Whole Brain Measurement of Dynamics of Arterial Spin Labeling Using Multi-Band Look-Locker Technique in Hypertension

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Target audience: Researchers in perfusion imaging who are interested in cerebrovascular disease

Purpose: The dynamics of perfusion signal changes immediately following arterial spin labeling (ASL) can provide information on the kinetics of water exchange between tissue and blood, transit time, and the tissue relaxation time that can be used to characterize cerebrovascular physiology. These metrics can be efficiently measured by the Look-Locker (LL) technique with multiple inversion time (TI) measurements after single spin labeling[1]. However, the time interval between two consecutive TI measurements is limited by the acquisition time for sufficient resolution of whole brain volume. Therefore, a sufficient number of TIs cannot be achieved with the conventional 2D multi-slice EPI technique. Recently, the multiband (MB) technique was developed to boost the speed of data acquisition[2,3]. We implemented the MB technique with LL-ASL to measure the perfusion dynamics with fine temporal resolution for whole brain volume with and without crusher gradients to remove the intravascular signal. In chronic hypertension, the structure of arterial cerebral vessels is remodeled to cope with increased arterial vessel resistance, resulting in impairment of cerebrovascular regulation and function. We applied our MB LL-ASL technique in untreated hypertensive and normotensive control groups, and tested whether our technique is sensitive in measuring perfusion dynamics for the detection of regional hypertension-induced cerebrovascular impairment.

Methods: Twelve subjects (7 normotensive and 5 hypertensive subjects) were studied on a 3T Siemens Trio system using a 32-channel head coil. The blood pressures in systolic/diastolic were 159±22/90±10 for hypertensives and 116±9/70±4 for controls. The FAIR technique was used for ASL. Data were acquired with LL MB GRE-EPI sequence with 15 readout steps after spin labeling (time interval between TIs = 259 ms and MB factor = 5) with and without bipolar gradients alternatively to crush the arterial component (b = 3 and 0 s/mm^2). The imaging parameters were as follows: voxel size = 3.69 x 3.69 x 4.0 mm^3, TR/TE = 4 s/31 ms, flip angle = 30°, and 40 averages. M_0 images were also acquired. High-resolution MPRAGE images were acquired and parcellated for multiple ROIs. The non-slice-selective data from ASL was averaged over each ROI and was fit to T_1 relaxation curves to obtain the effective T_1 of tissue that incorporates saturation effects caused by repetitive perturbation of the LL readout. The ASL signal (ΔS) was averaged over ROIs and fit to the general kinetic model [4] using the least-squares fitting algorithm to obtain the metrics of perfusion dynamics for multiple regions of brain.

Results and Discussion: We successfully acquired ASL maps at multiple TIs with MB LL-ASL (Fig. 1). The arterial and capillary transit times (Δt_a and Δt_c), maximal arterial arrival time (τ_a), and the maximal exchange time (τ_c) from multiple ROIs were measured with and without crusher gradients for hypertensive and normotensive subjects. Overall, hypertensives have slower hemodynamic responses than controls (Fig. 2). Δt_c and τ_a were significantly delayed in hypertensives for most ROIs ($p < 0.05$), while Δt_c and τ_a were not statistically different (Fig. 3). The data suggests that hypertension slows the flow of blood from the arteriole to the capillary while the physiology at the scale of the large arteries remains unaffected. The cerebral regulation of blood pressure is maintained by arterioles. Hypertension leads to increased resistance of the arterioles and remodeled (slowed) hemodynamics. In conclusion, we demonstrated that the dynamic changes of the perfusion signal can be monitored within specific regions of the brain using MB LL-ASL, and can be a critical imaging biomarker for cerebrovascular disease.

