

Background Suppression with Simultaneous Chemical Shift Artifact Reduction In Arterial Spin Labeling

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ABSTRACT

Purpose: Chemical shift artifacts from fat in echo planar sequences are difficult to suppress in arterial spin labeling (ASL) imaging without negatively impacting the label signal. The goal of this work is to suppress these artifacts by creating an angular dependency on the complex-value fat, brain, and ASL signals that allows for suppression of fat signals. To accomplish this, we created a custom pseudo-continuous ASL (pCASL) sequence using two different background suppression (BS) timings in one human subject.

Methods: Images were collected from one healthy volunteer on a 3T MR scanner (Cima.X, Siemens, Erlangen, Germany) using a 64-channel receive-only head-coil. A pCASL sequence was created using Pulseseq in MATLAB. Two conditions, A (0.369s, 1.047s, 2.204s, and 2.767s) and B (0.510s, 1.577s, 2.203s, and 2.845s) were created through different BS timings and ten label control pairs were collected for each condition. Complex-value label and control images were averaged independently for each condition, with one condition scaled prior to subtraction across conditions. Resulting complex-value label-control pairs were then pair-wise subtracted to yield perfusion images.

Results: The combination of the conditions, A and B, after scaling allowed for fat tissue suppression while retaining the ASL signal when performing complex-value processing prior to magnitude reconstruction. Standard magnitude subtraction or complex-value processing without image scaling retained chemical-shift artifacts in the label and control images.

Conclusion: We demonstrated that chemical shift artifacts from fat-shifted signals can be suppressed without substantially impacting the ASL signal by varying the BS timings between acquisitions and performing complex-value processing and scaling prior to pair-wise subtraction.

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INTRODUCTION

Arterial spin labeling (ASL) noninvasively measures tissue perfusion using magnetically labeled arterial blood water. Because the perfusion-weighted difference signal is approximately 1% of the background tissue signal, repeated label/control acquisitions and background suppression (BS) are commonly used to improve temporal stability [1]. However, residual nuisance signals may persist after BS and subtraction.

A recent clinical pCASL study reported spatially displaced scalp-fat signal along the phase-encoding direction that remained visible in perfusion-weighted images after subtraction [2]. We tested whether complementary BS timings could produce opposite signs of residual fat magnetization between conditions, to suppress the fat signal while preserving the ASL contrast. Furthermore, CSF was evaluated as an additional nuisance tissue because residual CSF signal may contribute to pulsation-related artifacts [3].

METHODS AND MATERIALS

Acquisition

One healthy volunteer was scanned with IRB approval on a 3T MAGNETOM Cima.X scanner using a 64-channel receive head coil. A custom pCASL sequence (Figure 1) was implemented in Pulseseq [4]. The acquisition parameters are listed in Table 1.

Acquisition Parameter	Setting
Readout	2D GRE-EPI
Coverage	5 slices
Slice Thickness / Gap	6/1.2 mm
Matrix / FOV	64x64 / 240x240 mm ²
TE / TR	22.7 ms / 5 s
Label Duration (LD)	1.8 s
Post Labeling Delay (PLD)	1.8 s
Repetitions	20 (10 label/control pairs)

Table 1: This table lists the ASL parameters for generating the perfusion contrast, as well as the readout parameters used for imaging.

Background-suppression conditions

Three pCASL acquisitions were acquired with different BS timing conditions:

- Reference:** no BS or pre-modulation pulses
- Condition A:** 1.399 s, 2.035 s, 2.642 s, and 3.243 s
- Condition B:** 0.735 s, 2.255 s, 2.802 s, and 3.389 s

Timings were estimated using Bloch simulations and then refined empirically [5]. Ascending order acquisition was used, with timings reported for the second slice.

