Continuous Arterial Spin Labeling by a Separate Neck Coil with Inversion-Recovery Suppression of Static Tissue Signals (ir-cASL)

Q. Shen[1], and T. Q. Duong[1]

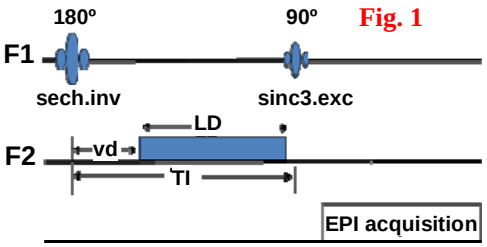
[1]Research Imaging Center, University of Texas Health Science Center at San Antonio, San Antonio, TX, United States

INTRODUCTION Arterial spin labeling (ASL) technique has been widely used to measure cerebral blood flow (CBF) in animals and humans. This approach uses "pair-wise" subtraction of alternate images taken with labeled and non-labeled conditions to obtain a difference signal that arises only from inflowing "labeling" water. Although the static tissue signal from static brain water is subtracted out in the CBF determination, instabilities in the static tissue signal can add substantial noise to the difference signal which is typically less than 5% of the total signal intensity. Reduction or elimination of the static tissue signal in an ASL study could improve sensitivity, contrast and reproducibility. Such static tissue signal reduction can be achieved using single or multiple inversion pulses (1–4) based on the fluid-attenuated inversion recovery (FAIR) and other ASL techniques. In this work, we implemented the inversion-recovery suppression of static tissue to the two-coil continuous ASL (ir-cASL) to image baseline CBF and stimulus-evoked CBF fMRI. This approach compares favorably with existing methods because static tissue suppression is independent of labeling efficiency. Comparisons with cASL were made in the same animals.

METHODS Diagram of ir-cASL sequence is shown in **Figure 1**. A nonselective adiabatic 180 degree inversion pulse (sech, 20ms pulse length) in the F1 channel was added before the spin labeling pulse in the F2 channel. A variable time delay (*vd*) was inserted between the inversion pulse and the spin labeling pulse to vary the inversion recovery time (*TI*) to optimize suppression of static tissue. Standard GE EPI acquisition was employed.

Twelve male SD rats were anesthetized with ~1.2% isoflurane in air. Body temperature and respiration rate were continuously monitored and maintained within normal ranges. MRI experiments were performed on a 7-T/30-cm magnet. A surface coil (2.3-cm ID) with active decoupling was used for brain imaging and a neck coil for perfusion labeling.

Fig. 1



cASL and ir-cASL were acquired using single-shot, gradient-echo, EPI acquisition. MR parameters were: data matrix=64x64, FOV = 3x3 cm, single 1.5-mm slice, TE = 14 ms, TR = 2 s and LD = 0.9 s. For ir-cASL, an adiabatic inversion hyperbolic secant pulse (sech, 20 ms width) was applied before labeling pulse. Stability of perfusion contrast measure was compared between the two methods using 3 four-minute baseline scans. Stimulations employed hypercapnic challenge (5% CO_2 in air) and forepaw stimulation (6mA, 0.3ms pulse, 3 Hz (5)). MRI signal time courses, standard deviation maps of signal time courses, activation maps, and contrast-noise ratio (CNR) maps were obtained for analysis. CNR was defined as ΔS of fMRI signals changes divided by the standard deviation of baseline.

RESULTS Figure 2A showed the typical labeled and non-labeled image time courses of cASL and ir-cASL. The ir-cASL provided much larger differences between non-labeled and labeled signals. This is also reflected in the ΔS/S maps in **Fig 2B** where the ir-cASL has a much larger dynamic range. The standard-deviation maps of the ir-cASL (**Fig 2C**) were smaller in value compared to cASL, indicating increased contrast stability. The whole-brain group-averaged standard deviation of ir-cASL (0.22 ± 0.03) was significantly smaller (P = 0.028, n = 6) than that of cASL (0.46 ± 0.25).

Fig. 2

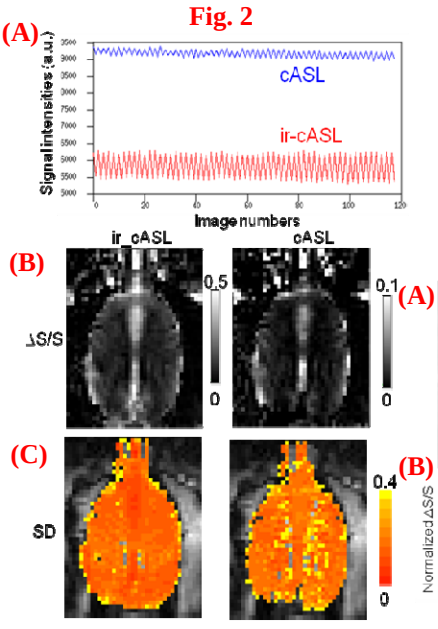


Fig. 3

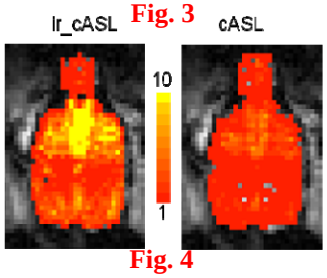


Fig. 4

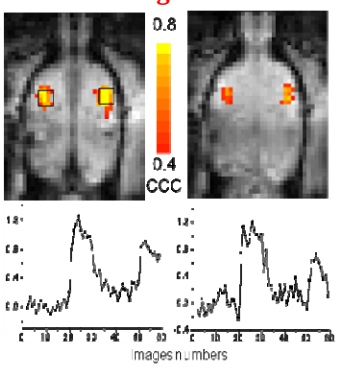


Figure 3 showed representative CNR maps associated with hypercapnic challenge using ir-cASL and cASL. The whole-brain group-averaged CNR of ir-cASL (2.7 ± 1.5) was significantly higher than that of cASL (1.1 ± 0.6) (P = 0.031, n = 5).

Cross-correlation activation maps and time courses of the forepaw stimulation (two epochs) at the same statistical threshold in the same animal are shown in **Figure 4**. Both the activation maps and time courses revealed that ir-cASL yielded higher functional contrast than cASL at the same statistical thresholds. The group-averaged results are summarized in Table 1.

DISCUSSION & CONCLUSION This work demonstrated that ir-cASL compares favorably with cASL in that it can provide: 1) larger dynamic range of perfusion contrast; 2) more stable perfusion signals, and 3) higher contrast-noise ratio in functional MRI. Future studies will be quantifying CBF using this approach.

Table 1	SD (n = 6)	CO_2 fMRI CNR (n = 5)	forepaw fMRI CNR (n = 6)	forepaw CCC (n = 6)
ir-cASL	0.22 ± 0.03 [a]	2.7 ± 1.5 [b]	18 ± 2.2 [c]	0.47 ± 0.07 [d]
cASL	0.46 ± 0.25 [a]	1.1 ± 0.6 [b]	5 ± 3.2 [c]	0.30 ± 0.10 [d]

[a] P = 0.028, [b] P = 0.031, [c] P = 0.030, [d] P = 0.009

REFERENCE: 1) Dixon WT, et al. MRM 1991;18:257–268. 2) Mani S, et al. MRM 1997;37:898–905, 73:266. 3) Ye FQ, et al. MRM 2000;44:92–100. 4) Garcia DM et al. MRM 2005; 54:366–372. 5) Liu ZM, et al. MRM 2004;52:277–285.