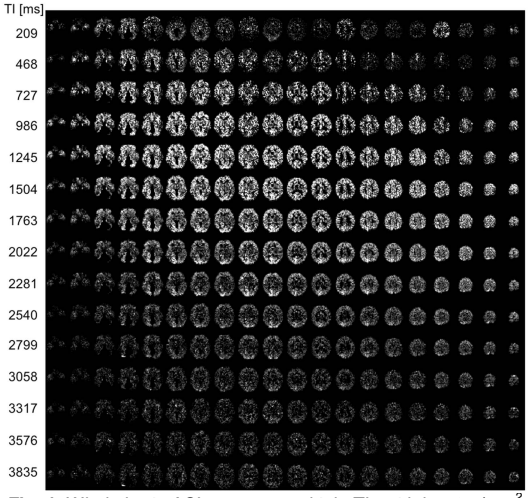

Fig. 1. Whole brain ASL maps at multiple TIs with b = 0 s/mm^2.

References: [1] Gunther et al. MRM 2001;46(5):974-84. [2] Moeller et al., MRM 2010;63:1144-53. [3] Setsompop et al., MRM 2012;67:1210-24. [4] Buxton et al. MRM 1998;40(3):383-96.

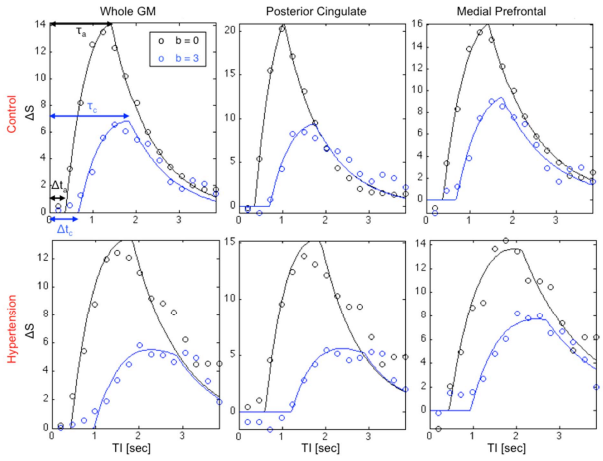

Fig. 2. LL-ASL data with b = 0 and 3 s/mm^2 (circle) and fitting results (line) from multiple ROIs for normotensive control (top row) and in hypertension (bottom row).

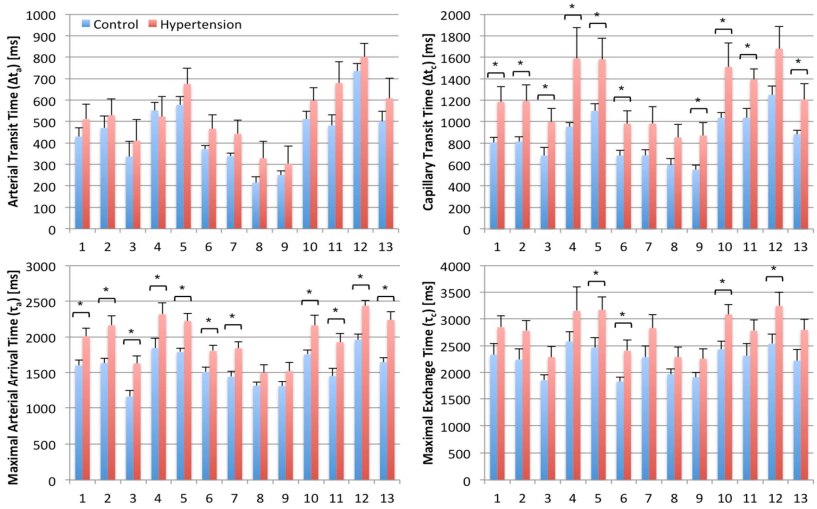

Fig. 3. Fitting parameters in control and hypertensive groups. 1: whole GM, 2: frontal, 3: insula, 4: occipital, 5: parietal, 6: subcortical, 7: temporal, 8: hippocampus, 9: para-hippocampal, 10: precuneus, 11: posterior cingulate, 12: lateral parietal, 13: medial prefrontal.