Transient Effects in Continuous Arterial Spin Labeling (CASL) with Slice Order RoTation (SORT)

V. Lakkavaram[1], W. Dai[2], H. M. Gach[3]

[1]Bioengineering, University of Pittsburgh, Pittsburgh, PA, United States, [2]Computer Science, University of Pittsburgh, Pittsburgh, PA, United States, [3]Radiology and Bioengineering, University of Pittsburgh, Pittsburgh, PA, United States

Introduction: Multi-slice CASL typically uses fixed slice ordering and the endogenous tracer is sampled after a transit delay and the acquisition time associated with each slice (Fig. 1). *S*lice-*O*rder *R*o*T*ation (*SORT*) was developed to dynamically vary the slice acquisition order to: 1) expand the number of slices that can be measured during an acquisition, and 2) characterize the change in the perfusion signal during the transit and acquisition delays[1]. Yet, dynamic acquisition ordering creates significant transient effects, particularly for the first repetition of each rotation. A model of the *SORT* magnetization was developed to correct for transient effects and fit the non-perfusion related variables.

Materials and Methods: All experiments were conducted on a 1.5T GE whole-body MRI (LX91, Milwaukee, WI). Using a 2% Agar phantom (T_1=1.3 s), low resolution images were acquired with *A*lternating *S*ingle and *D*ouble adiabatic inversions (ASD)[2] (3.7 s label or control duration at 92% duty cycle and 0.7 s transit delay) and spiral acquisitions (Matrix: 64x64; TR_{acq}: 2000 ms; TE: Min (8 ms); Thickness/Spacing: 5/0 mm; # of Slices: 19; FOV: 20 cm, FA: 90^0). Twenty-five pairs of control and label images were acquired and averaged for each set of *SORT* parameters (e.g., transit delays and rotation groups). The signal intensity was calculated over a region of interest (ROI) for each slice. Simulations of magnetization in free and bound compartments were conducted in Mathematica while data was fitted using Matlab models (Fig. 2).

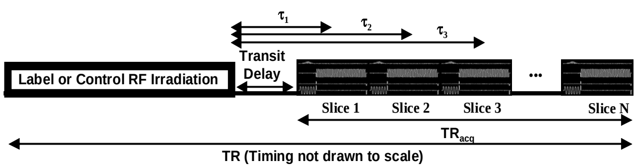

Figure 1: Multi-slice CASL sequence. Bound water is saturated during the label or control RF irradiation (in single-coil CASL) and relaxes between saturation and acquisition and between selective acquisition and re-saturation during the next off-resonance irradiation. The degree of relaxation during each interval is changed during dynamic acquisition ordering.

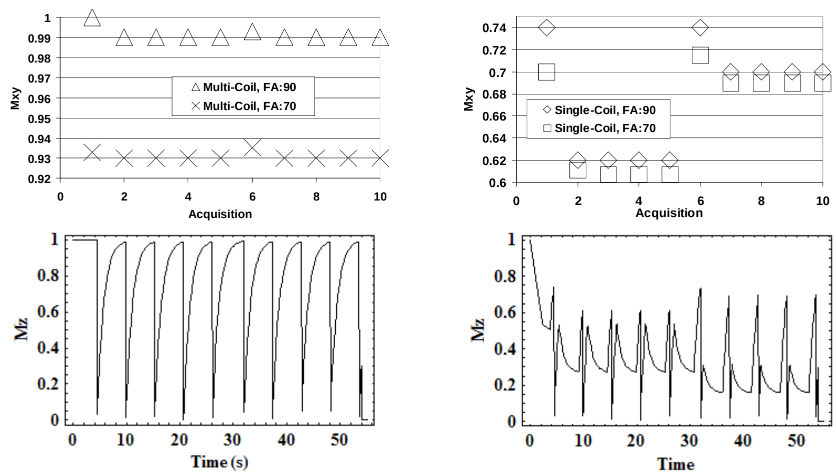

Figure 2: Simulations of *SORT* transient magnetization effects without (left) and with (right) off-resonance RF saturation. *SORT* used 2 rotations and 5 repetitions/rotation for 1st and 10th slice of 19 slice acquisition. The top row shows the transverse magnetization (M_{xy}) brought down for imaging with 90^0 and 70^0 flip angles. The bottom row shows the longitudinal magnetization (M_z) during the experiment (neglecting deadtimes), w: 0.7 s, TR_{acq}: 1 s, τ: 3.7 s, T_{1s}: 0.9 s, T_{1ns}: 1.2 s. Excitation crosstalk effects are not included. As with regular CASL, M_{xy} for (at least) the 1st acquisition of each rotation is significantly higher.

Results and Discussion: The model of transient magnetization with and without off-resonance saturation depends on B_1 (flip angle), T_1, and T_{1sat}, *r* (the ratio of bound and free water), M_0, and M_{ss} (steady-state magnetization after off-resonance saturation) (Fig. 3). Since B_1 (flip angle), M_0, T_1, and T_{1sat} are typically measured in each subject, the model can be simplified to a two-parameter fit (M_{ss} and *r*). Future work will involve the development of a calibration pre-scan to: 1) measure and decouple transient and image excitation cross-talk effects and 2) calculate and apply variable image excitation flip angles to minimize transient effects.

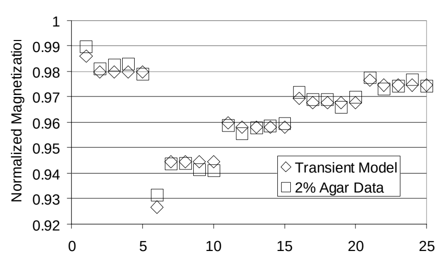

Figure 3: Transient effects in 2% Agar. The label magnetization measured in an ROI in a 2% agar phantom shows good agreement with our transient model. The data was measured from the 19th slice (original order) of a 19 slice acquisition. A total of 50 repetitions and 5 rotations were used. The model used B_1 (flip angle), M_0, T_1, and T_{1sat} values that were measured from B_1 and T_1 map sequences.

References:
1. HM Gach. 11th ISMRM, Toronto, 2003, p. 2209. 2. DC Alsop , JA Detre. Radiology 208: 410-416 (1998).