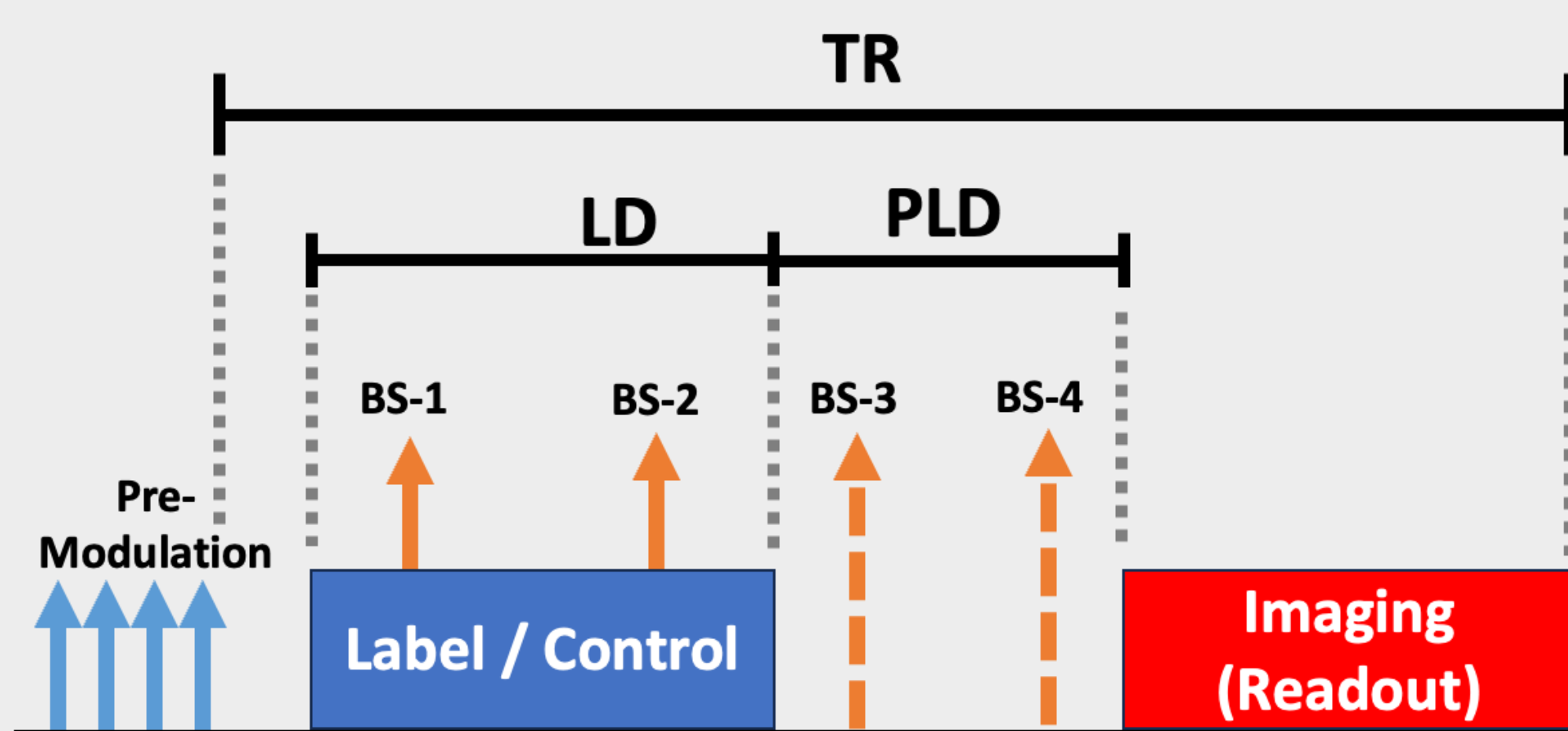


Figure 1: Pulse sequence diagram for the generic ASL conditions.

Data Processing & Analysis

Conditions A and B were reconstructed using a common coil-sensitivity profile derived from the reference acquisition to preserve relative phase.

