# Regional Perfusion Imaging Using pTILT

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## Introduction

Recently, pseudo-continuous arterial spin labeling (pCASL) sequences [1] have been modified to map vascular territories of major cerebral arteries either by selectively labeling each artery sequentially [2], or encoding two or more vessels simultaneously [3]. This regional perfusion measure allows for the investigation of collateral flows between major feeding vessels in the brain. Pseudo-continuous transfer insensitive labeling technique (pTILT) is a novel pseudo-continuous ASL approach, which uses non-adiabatic saturation RF pulses for tagging [4]. Here, we propose a modification of the pTILT sequence that allows for regional perfusion imaging.

## Method

The modified pTILT pulse sequence for regional perfusion imaging is shown in Figure 1. The employment of in-plane gradients between the concatenated RF pulses induces a spatial phase distribution in the labeling plane. For example, to separate the vascular territory of left internal carotid artery (ICA) from that by right ICA (Figure 2), the in-plane gradients are set to introduce a phase shift of π in left ICA according to Equation (1) , in which γ is the gyromagnetic ratio, $\Delta t$ is the duration of in-plane gradients, $G_x$ and $G_y$ are the time average amplitudes of the inserted gradients, $x_{1,2}$ and $y_{1,2}$ are the projection distance from the target vessels to the isocenter along the gradient x and y directions, respectively.

$$\gamma \Delta t \begin{bmatrix} x_1 & y_1 \\ x_2 & y_2 \end{bmatrix} \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} 0 \\ \pi \end{bmatrix} \quad (1)$$

Numerical Bloch simulations were carried out to investigate the labeling efficiency as a function of offset from the targeted vessels. Simulation parameters were: windowed-sinc 45° RF pulse with duration of 2560 μs, in-plane gradients duration 500 μs, amplitude of $G_x$ 0.587 G/cm and $G_y$ -0.587 G/cm.

In vivo acquisition parameters on a 3T Siemens Trio scanner were, FOV 22 cm, in-plane matrix size 64×64, TR/TE 5000/44 ms, SE-EPI readout, imaging slice thickness 6 mm, slice gap 1.2 mm, 30 averages, labeling slice thickness 10 mm, tagging repetition spacing ($T_{ps}$, as shown in Figure 1) 30 ms, RF pair repetitions 100, total labeling duration 3 s, post-labeling delay (PLD) 1 s, gradient spoiler duration and amplitude 4000 ms/[±10, ±12, ±14, ±16 G/cm].

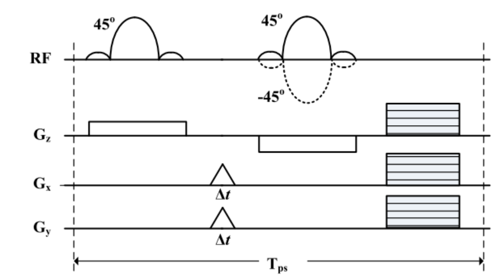


Figure 1: RF and gradient waveforms of one RF pair for RPI pTILT. Solid line in RF denotes (45°, 45°), and dash line (45°, -45°). The striped boxes indicate amplitude-varying gradient spoilers in three directions.

**Results and Discussions:** Simulations demonstrated good efficiency at two target vessels and rapid fall at places between them (Figure 3). Since the tag and control profiles of pTILT strictly follow a sinusoid shape [5], the relative labeling efficiency for each vessel can be estimated from their coordinates obtained from the planning scans and this efficiency can be used to improve the separation and accurate measure of each perfusion territory. In human studies, two acquisitions were implemented. The first one encoded left and right ICAs, and the second encoded anterior/posterior to extract the posterior perfusion region. Each acquisition took 5 mins, resulting in 10 mins scanning time in total. In vivo results showed highly separated vascular territories by left ICA (green), right ICA (red) and vertebral arteries (blue) (Figure 4). Similar to pCASL approaches [1], pTILT is also sensitive to magnetic field inhomogeneities, which could induce error in labeling efficiency for regional perfusion imaging. A robust correction method has been proposed to recover efficiency loss due to off-resonance effects [5].

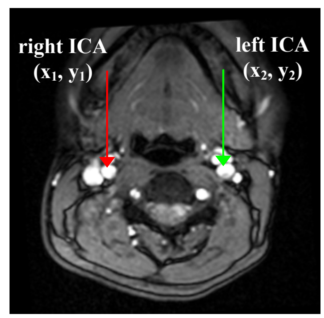


Figure 2: An example of the labeling geometry of regional perfusion imaging using pTILT. ($x_1$,$y_1$) and ($x_2$, $y_2$) are the projection distances of right and left ICAs to isocenter.

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**References:** 1. Dai, MRM. 2008, 60(6):1488-97. 2. Dai, MRM. 2010, 64(4):975-82. 3. Wong, MRM. 2007, 58(6):1086-91 4. Ouyang, ISMRM 2010, p1740. 5. Ouyang, ISMRM 2009, p1519.

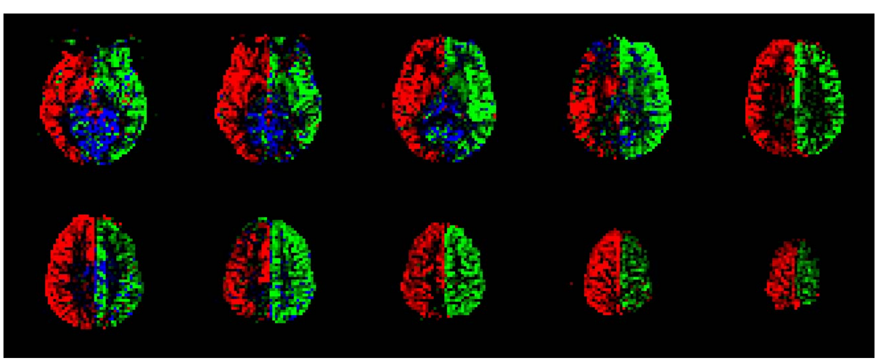

Figure 4: RGB-encoded RPI image of all three perfusion territories: right ICA (red), left ICA (green) and BA (blue).

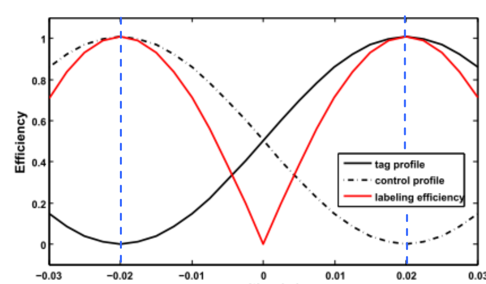


Figure 3: Simulated labeling efficiency (red) as a function of distance from targeted vessels (right ICA at -0.02 m and left ICA at 0.02 m). The solid and dash black lines denote the tag and control profiles, respectively.