Spatially Selective PCASL with Parallel Excitation

D. Yoon[1], H. Jahanian[2], D. C. Noll[2], and L. Hernandez-Garcia[2]
[1]Electrical Engineering, University of Michigan, Ann Arbor, MI, United States, [2]Biomedical Engineering, University of Michigan, Ann Arbor, MI, United States

Introduction

We present a new spatially selective pseudo-CASL(PCASL) method with parallel excitation to perform vessel selective arterial spin labeling(ASL). Vessel-selective ASL can provide very useful clinical information such as perfusion territory map of a single artery, and recently several non-invasive methods [1-2] have been proposed to avoid potential risks of conventional invasive techniques. In one case [1-2], multiple images with different labeling patterns are acquired and combined to isolate contribution of one vessel from others. This makes the methods potentially vulnerable to motion induced artifacts. Recently, Helle [3] introduced a method that directly tags only the desired vessel, but its spatial selectivity is relatively limited. We propose a novel PCASL scheme with parallel excitation that makes use of multiple RF transmission to tag only vessels of chosen locations. In our method, the superposition of RF pulses from each coil forms a train of tagging pulses only at locations of vessels to be tagged. Our new technique provides high inversion efficiency and superior spatial selectivity without any trade-off of temporal resolution, making it suitable for vessel selective ASL.

Theory

Our proposed parallel excitation method adopts an RF phase correction scheme presented in [4] which compensates for off-resonance during tagging sequence. The RF pulse optimization procedure is summarized in the box on the right. The goal of the optimization is to compute the pulses for each coil such that the final pulse applied on the selected vessel forms a tagging pulse train while other vessels experience no tagging RF pulse. To achieve such spatial selectivity, we exploit the fact that the net RF pulse observed at a certain location is the superposition of RF pulses modulated by the sensitivity of the associated transmission coil. For each coil, we transmit a train of Hanning pulses weighted by a complex scalar, and we optimize the scalar weight for each coil to have desired constructive or destructive summation of RF pulses. Note that we can exploit the regions where we do not care about their excitation result. For example, those regions occupied with static tissues can be ignored in the optimization to relax the problem constraints. For the control pulses, we use the same weights, but we alternate their signs such that no inversion occurs, but the same amount of magnetization transfer (MT) is introduced.

Experiments and Results

Transmission sensitivity maps were acquired by exciting a uniform ball phantom with individual transmission coils. The magnitude and the phase of B1 field map for each coil is shown in Figure 1 over a 24cm x 24cm FOV. The vessel selectivity of our method was tested with simulation where four vessels each occupying a single voxel (3.75mm x 3.75mm) are placed as shown in Figure 2. We attempted to tag the lower right vessel while other three vessels are left untagged. Other areas excluding these 4 vessels are set to be “don’t care” regions. 500usec Hanning pulse was used as the unit pulse (h(t)) and neighboring Hanning pulses were 1500usec apart. The blood flow velocity is assumed to be 30cm/sec. Figure 3 presents the average longitudinal magnetization of spins in the vessels as they pass the tagging plane for both tagging and control sequences. We see that desired vessel selective tagging was achieved for the tagging sequence while effectively suppressing inversion for the control sequence. As a benchmark, it was reported in [3] that the region 4mm away from the desired vessel had still the inversion efficiency of 30%. This implies that it was not able to successfully separate vessels so closely distributed. But with our method, we observed almost no perturbation of Mz in the same region, showing potentially much higher selectivity. Note that the RF power requirements increase as we try to separate more closely placed vessels.

Conclusion

We presented the theoretical foundation and simulations in support of a novel approach using parallel excitation to perform spatially selective spin labeling. We demonstrated that our method can provide highly selective spin labeling without acquiring multiple images to compute individual vessel’s contribution, making it more efficient and robust. Also, our approach can be easily extended to tag multiple vessels simultaneously.

References & Acknowledgement

[1]Wong, *Mag. Res. Med.*,58(6):1086-1091,Dec.2007 [2]Okell, *Mag. Res. Med.*,64(3):698-706,Sep.2010. [3]Helle, *Mag. Res. Med.*,64(3):777-786,Sep.2010 [4]Jahanian, ISMRM, 2010, 519. This work is supported by NIH grant R01NS058576

Problem Setup

PCASL consists of a train of unit RF pulses, and we extend the method with multiple coil transmission. The n-th unit pulse transmitted from the r-th coil is as follows.

$$b_r^n(x,y,t) = w_r s_r(x,y) h(t) e^{in\theta}$$

$b^n_r(x,y,t)$	the n-th RF pulse transmitted from the r-th coil observed at (x,y)
w_r	weight for the RF pulse transmitted from the r-th coil.
$s_r(x,y)$	sensitivity of the r-th transmission coil at (x,y)
h(t)	unit RF pulse in the pulse train. Hanning pulse is used as in [4].
$e^{in\theta}$	phase of the n-th unit RF pulse where θ is a function of blood flow velocity and B0 field inhomogeneity as in [4]

The net RF pulse observed at (x,y) is superposition of all pulses across coils as follows

$$b_{net}^n(x,y,t) = \sum_{r=1}^{R} w_r s_r(x,y) h(t) e^{in\theta} = h(t) e^{in\theta} \sum_{r=1}^{R} w_r s_r(x,y)$$

R : the number of RF transmission coils

Objective

Determine a set of w_r s to satisfy

$$\sum_{r=1}^{R} w_r s_r(x,y) = \begin{cases} 1 & \text{for } (x,y) \in \text{the locations of vessels to be tagged} \\ 0 & \text{for } (x,y) \in \text{the locations of vessels not to be taged} \\ \text{don't care} & \text{for all other } (x,y) \end{cases}$$

Optimization

Determine w_r s with a least square method with above constraints.

Figure 1. magnitude(top) and phase(bottom) of 8 transmission coil sensitivities

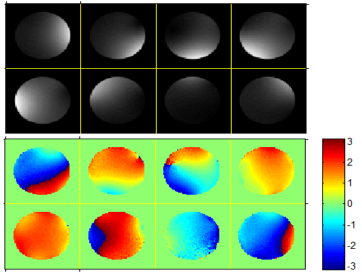

Figure 2. locations of vessels

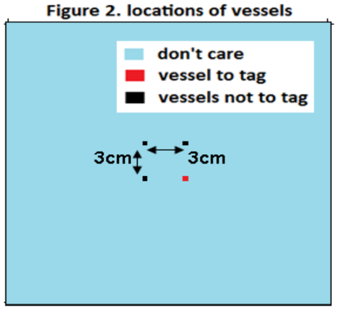

Figure 3. Mz change as spins pass the tagging plane