An equal number of control/label pairs from A and B were complex-averaged to form a matched-duration composite acquisition.

Suppression relative to the no-BS reference was measured in gray matter (GM), white matter (WM), CSF, and fat ROIs.

Signed perfusion-weighted images were generated by phase alignment to the mean reference control image followed by pairwise label/control subtraction.

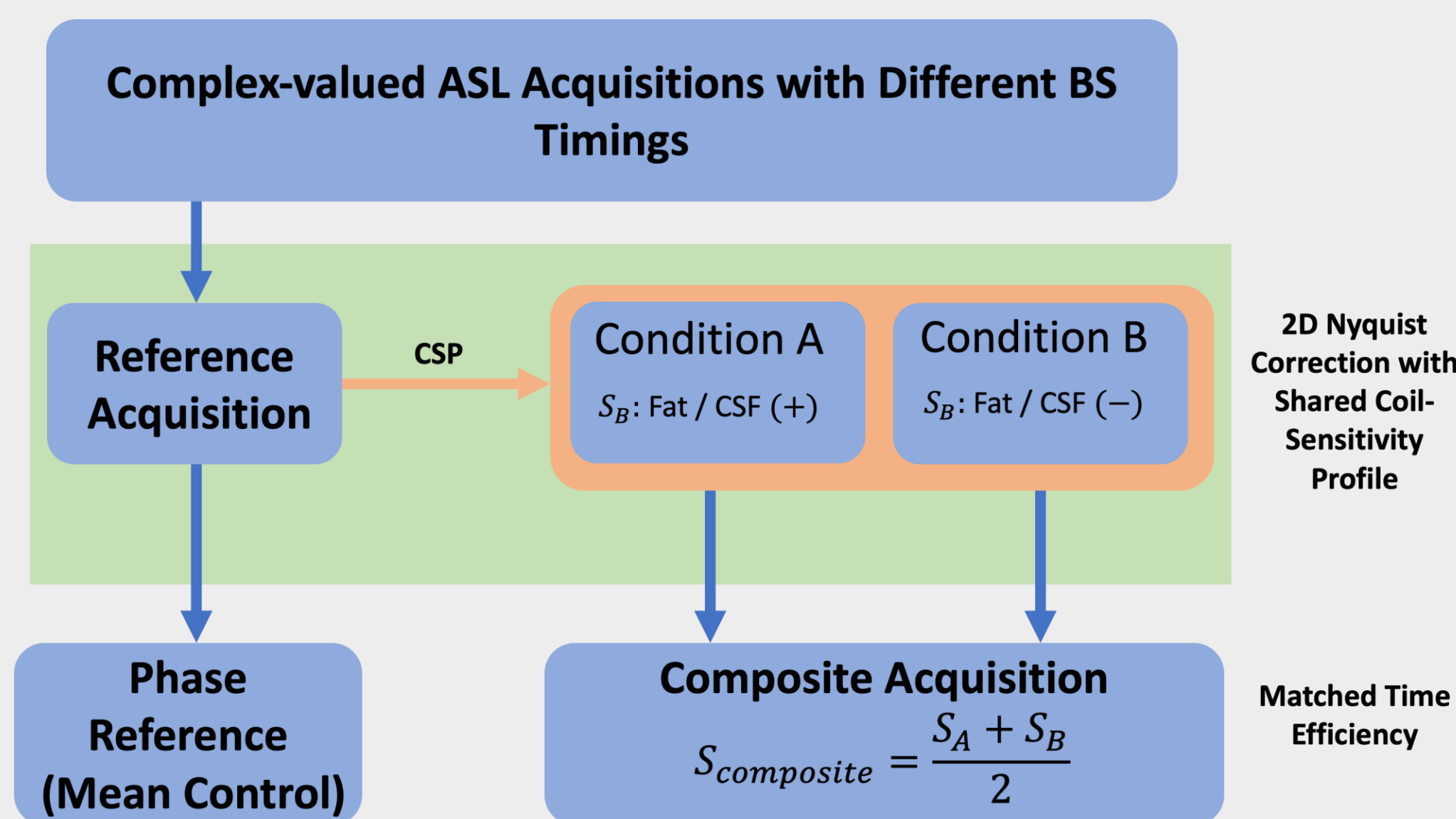


Figure 2: Reconstruction and combination of conditions A and B using only the first half of the pairs in A and B to match the time efficiency.

