

# Unilateral Labeling PASL Technique for Vascular Territory Perfusion Imaging

H. K. Song<sup>1</sup>, Y. Zhang<sup>1</sup>, R. L. Wolf<sup>1</sup>, J. Wang<sup>1</sup>, J. A. Detre<sup>1</sup>, F. W. Wehrli<sup>1</sup>

<sup>1</sup>Department of Radiology, University of Pennsylvania, Philadelphia, PA, United States

## Introduction

Perfusion imaging using non-invasive arterial spin labeling can be used to measure cerebral blood flow (1-3). Unlike exogenous contrast approaches, ASL methods can be modified to quantify perfusion in individual arterial distributions through the use of selective labeling. Such methods would help assess the clinical implications of vascular diseases, such as the effects of carotid stenosis on brain perfusion and the degree of collateral flow. Recently, techniques for adiabatic labeling with a separate coil were described for unilateral perfusion territory imaging (4-5), which required additional hardware for coil decoupling and control. Potential problems with surface coil labeling include local heating and uncertainties in labeling efficiency (6-7). In this work, a technique is described for unilateral perfusion territory imaging. Unlike CASL-based methods, the technique does not require separate coil or hardware, and can be used with PASL imaging sequences. In vivo demonstrations in volunteers confirm the feasibility of the technique.

## Methods

The technique involves selective inversion of one hemisphere of the brain during the labeling period, and a non-selective inversion for the control (Fig. 1). Saturation RF pulses and gradient spoilers are subsequently applied to the imaging slices to suppress the background signal. Following an inversion time to allow inflow of labeled blood, image data are acquired, and the labeled and control images subtracted to obtain the unilateral perfusion image. Since the arterial blood in one hemisphere is identically labeled, the signals will completely cancel, while the other hemisphere will yield the perfusion signal. For imaging the two hemispheres, a left-selective, a right-selective, and a non-selective inversion would be alternated. Global perfusion can be computed from the hemispheric images by summation. The proposed technique is different from the method by Eastwood, et al. (8) for MR angiography, in that our method is simpler, and is capable of measuring perfusion.

The proposed left/right/control unilateral labeling technique was incorporated into a QUIPPS II sequence. The following imaging parameters were prescribed: 24cm FOV, 4 (or 8) slices, 22ms TE, 2.3s TR, 8 (7) mm thick, 128kHz receiver bandwidth, 50 averages,  $T_1$  (pre-saturation delay time) = 600 (700) ms,  $T_2$  (total delay time) = 1400 (1700) ms. The saturation of the imaging slices was performed using 3 consecutive  $90^\circ$  sinc pulses, each followed by a gradient spoiler. Normal volunteers were imaged to demonstrate the feasibility of the technique. In the first experiment (using the first set of parameters), the results from combining the left and right hemisphere perfusion images were compared to that of a conventional QUIPPS II sequence. A subject with an anatomical variant in the anterior region of the circle of Willis was also imaged using the second set of imaging parameters.

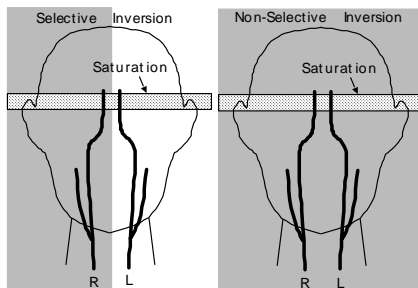
## Results and Discussion

Figures 2a and b show the left and right perfusion images of the first volunteer, and Fig. 2c is their sum. Although there is a reduction of SNR in the combined image due to the summation, there is an excellent agreement of the perfusion signal with the conventional QUIPPS II image (Fig. 2d). Figure 3 shows results from the subject with the morphological variation of the circle of Willis. Although not detected in the global perfusion data (Fig. 3c, d), it can be seen that perfusion of the anterior and midline regions (superior slice) of the brain corresponding to anterior cerebral artery territories is supplied primarily by the left carotid system, indicated by enhanced perfusion in Fig. 3b, and nearly complete absence of signal in these regions in Fig. 3c. This observation is confirmed by MRA shown in Fig. 3a.

