Mapping changes in spin-echo BOLD and CBF in the conscious rat

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INTRODUCTION Whole brain, functional MRI of the conscious rat may be a valuable technique for imaging large scale sensory processing circuits within the brain [2] and for imaging the effects of pharmacological challenge on neural activity in the absence of anesthesia. Simultaneous measurement of changes in the blood oxygen level dependent (BOLD) signal and cerebral blood flow (CBF) using a spin echo, echo planar imaging sequence and continuous arterial spin labeling (SE EPI CASL) may also provide enhanced specificity with respect to the visualization of neural activity over traditional gradient echo methods or over the use of the BOLD signal alone [1-3]. Using an integrated restraint and three coil imaging system, we demonstrate an imaging protocol able to simultaneously measure changes in BOLD and CBF in the conscious rat over regions including areas of susceptibility and ventral brain nuclei which are difficult to image using gradient echo sequences or two coil systems, respectively.

METHODS Five male SD rats (300-375g) were studied. During imaging studies rats were fully conscious and secured in an integrated imaging and restraint system (Insight Neuroimaging Ltd.). Hypercapnic (10% CO_2) challenge experiments were performed to modulate CBF and BOLD systemically. Combined CBF and BOLD measurements were made on a 4.7T Bruker scanner using the continuous arterial spin labeling technique with single-shot, spin echo, echo planar imaging acquisition as previously described [2]. An actively decoupled TEM resonator volume coil and surface coil system was used for brain imaging. A third, actively decoupled butterfly surface coil with external tuning and matching circuitry was developed for adiabatic labeling of arterial spins. The neck coil was positioned proximal to the carotid arteries (Figure 1, panel A). MR parameters were: labeling duration 1700ms, data matrix=64x64, FOV=3.0x3.0cm^2, twelve 1.2-mm slices (interslice spacing of 3mm), TE=55ms, and TR=3s. During the hypercapnic challenge, 30 pairs of images were acquired during baseline and 30 pairs during hypercapnic challenge. High-resolution anatomical images (128x128, RARE) were also acquired. BOLD images were derived from the control data set of the CBF measurements [2]. Generalized linear model analysis was performed using a single step boxcar model to resolve percentage changes in BOLD and CBF [4].

RESULTS & DISCUSSION Robust increases in BOLD and CBF were observed throughout the primary somatosensory cortex (10.9 ± 2.9% & 188 ± 19%), thalamus (16.4 ± 8.1% & 252 ± 68%), and striatum (5.3 ± 0.5% & 288 ± 25%). Importantly, increases in BOLD and CBF were also observed in regions difficult to image with two coils or gradient echo sequences, such as the hypothalamus (7.2 ± 1.0% & 75.4 ± 20%) , and entorhineal cortex (5.2 ± 1.2% & 240 ± 119%). Work by Fisher et. al. [5] has previously demonstrated the significant gains in signal to noise and uniform excitation of ventral brain regions made possible by a three coil configuration. This design permits the use of spin echo EPI sequences for whole brain imaging and simultaneous BOLD and CBF measurement and may also be used in conjunction with a hypercapnic challenge to calculate relative changes in $CMRO_2$ [6]. The extended acquisition time of multi-slice spin echo sequences exacerbates labeling artifacts, such as T1 relaxation of inverted arterial spins, in a slice dependent manner. Multi-segment acquisition, alternate slice acquisition plans, and calculation of slice dependent labeling efficiency are being investigated to address these challenges.

REFERENCES [1] Keilholz SD, et. al. Magn Reson Med. 2004, 52:89-99 [2] Duong TQ, et. al. Magn Reson Med. 2002, 48:589-593 [3] Buxton RB, et. al. Neuroimage. 2004, 23 Suppl 1:S220-33 [4] Worsley KJ & Friston KJ. Neuroimage 1995, 2:173-81 [5] Fisher T, et. al. Proc. Intl. Soc. Mag. Reson. Med. 11, 2004 [6] Davis T, et. al. PNAS 1998, 95:1834

