Pushing Transfer Insensitive Labeling Technique (TILT) from Pulsed Arterial Spin Labeling to Pulsed-Continuous Arterial Spin Labeling

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Introduction: Arterial spin labeling (ASL) permits noninvasive perfusion measurements with MRI[1,2]. In pulsed ASL (PASL), instantaneous RF pulses are applied to a thick slab proximal to imaging slices to achieve arterial labeling[3,4,5]. To obtain higher SNR compared to PASL, continuous ASL (CASL) uses continuous RF pulses, but this approach is limited by the availability of near continuous wave RF transmit and other imperfections in multislice performance[6,7]. Recently, pulsed-continuous ASL (pCASL) based on flow-driven adiabatic labeling has been developed to combine the advantages of PASL and CASL by using a train of discrete RF pulses to label arterial spins[8,9]. Magnetization transfer (MT) insensitive labeling technique (TILT) is previously used as a PASL method by employing concatenated RF pulses[5,10]. With the MT-insensitive feature, we propose to convert the original TILT to be further developed into a non flow-driven adiabatic pCASL technique with higher signal and fewer artifacts, named pulsed-continuous TILT (pTILT), which has comparable performance as current pulsed-continuous flow-driven adiabatic labeling techniques.

Theory: The labeling preparation in TILT is achieved by using two concatenated slice-selective RF pulses in a particular fashion: the 2nd RF pulse shape is inverted in time and the 2nd selective gradient has opposite sign compared to the 1st one[5]. For control preparation, the 2nd RF pulse has 180° phase shift as shown by the MR events in the labeling block of Fig 1. Thus, the MT signals are the same for both label and control sessions, resulting in complete cancellation of MT-related signal in static tissue by the subtraction procedure. Our proposed conversion of TILT from pulsed ASL to the novel pulsed-continuous ASL method, pTILT, includes three major modifications: (1) rather than implementing the concatenated labeling block only once as in TILT, we repeat the block for N_b times for a pulsed-continuous labeling. The number of repetition, $N_b = T_s/T_b$, where T_s is the total labeling duration and T_b the labeling block duration. Following each block, an amplitude-varying gradient spoiler is applied. (2) In order to reduce imperfections from static tissue signal due to different slice profile effects of label and control sessions, the labeling slab is decreased from 140mm (dashed yellow box) to 10mm (shadowed yellow box) in pTILT as shown in Fig.2. Also, with narrower labeling slice, the imaging slice could be moved closer. (3) 45°, instead of 90° RF pulses are implemented in pTILT, therefore we use saturation for labeling.

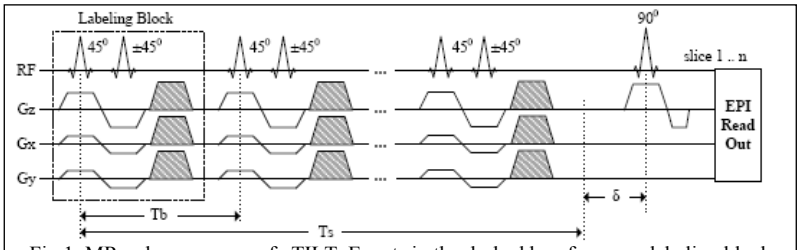

Fig.1: MR pulse sequence of pTILT. Events in the dashed box form one labeling block. ($+45^0$, $+45^0$) is used for label session, ($+45^0$, -45^0) is used for control session. Tb: labeling block duration, Ts: total labeling duration, δ: postlabeling delay.

Generic parameters: FOV=22cm, Matrix size=64x64, Slices=6, Slice thickness=6mm, Slice gap = 1.2mm, TR/TE=6000/44ms, Averages= 18, SE-EPI, ascending order of slice acquisitions. **pTILT parameters**: Windowed sinc 45^0 RF duration=2560us, Labeling slice=10mm, Tb=20ms, Ts=2s, δ=1s. **Eq.(1) parameters:** ΔM=subtraction image, $M_{0,CSF}$=magnetization of CSF, Water content, λ_{blood}=0.76, *a*=labeling efficiency, T1/T2 of blood at 3T=1680/275ms

$$CBF = \frac{\Delta M}{M_{0,CSF}} \cdot \frac{6000}{\lambda_{blood} \cdot \alpha \cdot T_{1,blood}} \cdot \exp(\frac{\delta}{T_{1,blood}}) \cdot \exp(\frac{TE}{T_{2,blood}}) \quad (1)$$

Methods: (I) The numerical Bloch equation simulation is used here to explore the label, control and their combined efficiencies of pTILT as a function of a range of blood velocities (0-60cm/s) by assuming plug flow. **(II)** In vivo investigations were performed using a 3T Siemens Trio whole body scanner in accordance with the institutional review board. Since this work is focused on the feasibility of the novel method pTILT, flow quantification in the unit of mL/100mL/min here is calculated based on Eq.(1), in which a single compartment model and no blood exchange are assumed[11]. **(III)** pTILT is used for a 30s finger tapping motor functional task with both hands, interleaved with 30s rest for 8 repetitions.