In addition to local SAR issues, there is increased potential for measurement error with two-coil labeling methods. It was previously shown that labeling efficiency depends on various parameters, including the B1 strength (depth of the carotid artery), labeling gradient strength, and blood velocity which varies with the cardiac cycle (6-7). The undesired labeling of contralateral arteries are also inevitable (7). A method for selective arterial spin labeling that utilizes pencil beam excitation of individual carotid arteries was recently proposed (9). The technique, which requires the targeted beam to be parallel to the image plane to avoid excitation of the imaging slice, is sensitive to the geometry of the vessel orientation and the blood velocity, and quantification is difficult due to these uncertainties. The proposed method described herein is simple and is insensitive to some of the issues that affect previous methods.

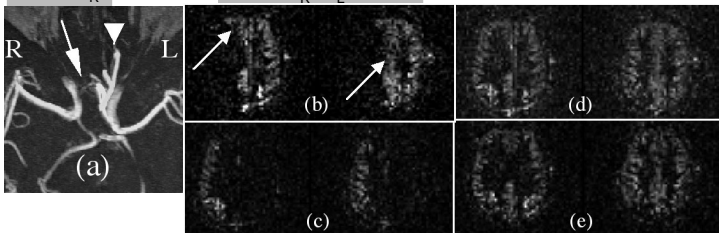
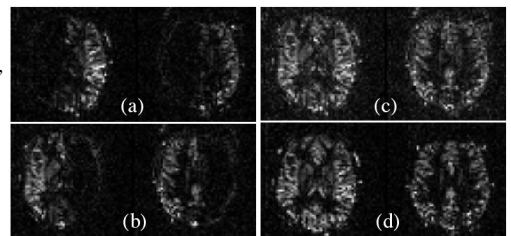
## Conclusion

A novel unilateral PASL technique is described that allows independent labeling of the right and left cerebral hemispheres. The method requires much less RF power than CASL techniques that employ adiabatic labeling, enabling its use at higher field strengths (> 1.5T). The method also does not require separate labeling coils and additional hardware, and is immune to uncertainties in labeling efficiency caused by inhomogeneous B1 profile and variations in the vessel depth and blood velocity.



**Fig. 1** (Left) The labeling scheme for unilateral PASL (left side labeled). (a) During the labeling period, a unilaterally selective adiabatic inversion pulse is applied (shaded area), immediately followed by saturation pulses and spoiler gradients at the level of the imaging slices. (b) During control, the selective inversion is replaced with a non-selective pulse.

**Fig. 2** (Right) Left-labeled (a), right-labeled (b), and combined (c) perfusion images (2 slices). (d) QUIPPS II perfusion image.



**Fig. 3** (a) MRA of the circle of Willis reveals a thin anterior cerebral artery (ACA) on the right (arrow), with both ACA territories supplied primarily from the left (arrowhead). The MRA is concordant with perfusion results, where the left-labeled images (b) show perfusion in bilateral ACA and left middle cerebral artery (MCA) territories (arrows), while the right-labeled images (c) show little to no perfusion in ACA territories. Summing the two sides (d) gives a result similar to a conventional QUIPPS II image (e).

**Acknowledgement:** NIH R01-HL68908

**References:** (1) Detre, JA, et al., Magn. Reson. Med. 23:37-45 (1992). (2) Kwong, KK, et al., Magn. Reson. Med. 34:878-887 (1995). (3) Kim, SG, Magn. Reson. Med. 34:293-301 (1995). (4) Zaharchuk, G, Magn. Reson. Med. 41:1093-8 (1999). (5) Mildner, T, Magn. Reson. Med. 49:791-5 (2003). (6) Trampel, R, Proc. ISMRM 11<sup>th</sup> Meeting, 663 (2003). (7) Song, HK, et al., Proc. ISMRM 11<sup>th</sup> Meeting, 2215 (2003). (8) Eastwood, JD, et al., Mag. Reson. Imaging 20:583-586 (2002). (9) Davies, NP, et al., Magn. Reson. Med. 49:1133-1142 (2003).