Single artery selective labeling using pseudo-continuous labeling

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Introduction: Pseudo-continuous arterial spin labeling (ASL) (1) can achieve high continuous labeling efficiency and can be modified to encode source vessel position. Previous vessel encoding strategies with pseudo-continuous labeling require knowledge of all vessel positions and encode all vessels using Hadamard type encoding (2). In many applications, specification of many vessels is undesirable and selective labeling of an individual vessel is a better analogy to single vessel catheter injection. Here we propose a modification of pseudo-continuous ASL that allows for single artery selective labeling. This method potentially labels a disc around the targeted vessel (Figure 1). Therefore it does not require the position of other vessels as an input.

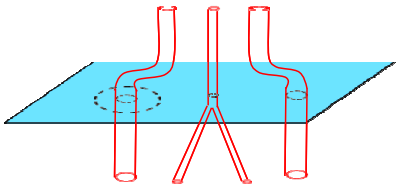

Figure 1. The geometry of single artery selective labeling. Only a disc within the pseudo-continuous labeling plane surrounding the targeted vessel is labeled.

Methods: The pulse sequence of single artery selective labeling is shown in Figure 2. To achieve artery selective labeling, in-plane gradients are applied between the rf pulses. The fully refocused control approach (1) was found unsuitable for selective labeling because it always produced less labeling than the label. Instead, the same gradients as the label were used but the RF pulses were alternated in sign (2). Single vessel selectivity is achieved by rotating the direction of the in-plane gradients by analogy to adding the gradients in amplitude modulated control to achieve single artery selective imaging (3). The center of the selective disc is determined by the phases of the RF pulses. Each RF pulse must be incremented in phase by the integral of the gradients over the previous repetition, times the distance from isocenter and the gyromagnetic ratio.

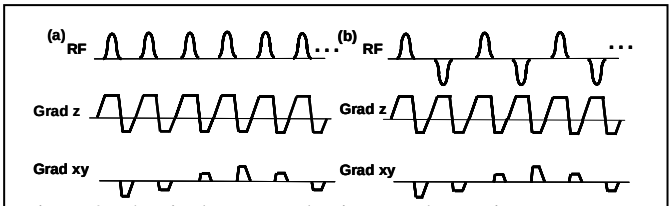

Figure 2. The single artery selective pseudo-continuous sequence. (a) label and (b) control RF and gradient waveforms.

Numerical simulation of the Bloch equations was used to explore the inversion efficiency for vessels as a function of distance from the targeted vessel. Simulation parameters were: 500 µs Hanning window shaped RF pulse, 1500 µs spacing, with amplitudes 0.017G; maximum z gradient amplitude of 0.9 G/cm, with average z gradient 0.05 G/cm; Blood relaxation times T1 and T2 of 1.55 s (4) and 0.25 s (5). a range of fixed average xy gradient strengths (0.03-0.10 G/cm), and rotation rates (10^0-90^0 increment between TRs). Due to unsatisfactory results with fixed amplitude of xy gradient, amplitude modulation (AM) (modulated by a triangle function with minimum value 0.5 and maximum value 1.5, with period of 192 TRs) was also investigated.

In vivo scanning parameters were: GE 3T scanner; the same RF pulse and z gradients as the simulation; average xy gradient strength 0.03 G/cm and 15^0 increment between TRs; labeling duration of 1.5 s and post labeling delay of 1.5 s; a TR of 6 s and a TE of 25 ms in a 5-mm-thick axial slice with 24-cm FOV; background-suppressed FSE image acquisition.

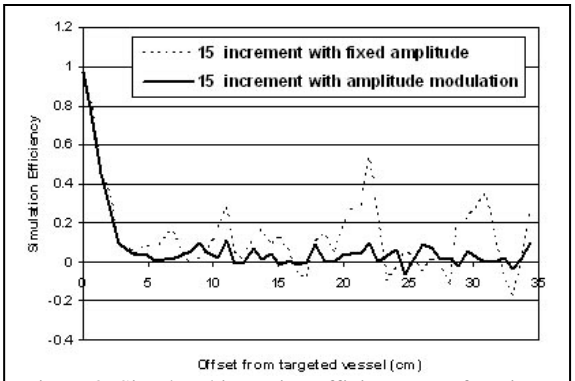

Figure 3. Simulated inversion efficiency as a function of offset from targeted vessels. G[xy] rotates in 15^0 increments. The RF amplitude is either fixed (dashed line) amplitude or slowly modulated in amplitude (AM) between TRs. An average xy gradient of 0.03 G/cm was used.

Results: Simulations of the rotating gradient strategy showed good efficiency but poor suppression of labeling at large distances (figure 3). Addition of amplitude modulation appeared to spoil the coherent "ringing" at large distances and resulted in good suppression of distant vessels. In-vivo results demonstrated highly selective labeling of individual vessels (figure 4). The perfusion signal as a function of distance between the center of the labeling disc and the carotid artery showed a desirable rapid falloff, figure 5, in agreement with simulation results.

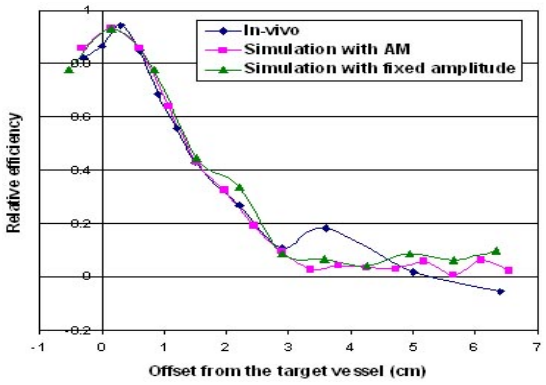

Figure 5. Comparison of in-vivo inversion efficiency with both amplitude modulated and fixed RF amplitude simulations.

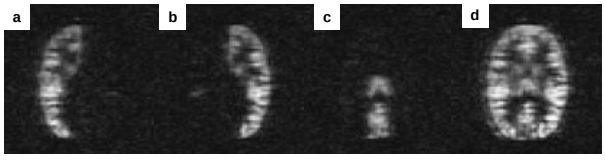

Figure 4. Artery selective imaging of (a) right carotid artery, (b) left carotid artery, (c) basilar artery, compared with (d) nonselective labeling.

Reference: 1. Garcia et al, ISMRM 2005, p. 37. **2**. Wong, ISMRM 2006, p. 668. **3**. Werner et al, Magn Reson Med 2005:53(5):1006-12. **4.** Lu et al, Magn Reson Med 2004;52(3):679-82. **5.** Wright et al, J Magn Reson Imaging 1991; 1(3):275-83.