

Background-Suppressed Hybrid Pulsed and Pseudo-Continuous Labeling Scheme for ASL-Based Carotid MR Angiography

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INTRODUCTION: MR angiography is routinely used to assess carotid arterial occlusive disease. Recently, pseudo-continuous arterial spin labeling (pCASL) has been proposed for carotid and intracranial MRA [1,2]. Despite the excellent vascular contrast provided by pCASL, the method is subtractive which can result in artifacts in patients who move or swallow during the imaging exam.

The primary goal of this work is to describe a background suppression (BS) sequence that is compatible with pCASL MRA, is self-configuring (i.e. automatically and optimally adapts to the user prescribed sequence repetition time (TR)), combines (i.e. “hybridizes”) pseudo-continuous as well as pulsed labeling (hASL) to maximize vascular conspicuity [2], and incorporates an optional post-labeling delay period (PLD) to minimize image quality degradation by non-vascular background tissue during parallel imaging reconstruction. The secondary aim of this work is to evaluate the utility of the method in patients with carotid artery stenosis (CAS).

METHODS: *Labeling Scheme:* The proposed labeling scheme is diagrammed in Fig. 1. The method applies a presaturation (90°) RF pulse over the primary field-of-view (pFOV) [1,2,3], pseudo-continuous labeling upstream of the pFOV, adiabatic inversion RF pulses ($n = 2$) to suppress the appearance of non-vascular tissue [1,4,5], a pulsed ASL (PASL) inversion to the secondary field-of-view (sFOV), and supports the use of an optional PLD. Optimal inversion times (TIs) for the BS IR pulses were numerically computed for TRs ranging from 0.5 s to 2.0 s (0.1 s increments) in a manner similar to that of [6] considering a weighted contribution of tissue (fat [25% contribution], muscle [70%], cerebrospinal fluid [5%]) and parameterized to the sequence TR by logarithmic regression. To optimize vascular conspicuity by minimizing saturation of the inflowing blood in the sFOV, BS inversion pulses were either spatially selective or spatially non-selective if executed before or after the PASL inversion RF pulse, respectively.

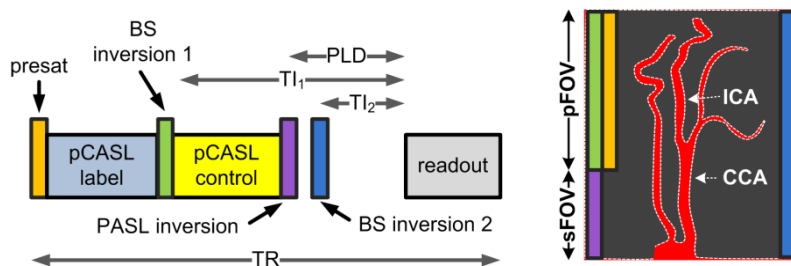


Fig. 1. Left, timing diagram for the presented labeling and background suppression scheme. Right, diagram of the carotid and vertebral arteries showing the regions affected by the RF pulses at left. Pseudo-continuous labeling occurs at the junction of the primary (pFOV) and secondary (sFOV) field of views. CCA/ICA = common/internal carotid artery.

In vivo imaging: This portion of the study was IRB approved. The aforementioned labeling scheme was applied to patients with sonographically documented CAS. Imaging was performed on a 1.5T MR system (MAGNETOM Avanto; Siemens Healthcare, Erlangen) with the junction of the primary and secondary field of views 5 cm below the carotid bifurcation and the following imaging parameters: coronal slab acquisition, GRAPPA x3, TR = 1.7s, PLD ranging from 0.0-0.3 s, 1.0 mm in-plane spatial resolution. Apparent arterial contrast-to-noise ratios (CNR) were measured to evaluate the impact of BS, hASL and PLD.

RESULTS: At 1.5T, numerically optimized inversion times for background suppression (in ms units) for a given TR (ms) were given by $Tl_1 = 417.8 \ln(TR) - 2278.7$ ($R^2=0.997$) and $Tl_2 = 57.6 \ln(TR) - 257.7$ ($R^2=0.983$). The measured CNR of vascular segments near the carotid bifurcation increased 35%-49% ($P < 0.02$) with the use of background suppression, 12-25% ($P < 0.01$) with the use of hybridized spin labeling (PLD = 0.3 s), and 59%-89% ($P < 0.03$) with combined use of hybridized labeling (PLD = 0.3 s) and background suppression (Fig 2). The use of no PLD resulted in substantial parallel imaging (i.e. g-factor) related noise amplification that degraded vascular CNR.

CONCLUSION: The proposed background-suppressed and hybridized labeling scheme improves vascular CNR in patients undergoing carotid spin labeled MRA using parallel imaging. Furthermore, the proposed scheme automatically configures the timing and spatial selectivity of the RF pulses used for background suppression, which allows the user to freely alter the sequence TR and PLD without compromising image quality.

REFERENCES: [1] Robson et al. Radiology 2010; 257:507-515. [2] Koktzoglou et al. JMRI 2011; 34:384-394. [3] Wielpolski et al. MRM 1995; 33:432-8. [4] Mani et al. MRM 1997; 37:898-905. [5] Robson et al. MRM 2009; 61:1374-9. [6] Maleki et al. Proc ISMRM 2008 p. 1929.

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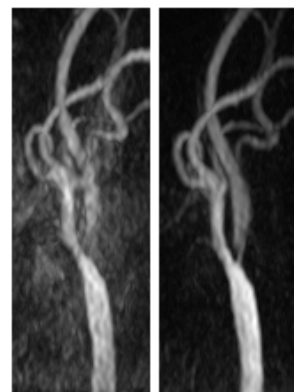


Fig. 2. Carotid angiograms obtained with pCASL (left) and hybrid ASL with BS and 0.3 s PLD (right).