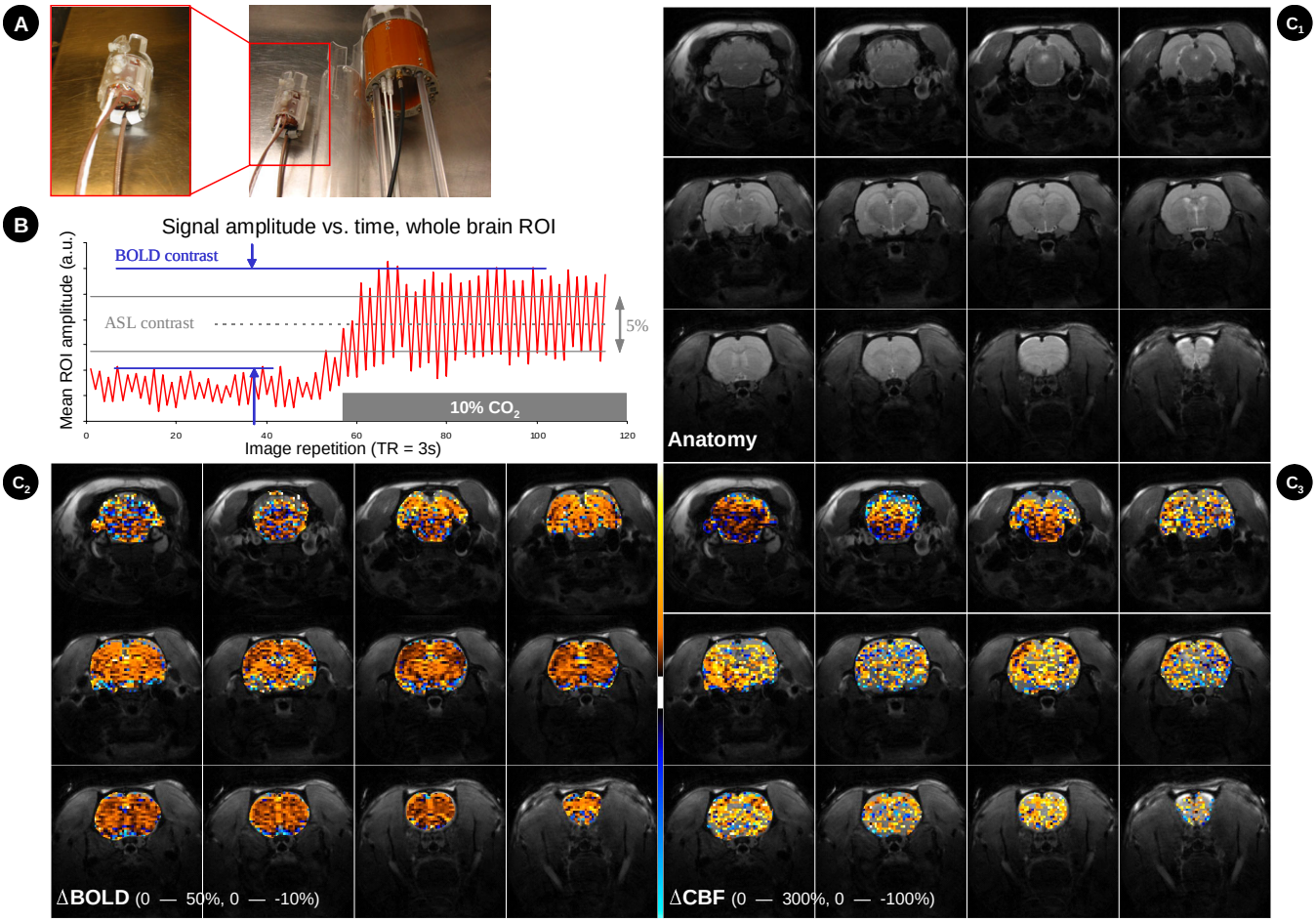

Figure 1: A – Image of the three coil system used, right panel shows TEM resonator for slice excitation, left panel shows enlarged image of integrated restraint, surface receive and neck labeling coil (tuning and matching circuitry of neck coil not show). B – Time course of mean signal amplitude for a whole brain ROI illustrating the increase in BOLD signal and the increase in ASL contrast following administration of 10% CO_2 in the conscious rat. Panels C1 – C3 illustrate the anatomy acquired, overlaid with changes in BOLD and changes in CBF following administration of 10% CO_2. Orange and Blue scales represent positive and negative changes, respectively.