Dependence of Functional ASL MRI Signal on Number of Slice Acquisitions

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INTRODUCTION: ASL perfusion MRI offers several advantages over the widely used BOLD fMRI: 1) ASL does not suffer from signal drifts due to 1/f noise[1], 2) It offers better localization of the activated areas[2], 3) It yields absolute quantification of the observed signal change in physiological units[2], 4) It has a lower intersubject variability of the activation contrast[2]. Despite these advantages, ASL has yet to become the method of choice for functional imaging. One of the reasons is its low inherent SNR; raw ASL signal, measured as percent change, is of the order of 1-3%[2]. Furthermore, ASL measurement is confounded by the uncertainty in transit times. The introduction of a post-labeling delay (PLD) by Alsop et al.[3] meliorates this problem to some extent, especially in the gray matter where most of activation is thought to occur. Ideally, one would need a PLD of few seconds to account for the full range of arterial transit times to the upper slices. However, due to T1 relaxation, the longer the PLD the lower the ASL signal. Moreover, even if PLD was set to be sufficiently long, saturation effects due to rapid sequential acquisition of slices could potentially impede the arrival of all labeled spins in the upper slices. In this study, we investigated the effect of number of slices on ASL functional SNR by acquiring motor activation data with 5 and 13 slices. Finger-tapping was chosen as a paradigm that activates the motor cortex in the superior part of the brain where the signal saturation is expected to have the largest effect. The study is designed to test the hypothesis that, ceteris paribus, continuous ASL (CASL) contrast is adversely affected by the number of slice acquisitions.

METHODS: ***Subjects*** - CASL functional data were acquired on 4 right-handed subjects (age 28 ± 4 years, 1 male). Written consent was obtained as approved by the institutional IRB. ***MRI*** - Images were acquired on a 1.5T scanner (Philips) using a standard transmit-receive coil. Single shot SE-EPI CASL images were acquired in ascending slice-order with: TR/TE=4s/35ms, θ=90º, FOV=220x198 mm^2, acq. matrix=64x58, slice thickness/gap =8mm/1mm. Adiabatic inversion of water spins and correction for off-resonance effects in control images were done as described by Alsop et al.[3]. For each subject, a high resolution, 3D T1 (SPGR): TE/TR=3 ms/34 ms, θ=45°, 100 slices (1.5mm/1mm-gap), FOV=240x240mm^2, acq. matrix=256x256, was also acquired. All EPI images were motion corrected, co-registered to the corresponding SPGR, and spatially normalized to MNI standard space using SPM99. Each control-label pair yielded a CBF image using the formula derived by Alsop *et al.*[3] and correcting for the slice-dependency of PLD. ***Activation data acq. & processing*** –The motor activation paradigm consisted of 80 sec. of bilateral sequential finger-tapping (ON) followed by 80 sec. of resting (OFF); each ON/OFF run was repeated 5 times resulting in a total of 50 CBF images per condition per subject. This procedure was applied to two imaging volumes: 5 slices, positioned around the motor cortex, and 13 slices covering most of the brain (i.e., 50 ON and 50 OFF CBF images were acquired for each imaging volume). For the whole brain acquisition, slices 9-13 were positioned to coincide with slices 1-5 for the partial coverage. The condition runs were randomized to minimize any systematic effects such as fatigue. Labeling plane was positioned at the same anatomical place for both imaging volumes. Importantly, to ensure that the effective PLD in the slices of interest (in the motor-cortex area) was the same in both cases, PLD was set to 600ms and 1112ms for 13-slice and 5-slice volumes, respectively. Activation volume was defined as the total number of voxels surviving the statistical threshold (T>3.1, P < 0.001, uncorrected) for each imaging volume. Activation SNR was defined as mean t-value within the conjoined activation masks from both volumes divided by the mean over the non-activated voxels common to both acquisition volumes.

RESULTS: Group SPM{T} maps of ON-OFF CBF contrast for 13- and 5-slice acquisitions are shown in Fig.1A and 1B, respectively. Activation SNR and activation volume were respectively ~27% and ~50% larger in the 5-slice imaging volume. However, due to partial coverage, areas in the cerebellum known to be associated with motor stimulation were missed by the 5-slice acquisition but present for the whole brain imaging (Fig.1). To give a sense of the time-course of the CBF, for one subject, average CBF values from the activation map are shown in Fig.2 in blue and red for 5- and 13-slice volumes, respectively; solid line denote the average values for all ON and OFF conditions. Group average CBF data are shown in Fig.3 where rest and activation are denoted in blue and red, respectively. Note that both resting and activation CBF were higher for 5-slice imaging volume (Figs. 2 & 3). In addition to higher signal, both intersubject and intrasubject variances were lower for the smaller imaging volume thus further contributing to a higher overall SNR.

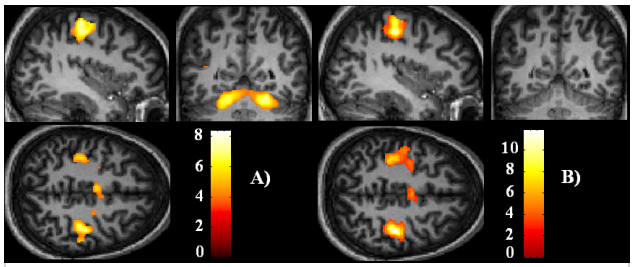

Fig.1: Talairach-normalized group SPM{T} maps (T > 3.2, P < 0.001, uncorrected) for 13-slice (A) and 5-slice (B) volumes.

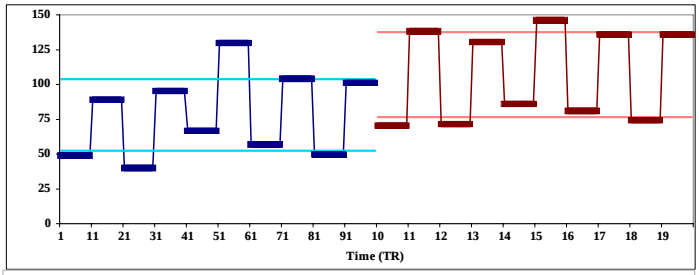

Fig.2: Plots of CBF vs. time with TR=8s (the effective TR of each CBF value.) In this subject, 13-slice acquisition (blue) was followed by the 5-slice (red). Vertical lines denote the switching between ON & OFF states.

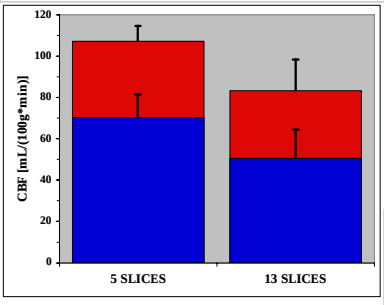

Fig.3: CBF values averaged across subjects for resting (blue) and activation (red). Error bars represent s.e.

DISCUSSION: Experimental data presented here show a dependency of functional CASL SNR on the number of acquired slices, which we think is caused by the saturation effects on the labeled spins destined for the upper slices. Both resting and activation CBF values were higher for partial brain coverage as compared to whole brain acquisition (despite PLD and all other acquisition parameters being the same). Future work is needed to further investigate the interconnection between various acquisition parameters such as slice timing and PLD for optimization of CASL activation SNR.

REFERENCES: **1)** Aguirre JK et al., Neuroimage 15 (2002), **2)** Wang J et al., *MRM 49* (2003), **3)** Alsop DC & Detre JA, *JCBFM* 16(6) (1996)