Functional Changes in Cerebral Blood Flow and Transit-Time to Somatosensory Stimulation Measured with Dynamic Arterial Spin Labeling

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INTRODUCTION

Arterial spin labeling (ASL) is a one-stop-shop MRI technique [1] that allows quantitative measurements of whole brain perfusion and perfusion territories of the major feeding cerebral arteries [2]. In ASL, the parameters needed to calculate cerebral blood flow (CBF) are usually measured in separate experiments and in single instances, hampering dynamic analysis of fast variations in CBF such as the ones associated with functional brain activation. One efficient way to obtain fast measurements of CBF is to use the dynamic ASL (DASL) technique [3], which has improved temporal resolution and enables the measurement of both BOLD and CBF changes due to stimulation. In the present study, the DASL scheme was used to simultaneously measure maps of whole brain CBF, perfusion territories, transit times of the labeled blood from the labeling plane to the exchange site, and the hemodynamic responses (CBF and BOLD) to somatosensory stimulation in α-chloralose anesthetized rats.

MATERIALS AND METHODS

Six adult male rats (298±39g) were anesthetized under α-chloralose, orally intubated and mechanically ventilated. Functional images were obtained at 7T MRI (Bruker-Biospin, Billerica, MA) with the following parameters: TR/TE=250/15ms, FOV=25.6x25.6cm2, matrix=64x64, slice thickness=2mm, and labeling time=221.85ms. For ASL, a small home-built labeling surface coil was positioned under the neck of the animal. For measurement of whole brain CBF, θ=0° was used; for acquisition of perfusion territories, θ was ±60° (Fig. 1a) [2]. For somatosensory stimulation, needle electrodes were inserted in both forepaws and the stimulus (333 μs pulses, 2mA amplitude, 3 Hz) was presented during each stationary period of the DASL cycles (Fig. 1b). The functional paradigm consisted of 8 epochs of 120 images (40 off/20 on/ 60 off). Arterial blood gases were sampled and kept within normal values throughout the experiments.

RESULTS AND DISCUSSION

Fig. 2a shows a typical resting CBF map in a 2mm-thick coronal slice of the rat brain. Due to the periodic repetition of the ASL cycles in DASL, the CBF map has high SNR, and excellent gray versus white matter contrast. Fig. 2b shows the transit time map. The average CBF and transit time values for all six rats were 67±9mL/100g/min and 358±110ms, respectively, which are in agreement with previously reported values [4,5]. Robust BOLD and CBF responses to the stimulus were present in both left and right primary somatosensory cortices (S1FL) in all rats. Fig. 3a shows the BOLD t-score map, and Fig. 3c-d show the respective combined DASL-fMRI time courses for left and right S1FL. The CBF and BOLD responses to the stimulation were 76±19% and 2.8±0.4%. Due to the functional increase in CBF, the transit time value in the functional regions was significantly decreased to 248±62ms (paired t-test, $p<0.05$). This significant shortening in transit time can be clearly noticed in both left and right S1FL regions in Fig. 2b. Figure 3b shows the left (red) and right (green) CBF territories of the major feeding cerebral arteries.

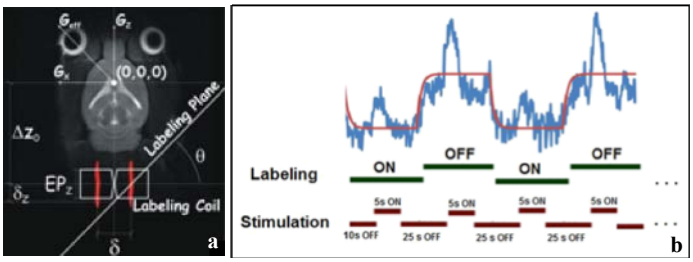

Figure 1: (a) Labeling scheme used to label blood flowing in the desired artery (θ=0° for both arteries, θ=-60° for the left artery and θ=60° for the right artery). (b) Schematic representation of the fMRI experiment using DASL to measure simultaneously resting CBF, transit times, and BOLD and CBF responses to stimulation.

CONCLUSIONS

The DASL technique enables the simultaneous measurement of resting CBF (whole brain and regional territories), transit times, and the functional hemodynamic responses (CBF and BOLD) to brain stimulation, constituting an efficient way to obtain a snapshot view of multiple aspects of the cerebral hemodynamics. The technique is sensitive enough to detect the decreases in transit-time associated with functional increases in CBF. It makes the technique attractive for the studies of spatial and temporal characteristics of functional cerebral hemodynamics, as well as for the characterization of changes in vascular perfusion patterns associated with cerebrovascular diseases such a stroke.

REFERENCES: [1] Golay X et al., *IEEE EMBS* 2007. [2] Paiva FF et al., JMRI 27(2008)970-977. [3] Silva AC and Paiva FF, 2009. [4] Barbier EL et al., *MRM* 41(1999)299-308. [5] Duong TQ et al., *MRM* 43(2000)383-392.

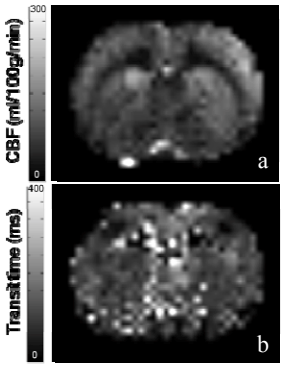

Figure 2: (a) CBF and (b) transit time maps for a representative rat.

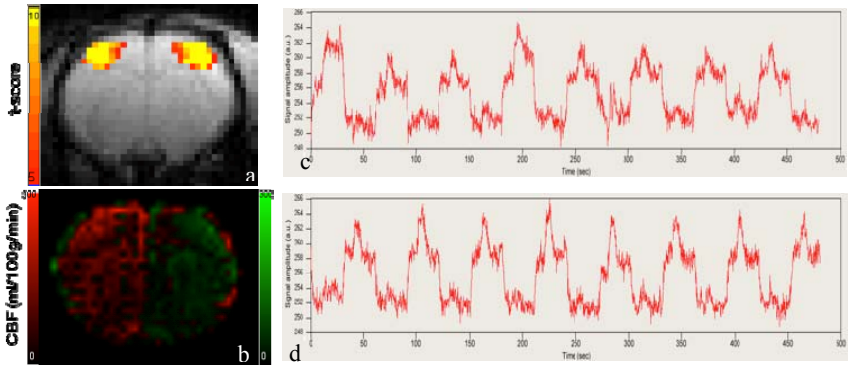

Figure 3: (a) BOLD functional map of a representative rat. (b) Baseline map of the left (red) and right (green) perfusion territories. (c) Average DASL time-course for the left S1FL region. (d) Average DASL time-course for the right S1FL region.