RESULTS

Enhanced Fat and CSF Suppression

Complex averaging increased fat and CSF suppression to greater than 95%, while GM and WM suppression remained greater than 90%. Although all tissues showed substantial phase differences between A and B, fat and CSF had more closely matched residual magnitudes and therefore underwent greater destructive interference (Table 2). Perfusion-weighted contrast remained visually similar across acquisitions.

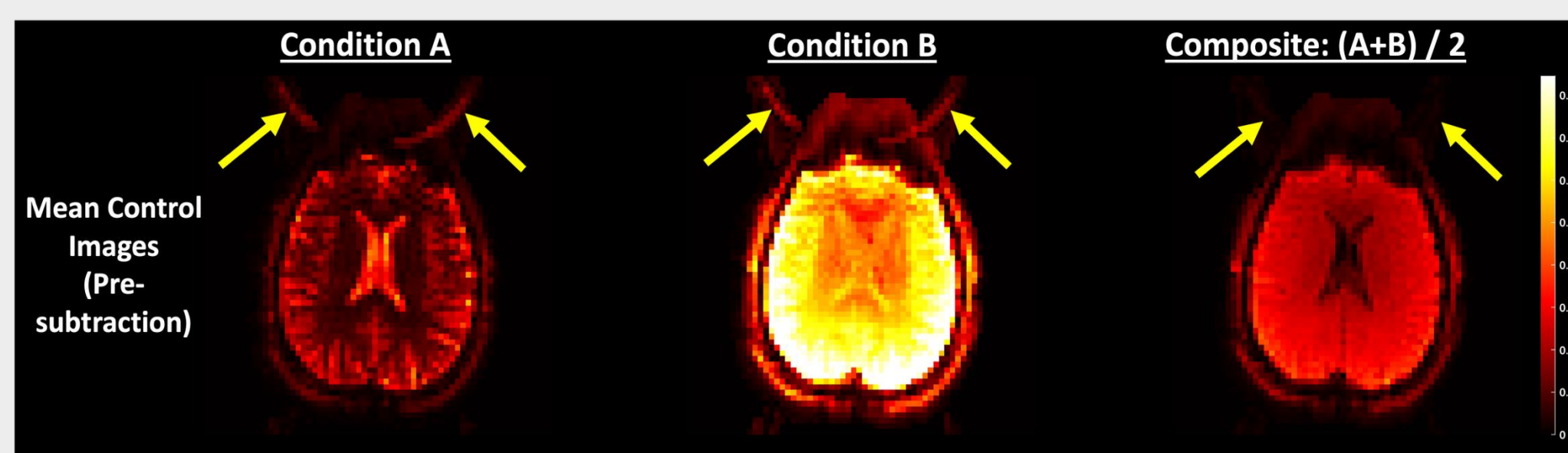


Figure 3: Averaged controls of the pre-subtraction images are displayed using a common scale. Yellow arrows identify spatially displaced fat signal, which is visibly reduced in the composite acquisition.

