# Enhanced sensitivity of perfusion imaging to neuronal activation using Turbo pseudo-continuous arterial spin labeling (Turbo-pCASL)

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**Introduction:** The recent introduction of pseudo-continuous inversion pulses has greatly facilitated the use of continuous Arterial Spin Labeling (ASL), by compensating for magnetization transfer effects in an efficient manner without using additional hardware [1]. A fast multislice imaging scheme based Turbo-CASL [2] methodology was implemented in order to improve the temporal resolution and sensitivity of pseudo-continuous ASL (pCASL) in functional MRI studies. This method leverages changes in arterial transit time to boost activation constrast.

**Materials and Methods:** A male subject was scanned using a 3.0 T Signa Excite scanner (General Electric, Waukesha, WI) in accordance to the University of Michigan's IRB regulations. The pCASL experiment was conducted using the method described in [1] and [3]. The inversion plane was located at the carotid arteries (approximately 3 cm below the circle of Willlis). Images were collected using a gradient echo spiral imaging sequence (flip angle = 80 deg, TE = 12 ms, N. slices = 9, sl. thickness = 7 mm, FOV = 24 cm, tagging duration = 1400). Arterial contributions to the signal were suppressed by using a pair of crusher gradient around the refocusing pulse (b = 4 s/mm2). Using these parameters, twenty four pairs of pCASL images were collected using each of the following TR values: 800, 900, 1000, 1100, 1200, 1300, 1400, 2000, 3000 and 4000 ms. Tagging time was 200 ms less than TR to allow for image acquisition. This series of images was used to determine the Turbo-pCASL optimal regime. To estimate the mean transit time and the optimal TR, the images of this experiment were reconstructed, pairwise subtracted and averaged for each TR. Then the data were displayed together along with a plot of the global mean as a function of TR, as in figures 1. Mean transit time across the brain was then approximated to be 1400 ms by simple visual inspection, i.e., by choosing the TR that yielded the images with the best *negative* signal. The optimal TR for detection of activation was chosen 200 ms less than this approximated transit time. Using these parameters, the delays in the wash-in and wash-out kinetics of the system is used to dramatically reduce the time it takes to collect a *continuous* ASL image pair.

Next, the subject performed a simultaneous motor (sequential finger opposition) and visual (8Hz flashing checkerboard) activation task while being scanned once using the standard pCASL approach (TR = 3000 ms, tagging duration = 1400 ms, post-tagging delay = 1400 ms, number of frames = 100) and again with the Turbo-pCASL method (TR = 1200 ms (estimated from previous experiment), tagging duration = 1000 ms, post-tagging delay = 5 ms, number of frames = 250). The activation paradigm consisted of three cycles of alternating rest (50 seconds) and activation (50 seconds). Both datasets acquired using standard- and Turbo-pCASL were reconstructed, pair-wise subtracted and analyzed by estimation of standard general linear model (GLM) using home written software.

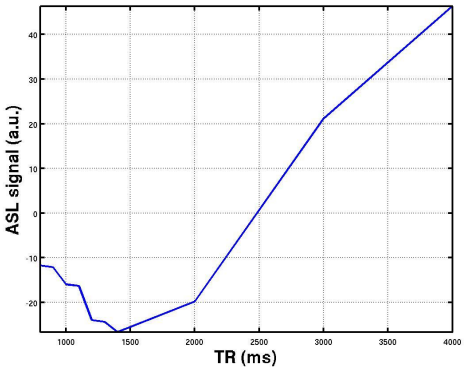


Figure 1. Mean subtraction images at different TR values

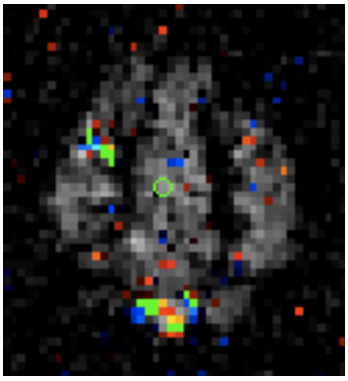

Figure 2. Activation maps (Z-score threshold = 2) acquired using Turbo-pCASL (red), standard pCASL (blue) and their overlap (green) overlaid on mean subtraction image.

**Results:** Both experiments indicated activation in visual and motor cortices. Figure 2 shows a slice of the activation maps (Z-score threshold = 2) obtained using standard pCASL (red), Turbo-pCASL (blue) and their overlap (green). We compared the mean Z-score of each activation map at visual and motor cortex regions of interest (ROI). The ROIs were defined as voxels in a 12 mm radius sphere in visual and motor cortex whose Z-scores were above 2. The Z-scores from the Turbo-pCASL data were 7.3% and 7.2% higher in the visual and motor cortex ROIs than those from the standard pCASL data. This means that higher sensitivity is achieved using the Turbo- pCASL using the same amount of time.

**Discussion:** This result is consistent with the previous results obtained using a separate coil for labeling [4] and suggests that Turbo-pCASL is more sensitive to cerebral activation than pCASL. It is due to the larger number of data acquired over the same time period. In addition, the reduction in transit time exaggerates the perfusion signal.

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**References:** [1] Garcia *et al*, ISMRM, 2005. [2] Hernandez-Garcia *et al* , MRM, 51(3):577-585, 2004. [3] Wu *et al*, ISMRM 2007. [4] Lee *et al*, MRM, 57(4):661-9, 2007.