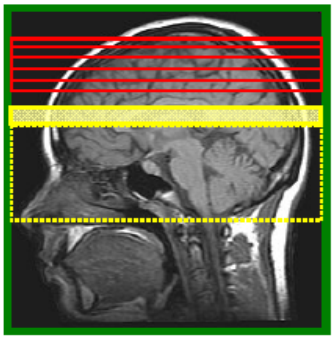

Fig.2: Geometry of pTILT and TILT. Red: imaging slab, Shadowed yellow: pTILT labeling slice, dashed yellow: TILT labeling slab, green: shimming volume.

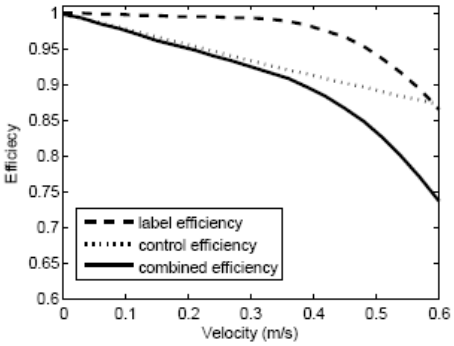

Fig.3: Simulated efficiencies as a function of velocity. T1 and T2 relaxations of blood are not considered in this simulation.

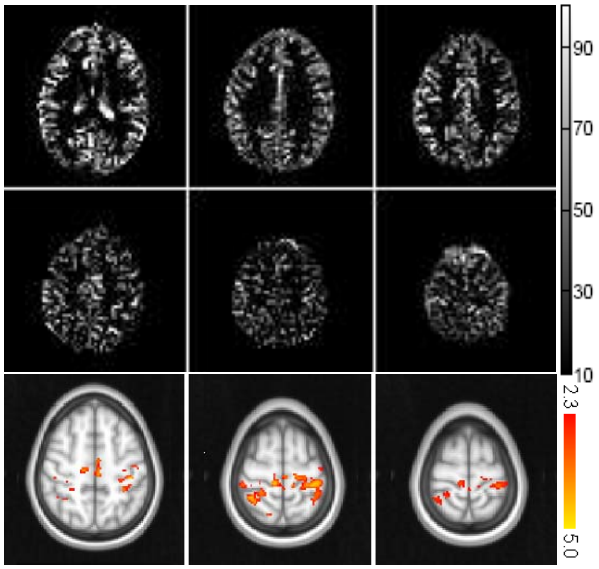

Fig.4: top 2 rows: multislice perfusion maps by pTILT. Color map: CBF in mL/100mL/min. Last row: z-score activation map of the second row.

Results: (I) Simulation results (Fig.3) demonstrates comparable labeling efficiency with current pCASL methods[12,13], and pTILT has good efficiency for slow spins since it does not require flow-driven adiabatic condition. **(II)** In vivo perfusion maps computed by Eq.(1) with surround subtraction are shown in Fig. 4. The quantified average CBF value in gray matter ROIs of the six slices is 65.7±9.6 mL/100mL/min. **(III)** The z-score activation maps of the upper three slices are also shown in Fig.4

Discussion: pTILT, the pulsed-continuous non-flow-driven labeling method was successfully implemented to measure brain perfusion map. Future work will estimate the slice profile effect, off-resonance influence and SNR analysis of pTILT.

References: 1. Detre,MRM,1992; 2.Williams,PNAS,1992; 3.Kim,MRM,1995; 4.Luh,MRM,1999; 5.Golay,JMRI,1999; 6.Alsop,Radiology,1998; 7.Wang,Radiology,2005; 8.Garcia,ISMRM05,p37; 9.Wong,MRM,2007; 10.Pruessmann,JMR,2000; 11.Chalela,Stroke,2000; ; 12.Wu,MRM,2007; 13.Dai,MRM,2008.