# A Flexible Framework of Perfusion fMRI using Asymmetric Label and Control Acquisitions with Background Suppressed pCASL GRASE

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**Introduction:** Compared to BOLD fMRI, ASL perfusion fMRI offers the unique advantage that allows the quantification of cerebral blood flow (CBF) both at rest and during task activation. However, the temporal resolution and efficiency of existing perfusion fMRI is relatively low due to the pairwise acquisition of control and label images. With the advent of pseudo-continuous ASL (pCASL) with background suppressed (BS) 3D GRASE (a hybrid of gradient and spin echo) (1), the temporal stability and sensitivity of perfusion fMRI have been improved with reduced BOLD contamination. Furthermore, the use of BS allows much fewer control images to be acquired than label images for CBF quantification (2), thereby may improve the temporal resolution and estimation efficiency of perfusion fMRI. The purpose of this study is to explore a flexible framework for perfusion fMRI by using an uneven number of (or asymmetric) label and control acquisitions in pCASL GRASE scans. We also investigated the effect of BS on the sensitivity of perfusion fMRI.

**Theory:** ASL data can be directly modeled using General Linear Model (GLM) without the separation or subtraction of control and label images (3). It can be expressed by $Y=X\beta+\varepsilon$, whereY is the vector of raw time-series data, X is the design matrix, β is the parameters, and ε is the error vector. As shown in Figure 1, the design matrix X comprises of 4 covariates (columns): two baseline covariates (β2: baseline perfusion signal and β4: baseline intensity of raw MR images) and two activation-related dynamic covariates (β1: task induced signal change of raw MR images or BOLD and β3: task-induced changes of perfusion signal). The advantage of such a GLM approach is that all the mean baseline CBF, task-induced perfusion and BOLD activation maps can be simultaneously estimated. In addition, other covariates such as motion can be included.

**Method:** Four healthy volunteers participated in this study on a Siemens 3T TIM Trio system with the product 12 channel head coil. PCASL with BS GRASE were used for perfusion fMRI. For comparison, pCASL GRASE scans with a reduced degree of BS (by shifting one inversion pulse 200ms from the optimal TI) were also performed. Flexible acquisitions of perfusion fMRI were implemented with asymmetric control and label acquisitions. An asymmetric label factor (ASF) was defined as the number of label acquisitions between two adjacent control acquisitions. In this study, 2 perfusion fMRI scans with the ASF of 1/3 were performed using PCASL GRASE with full and compromised BS respectively. Visual cortex stimulation was performed with a 1min OFF/ON block-design of flashing checkerboard. Imaging parameters were: FOV=220mm, Matrix=64×64, TR=3s, Label Duration=1.5s, Post-Label Delay=1s, 26 slices of 5mm thickness were acquired. Each scan with 160 acquisitions took 8 min. For each subject, conventional T1 weighted 3D MPRAGE images were acquired for anatomic MRI. Standard processing steps including motion correction, normalization and smoothing were done using SPM8. GLM analyses were performed as outlined in Theory and the covariates of β2 and β3 were designed based on the ASF used.

**Results:** Robust visual cortex activation was observed in each ASL scan of each subject. Figure 2 shows the visual activation (a) and mean baseline CBF maps (b) with full and compromised BS at different ASFs from a representative subject. Mean activation voxel number, T-max value and CBF of all the subjects were also listed in Fig2. PCASL GRASE with full BS detected greater visual cortex activation than its counterpart with compromised BS, while greater activation using the ASF of 3 was obtained compared to the standard pairwise acquisition of label and control images (ASF=1). Moreover, the mean baseline CBF maps acquired with full or compromised BS showed little differences between the 2ASFs.

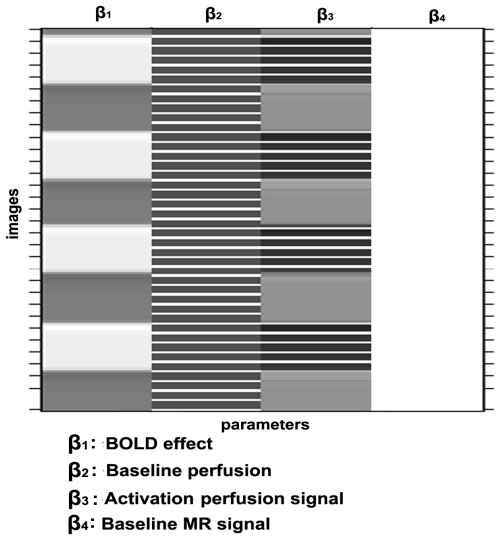


Figure 1 An example of the design matrix of the visual stimulation with ASF of 3.

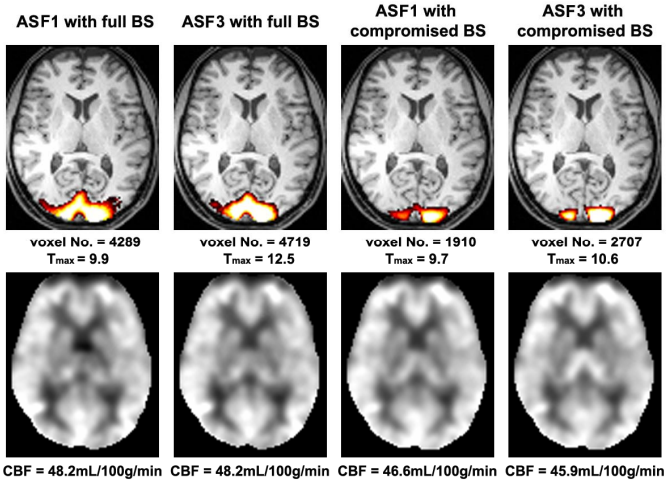


Figure 2 Visual activation (a) and CBF maps (b) with full and compromised BS at different ASF factors from a representative subject. Mean activation voxel number, T-max and CBF value of all the subjects were listed under the images.

**Discussion:** Our results suggest that BS can improve the sensitivity of perfusion fMRI using pCASL GRASE scans. The use of asymmetric label and control acquisitions (more perfusion sensitive label images) can further improve the efficiency of perfusion fMRI without compromised CBF quantification. Such a flexible design of perfusion fMRI is easy to be implemented, and can be processed using the standard GLM. Such design can be adapted for event-related perfusion fMRI studies and for ASL scans with a random number of label and control acquisitions.

**Reference:** [1] Fernández-Seara, MA. et al., Magn Reson Med, 54(5):1241-1247, 2005. [2] Duyn, JH.et al., Magn Reson Med, 46:88-94, 2001. [3] Mumford JA. et al., NeuroImage, 33:103-114, 2006.