# A Systematic Approach to Optimizing Background Suppression for Arterial Spin Labeling Perfusion Imaging

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**Introduction:** Arterial spin labeling (ASL) offers a means for investigating tissue perfusion in numerous functional and pathological states non-invasively. Background suppression using multiple inversion pulses to further improve ASL sensitivity in the presence of physiologic noise can be effectively employed in pulsed [1] and continuous [2] ASL sequences. Some work optimizing the timing of background suppression pulses has been reported for short delay, angiographic sequences [3]. However, no systematic approach to optimizing background suppression for perfusion has been reported. In this study we describe an algorithm to optimize the timing of background suppression pulses to decrease the background static signal for a broad range of T1s.

**Methods:** The background suppression timing was optimized by casting it as a nonlinear optimization problem with bounds on the pulse timings. The squared residual background signal summed across a target range of T1's, with optional weights, was minimized with a proprietary iterative minimization technique available within IDL (ITT Visual Information Solutions). The optimization of background suppression timing was investigated in both PASL and CASL. Inefficiency of the inversion pulses was also modeled based on the experimentally measured data [4]. Studies were performed on a 3.0 Tesla GE HD MR system with an 8-channel phased array head coil on 5 healthy subjects and on a phantom consisting of an array of tubes containing MnCl-doped deionized water in various concentrations for validation. The optimal background suppression scheme determined by simulation was added to the pseudo-continuous [5] sequence and axial brain images at the level of the optic nerve were acquired using a 2D half Fourier single shot fast spin echo SSFSE sequence with the following parameters: FOV=24cm, Matrix=96x96, TR=7s, TE=36.5msec (min TE), Band width=20.83 kHz, and slice thickness=10mm. The labeling slab was also in the axial plane, approximately 5cm below the slice. Image pairs (label & control) were acquired at delays of 0.5, 0.75, 1, 1.25, 1.5, and 2.5 seconds. The pairs were repeated 20 times in subjects and 2 times in phantom to improve SNR.

**Results:** Greater than 100 fold decreases in background signal intensity was achieved such that the ASL signal change exceeded the residual signal from static tissue (fig 1). In general, the background suppression performance improved with the number of inversion pulses employed but with minimal benefits beyond 5-7 pulses. Imaging results for one subject are shown (fig 2). Similar trends in the level of background intensity against T1 were seen in simulated and phantom results both qualitatively and quantitatively (fig 3). Background suppression facilitated imaging of retinal perfusion in the presence of eye motion and a large background signal intensity gradient. These results confirmed the validity of the optimization resulting from our simulations. Also, simulation results showed that the optimal number of pulses in pulsed ASL is generally smaller than for continuous ASL and benefits beyond 4 pulses are limited. The residual static signal intensity vs. T1 for FAIR with different number of optimally timed inversion pulses is plotted in figure 4.

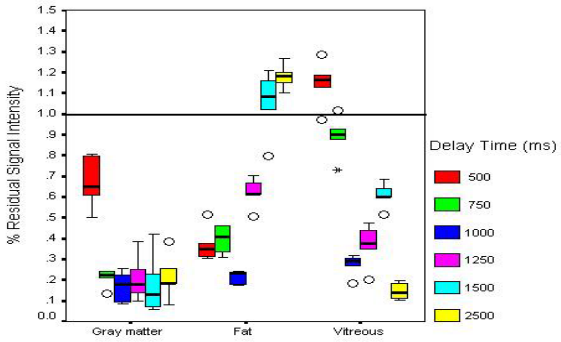


**Figure.1.** % of the static background signal remaining following background suppression

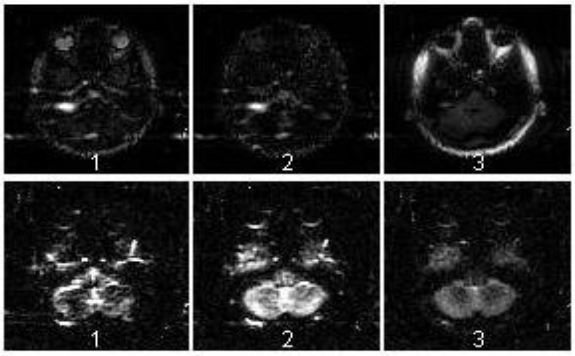


**Figure.2.** Background suppressed and corresponding perfusion images at 0.75s (1), 1.25s (2), and 2.5s (3).

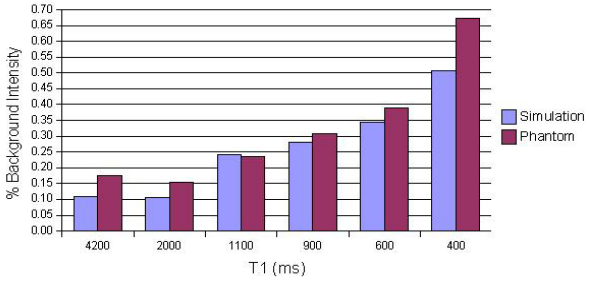


**Figure.3.** Background intensity MnCl-doped phantoms vs. simulation results at post labeling delay of 1s.

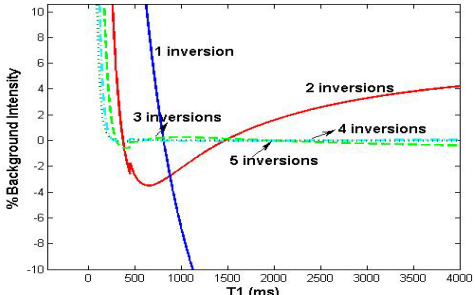


**Figure.4.** Residual static signal intensity vs. T1 relaxation time for optimized FAIR sequences with different number of inversion pulses.

**Conclusion:** Up to 100 fold decreases in background signal intensity across a broad range of T1's is achievable using optimally timed multiple inversion pulses for a broad range of T1s. Our results were validated both in vivo and in phantoms.

***References:*** *[1]MRM 2000; 44:92-100. [2]ISMRM 1999, p601. [3]MRM 1997;37:898-905. [4]MRM 2005; 54:366–372. [5]ISMRM 2005, p.37.*