# Continuous Arterial Spin Labeling with Reduced Power Deposition using Velocity Dependent Labeling Power Modulation

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## Introduction

In continuous arterial spin labeling (CASL), a long (2-3 s) labeling RF pulse is applied to invert the blood flowing into the brain. Current protocols use constant amplitude labeling RF pulses to match the average velocity over the cardiac cycle. This can lead to lower inversion efficiency during the high flow velocity periods. If the labeling RF amplitude is increased to accommodate the higher velocities, use of a constant labeling RF leads to higher RF power deposition. In addition, the inversion efficiency for lower velocities may also be compromised.

An approach to attain maximal labeling efficiency throughout the cardiac cycle with minimum RF power deposition is to modulate the labeling RF amplitude as a function of blood flow velocity. This idea has been tested using the pseudo-CASL method by modulating the labeling RF using a measured average blood velocity profile (1). Here, we evaluate this approach with real-time detection of R-waves to synchronize a higher level of labeling RF amplitude to higher blood velocity periods. For this work, CASL with a separate labeling coil placed on the neck (2) was used with a labeling plane ~3 cm below the bifurcation. Since the carotid blood flow is more pulsatile in the neck region, we hypothesized that use of velocity dependent labeling RF during each cardiac cycle will be more effective with the neck labeling coil.

## Method

All studies were conducted under an approved IRB protocol using a 3T MRI scanner (GE Healthcare). CASL perfusion MRI was performed using a separate surface labeling coil placed on the neck (2). RF power to the neck labeling coil was applied using the second transmit RF channel of the scanner modified to include a gated, low power RF amplifier and an inline power monitor. A calibrated RF modulator was placed at the output of the exciter to provide real-time control of the labeling RF amplitude. A LabVIEW software program running on a laptop PC monitored the subject ECG waveform via a data port on the scanner and generated the control voltage for the modulator using a NI-DAQ card.

CASL data were acquired using a modified single shot, 2D gradient-echo EPI sequence with following parameters: labeling duration 3s, labeling gradient 0.3G/cm along S/I direction, ~20kHz labeling RF frequency offset based on the position of the labeling coil, post-labeling delay 1.2s, acquisition of 20 axial slices in 0.8s (effective TR 5s), TE 18ms, slice thickness 3.5mm, gap 1.5mm, FOV 22.4cm, matrix 64 X 64, and an ASSET factor of 2. Fifty pairs of arterial spin labeled and control images were acquired alternatively by turning on and off RF power to the labeling coil. Images were acquired using the standard receive-only 8 channel brain coil with body coil transmission.

Perfusion data were acquired with labeling RF power levels held constant for the entire labeling duration and with variable labeling power during each cardiac cycle within the labeling duration. For constant power experiments, labeling RF power levels ~2, 1.5, 1.0 or 0.5 W were applied to labeling coil. For variable power experiments, upon detection of each R-wave, the labeling power was set to a high value (~2 W) for ~30% of the cardiac cycle and to a lower value (~ 1.5, 1.0 or 0.5 W) for the rest of R-R interval. This 30% window of the cardiac cycle was chosen because, at the selected labeling plane, the maximum carotid blood flow was found to occur within this time (Fig. 1). The R-waves were detected by thresholding the ECG waveform followed by a blanking period after each R-wave to avoid false detections due to high T-waves.

All data series from each subject were motion corrected to the 1st volume of the 1st perfusion image series using AFNI software. The average perfusion signal (ΔM%, 1-label/control) was calculated within manually drawn cortical gray matter ROIs representing the perfusion territory of the carotid artery in 2 slices above the lateral ventricles. Each subject data were normalized to the corresponding perfusion value obtained with the maximum constant power.

## Results

Figure 2 shows the perfusion data from all the subjects (n=5) obtained with constant and variable labeling RF power during the cardiac cycle. The data points corresponding to variable labeling power are plotted at the corresponding average power. Data indicate that, in some cases, variable labeling can provide higher perfusion signal compared to the signal obtained with the highest constant power. On average, variable labeling provided a signal level similar to that obtained with the highest constant power (2W) but at a lower average power (~1.5 W).

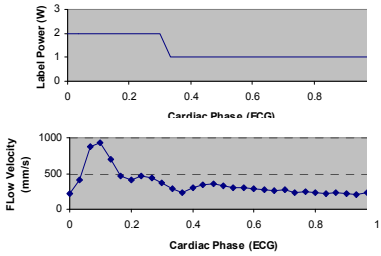


Fig. 1: Carotid artery flow profile measured at the labeling plane (bottom). Variable labeling power pattern for the case of 2 W during high flow and 1 W during low flow cardiac phases (top).

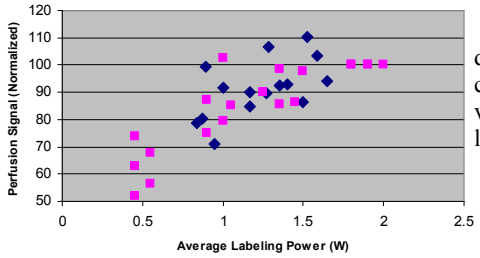


Fig. 2: CASL perfusion data acquired with constant (squares) and variable (diamonds) labeling RF power.

## Discussion

Present results indicate that real-time change in labeling RF power during the cardiac cycle may be used to reduce the power deposition from the labeling pulse without loss in perfusion sensitivity. Therefore, this method should be especially useful at 7T and higher fields. This real-time approach could also be adapted for use with pseudo-CASL. Significant scatter in the data is due to several reasons. In some subjects, real-time detection of R-waves was difficult due to elevated T-waves in the magnet and fluctuations of the R-R interval. Other contributing factors are inter-subject variation in blood flow profiles and labeling RF system instability. More reliable real-time detection of R-waves should allow the advantages of velocity dependent variable power labeling schemes to be realized in all subjects.

**References:** 1) Luh et. al, ISMRM 16: 3341 (2008). 2) Talagala et al., MRM 52:131 (2004).