We propose a new segmentation scheme for an isotropic 3.2mm spatial resolution acquisition combining both in-plane and through-plane segmentation, improving through-plane point spread function (PSF) and SNR of 3DGRASE pCASL.

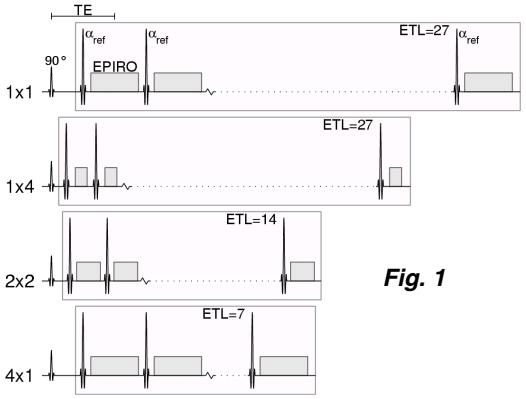
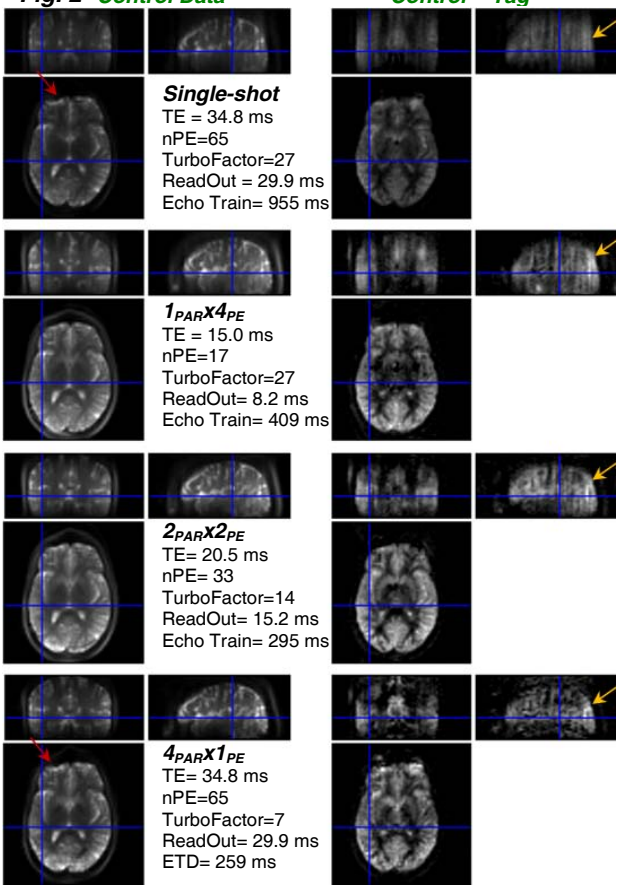


Fig. 1

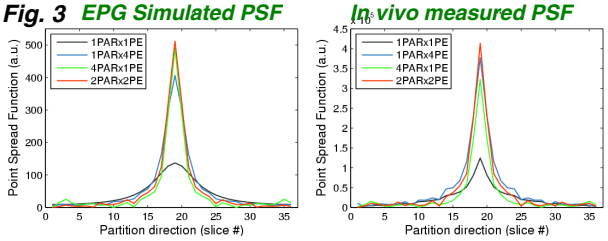
Methods. 5 subjects were scanned on a 3T Tim Trio Siemens scanner (32-channel head-coil) with 4 segmentation schemes, either 1-shot or 4-shot (**Figure 1**). Common Parameters: 30 partitions (20% oversampling, 6/8 partial Fourier), FoV (220mm)², matrix 64x64, nominal voxel size (3.2mm)³, TR = 4100 ms, acquisition time 4'31", BW = 2790 Hz/Pixel, 130° refocusing flip angle, 32 or 8 averages respectively for single-shot and 4-shot schemes. Other parameters are shown in **Figure 2** (nPE=PE steps/shot). PCASL labelling and background suppression (BS) were implemented as in [3]. Echo-shifting [8] was applied for segmentation in the PE direction. For each scheme, M0 images were acquired without BS (41s, 8 and 2 averages for single-shot and 4-shot respectively). We acquired images without phase encoding (PE) and BS in order to measure the PSF. The PSF was also simulated with the extended phase graph (EPG) algorithm [7] using T1/T2/T2*=1310/100/45ms.

Fig. 2 **Control Data** **Control - Tag**



Results. Average control and difference images for one subject are shown in **Figure 2** with the same intensity scaling. Low segmentation factor in the PE direction leads to severe distortions in the orbito-frontal cortex (**red** arrows) while through-plane blurring is reduced at shorter Echo Train durations, ETD (**yellow** arrows). Higher SNR is observed at shorter TE and shorter ETD. Moreover SAR reduces with Turbo Factor (aka ETL): by 11% and 17% in the 2x2 and $4_{PAR}x1_{PE}$ schemes respectively *vs* 1-shot and $1_{PAR}x4_{PE}$ schemes. Simulated PSFs in the partition (through-plane) direction show good agreement with *in vivo* data (**Figure 3**). As expected the PSF becomes narrower for shorter ETD (2x2 and $4_{PAR}x1_{PE}$). Results from the other subjects were consistent with these findings.

Fig. 3 **EPG Simulated PSF** **In vivo measured PSF**



Discussion and Conclusions. Novel acquisition schemes using segmentation in the partition direction have been proposed. Taking into account objective criteria (SNR, SAR, spatial resolution and geometric distortions), the best trade-off is achieved for a 4-shot 3DGRASE with the $2_{PE}x2_{PAR}$ segmentation scheme. This scheme provided promising results and, negligible through-plane blurring, avoiding excessive in-plane geometric distortions, increasing the SNR and reducing the SAR. A wider range of segmentation schemes and echo trains with variable flip angles is currently under investigation for further optimisation.

References. 1. Ye, MRM 2000, 44(1):92; 2. Gunther, MRM 2005, 54:491; 3. Vidorreta, NeuroImage 2012; 66C:662; 4. Feinberg ISMRM 2009,622; 4. Cutajar, MAGMA 2012, 25(2):145; 5. Balteau, ESMRMB 2013, 333; 6. Tan, MRM 2011. 66(1):168; 7. Hennig, JMR 1988, 78:397; 8. Feinberg, JMR 1992, 97:177.

Acknowledgments. COST Action BM1103: ASL Initiative in Dementia (AID).