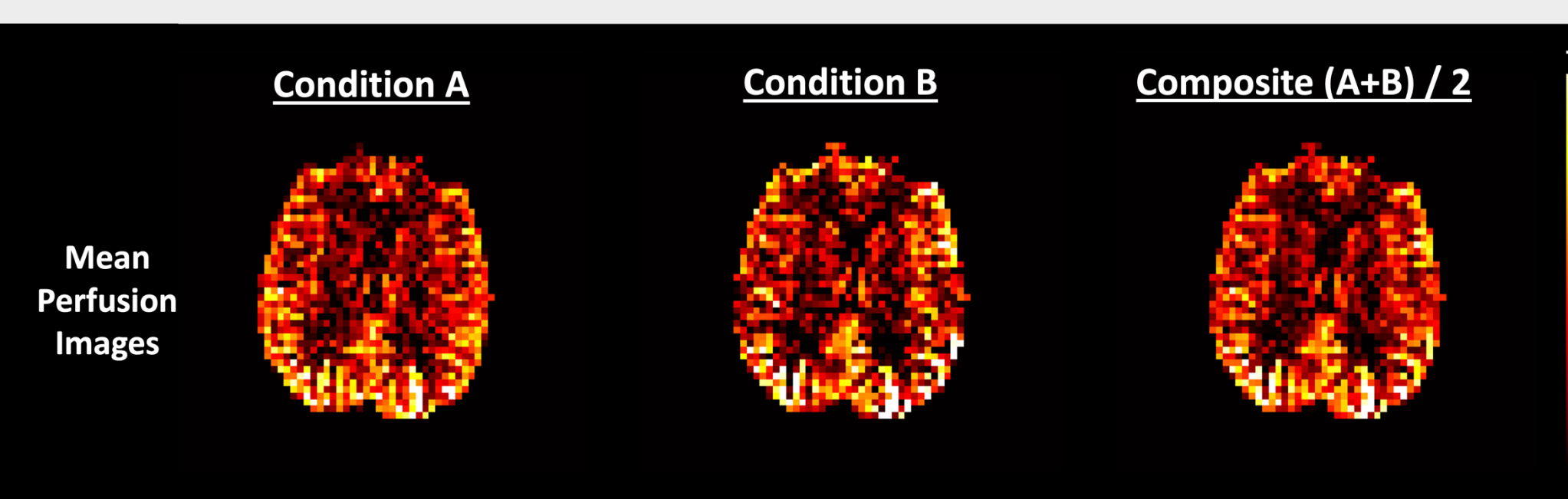


Figure 4: Mean perfusion images for each condition are displayed at the same scale for condition A, B, and the composite acquisition. Perfusion was visually preserved across the conditions

Tissue	A Suppression (%)	B Suppression (%)	Composite Suppression (%)	Avg. Relative Phase (°)
GM	95.16	78.45	91.61	177
WM	96.58	78.30	90.79	171
CSF	89.75	80.35	95.06	175
Fat	81.56	75.80	96.27	138

Table 2: Background suppression relative to the reference acquisition without BS pulses was calculated for multiple tissue ROIs. The background suppression combined with the destructive complex-signal interference enhances the suppression for fat and CSF. However, effective cancellation requires both opposite polarity and similar magnitude.

DISCUSSION

Complementary BS timings controlled the sign and amplitude of residual tissue magnetization before complex averaging. Although GM and WM were also largely out of phase between conditions A and B, their unequal residual magnitudes limited cancellation. Fat and CSF were more closely matched and therefore showed the greatest additional suppression, while perfusion-weighted contrast remained visually similar. Thus, cancellation depends on both phase opposition and residual-signal matching

The CSF finding does not directly demonstrate reduced pulsation, but it may be relevant to Hu et al., who showed that CSF-targeted BS reduced pulsation-related artifacts and improved CBF-map reproducibility [3]. Fat signal was also reduced without a dedicated fat-suppression pulse.

Because imperfect inversion pulses can attenuate ASL signal [6], future work should optimize a two-pulse implementation, compare the method with conventional fat suppression, quantify perfusion preservation, and validate the approach in 3D acquisitions and additional participants.

CONCLUSIONS

Complementary BS timings reduced residual fat and CSF signals through complex-domain cancellation without a dedicated fat-suppression pulse, while visually preserving perfusion contrast in a single-subject proof of concept.

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