Comparison of CASL perfusion signal with and without velocity dependent labeling RF power modulation

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Introduction

In continuous arterial spin labeling (CASL) perfusion MRI, the labeling RF amplitude is typically held constant for 2-3s to invert the blood flowing into the brain. Because of the variation of blood flow velocity over the cardiac cycle, use of a constant amplitude labeling RF can lead to lower overall inversion efficiency or higher power deposition. Velocity dependent labeling RF power modulation (VDLM) has been proposed as a possible method to achieve a high labeling efficiency throughout the cardiac cycle with minimum power deposition (1,2).

When using VDLM, the CASL labeling RF power is modulated either using a predetermined average blood velocity profile (1) or a step function controlled in real-time (2) to apply a higher labeling power during the high blood flow velocity period within the cardiac cycle. Previous work has shown that VDLM may be used to improve the overall tagging efficiency in pseudo-CASL (1) or to reduce power deposition in CASL when using a neck labeling coil (2). Here, we investigate if real-time controlled VDLM could be employed to increase the CASL signal when using a 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 (3). RF power to the neck labeling coil was applied using the second transmit RF channel of the scanner modified to include a calibrated RF modulator, a gated, low power RF amplifier and an inline power monitor. The RF modulator allowed real-time control of the labeling RF amplitude based on the cardiac waveform. The ECG waveform (analog) from the patient monitor (Precess, Invivo) was acquired using a laptop PC equipped with a NI-DAQ card and running custom LabVIEW software. R-waves were detected in real-time by thresholding the ECG waveform. At each R-wave, the RF modulator control voltage was modified as a step function independent of the scanner state. The timing of the labeling pulse was controlled by the pulse-sequence while the amplitude was determined by the instantaneous input voltage to the modulator.

CASL data were acquired using a modified single shot, 2D GE EPI sequence with 18 ms TE, 3.5 mm isotropic resolution, 20 axial slices, 3 s labeling duration, 0.3 G/cm labeling gradient (S/I), ~20 KHz labeling RF frequency offset (based on the position of the labeling coil), 1.2 s post-labeling delay and 5 s effective TR. Twenty five 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.

CASL data without VDLM were acquired with 2W RF power applied to the labeling coil. This power level typically produced the maximum perfusion signal when using constant amplitude labeling. For experiments with VDLM, upon detection of each R-wave, the labeling power was set to a higher value for ~25% of the cardiac cycle and then to a lower value for the rest of R-R interval. VDLM data were acquired with 3.5/1.5, 5.0/1.0, and 6.5/0.5W high/low power combinations. The average labeling power was the same for all acquisitions. The 25% window of the cardiac cycle was chosen because, at the selected labeling plane, the peak carotid blood flow was found to occur within this time (Fig. 1).

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 corrected for slice dependent post labeling delay) over 8 slices was calculated using a gray matter mask. Each subject VDLM data were normalized to the corresponding perfusion value obtained without VDLM.

Results

Figure 2 shows the perfusion images acquired with VDLM using a 3.5/1.5 W modulation. The average perfusion signal with 3.5/1.5 W VDLM was found to be slightly higher (4.6 ± 3.3%, n = 5, p = 0.047) compared to data acquired without VDLM (constant 2 W). However, VDLM data acquired with 5.0/1.0, and 6.5/0.5 W combinations were 8.8 ± 6.5% (p = 0.055) and 11.2 ± 5.1% (p = 0.012) lower compared to data without VDLM, respectively. These results indicate that 2 W of power already provides good labeling efficiency for high velocities. 5.0/1.0, and 6.5/0.5 W VDLMs produce lower signal due to reduction in labeling efficiency for lower velocities.

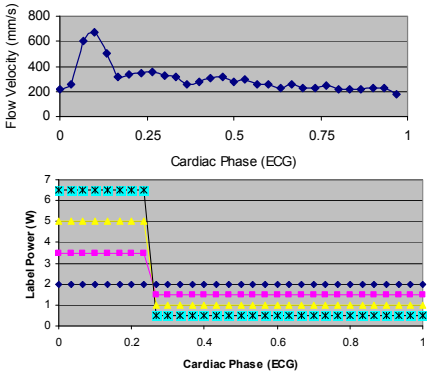

Fig. 1: Carotid artery flow profile measured at the labeling plane (top). Labeling power modulations with and without VDLM used in this study (bottom).

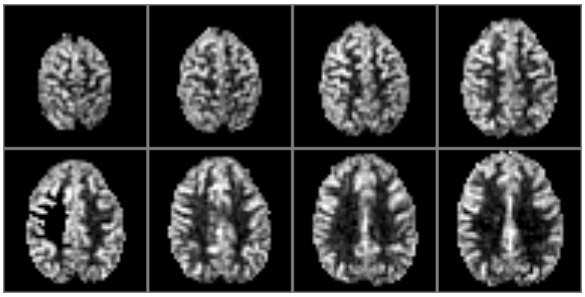

Fig. 2: Representative CASL data (8 slices used for analysis) acquired with VDLM 3.5/1.5 W.

Discussion

In this study, effect of VDLM was compared to the constant labeling power level that typically affords the highest perfusion signal. Current data indicate that the perfusion signal is dependent on the particular VDLM employed. When using the same average power, 3.5/1.5W VDLM was found to yield slightly higher perfusion signal compared to constant labeling. Further studies are needed to optimize VDLM in terms of perfusion signal. However, since VDLM may be used to reduce the power deposition from the labeling pulse without loss in perfusion sensitivity, it should prove useful for CASL perfusion MRI studies at higher field strengths.

References: 1) Luh et. al, ISMRM 16: 3341 (2008). 2) Talagala et al., ISMRM 18: 1741 (2010). 3) Talagala et al., MRM 52:131 (2004).