# Physiological modulations in arterial spin labeling

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## Introduction

Physiological fluctuations have been shown to confound arterial spin labeling (ASL) signals (1,2). While respiration generates a thoracic modulation of the magnetic field in the head, cardiac pulsation affects the amount of blood that is tagged and delivered to the imaging region. However, it remains unclear if continuous (CASL) and instantaneous (PASL) tagging schemes are subject to these effects in different manners. On the other hand, background suppression (BGS) has proven effective in stabilizing ASL signals (3) but its effect on physiological noise has not been addressed. This study examines these issues experimentally.

## Materials and Methods

Four healthy volunteers (2 women, 2 men, age range = 24-30 years) were scanned after informed consent was obtained. All experiments were conducted on a 3T Siemens Trio system. Nine 5mm-thick axial slices were prescribed with the center slice at the level of corpus callosum (FOV = 220 mm, in-plane matrix size = 64x64, inter-slice gap = 1 mm). PASL images were acquired using FAIR (4) (TR/TE/TI = 4000/17/1700 ms, body coil transmission and head coil reception) with and without BGS (two non-selective inversion pulses at 1600 and 500 ms prior to data acquisition, respectively) in two separate experiments. QUIPSS II (5) was used to generate a tag bolus of 700 ms. CASL images were acquired with an amplitude-modulated method (6) (TR/TE = 4000/17 ms, post-labeling delay = 1000 ms, labeling duration = 2000 ms, transmit/receive head coil). All data were acquired with gradient echo EPI. Cardiac and respiratory signals were recorded using the scanner's built-in photoplethysmograph and a respiratory belt. Cardiac phase was calculated assuming it linearly advanced from 0 to $2\pi$ between two adjacent peak pulse signals (7), whereas a histogram-equalized transfer function between respiratory amplitude and phases was applied (8). Tag and control signals were separately fitted (1) to a second-order Fourier series to extract physiological components.

## Results and Discussion

Fig 1 shows the spatial distribution of cardiac and respiratory noise (denoted by $N_C$ and $N_R$, respectively) in a representative subject. In agreement with previous studies, $N_C$ is mostly localized to the regions neighboring vessels whereas $N_R$ affects signals more globally. $N_C$ is markedly higher in PASL as compared to CASL. This is because PASL tags spins using a short pulse that hits arterial blood at different cardiac phases from TR to TR (unless the TR is in step with the cardiac cycle). By contrast, CASL applies a long duration of tagging (usually longer than an R-R interval) and therefore generates signals less sensitive to cardiac pulsation. By inspecting the signal-phase curves in a region of interest (Fig 2), cardiac modulation can be easily recognized as grater in PASL than in CASL. Signal variation (computed as std/mean) as a result of $N_C$ is 1.6% and 0.6% in PASL and CASL, respectively. By contrast, $N_R$ imposes a similar effect on both tagging schemes. On the other hand, BGS suppresses both periodic ($N_C$ and $N_R$) and non-periodic noise by globally attenuating signals from parenchyma, thereby improving the signal-to-noise ratio of ASL. In PASL, the temporal standard deviation of $dM/M_0$ (from the ROI shown in Fig 1) is 0.24% before correction, 0.15% and 0.20% after corrections of $N_C$ and $N_R$, respectively, and 0.14% after BGS. In conclusion, physiological modulations affect PASL and CASL differently and can be effectively removed by retrospective correction and BGS. One concern regarding BGS, however, is that it results in ~20% underestimation of flow. The reason for this discrepancy is still under investigation (9). Correction for physiological noise is not critical for measurement of baseline flow but can be crucial in functional MR studies in regions near arteries or susceptible to thoracic motions.

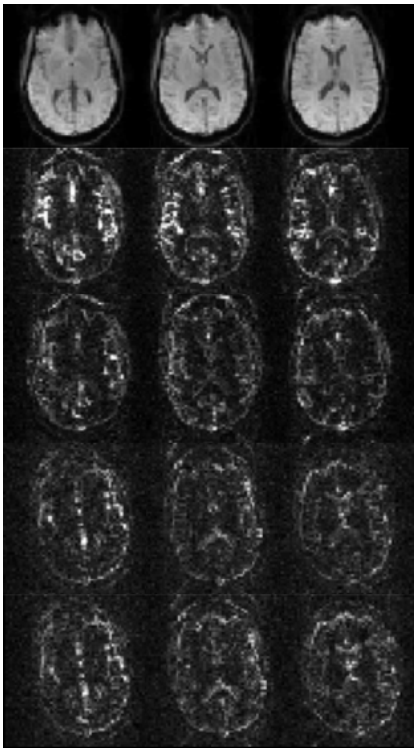
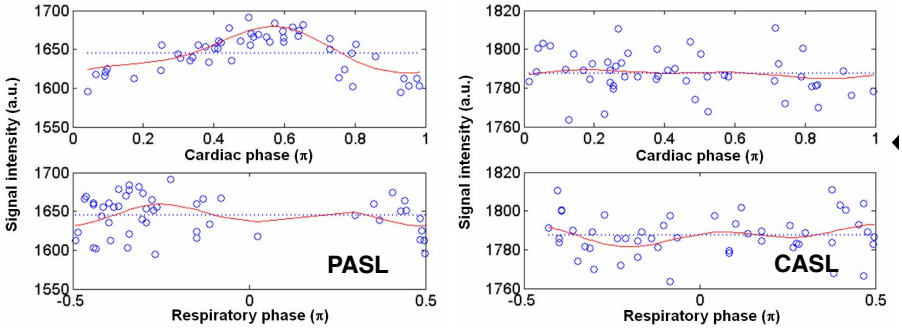


Fig 1 ▸




◂ Fig 2

**Fig 1.** Spatial distribution of physiological noise (three axial slices from a subject). From top to bottom: (row 1) anatomic EPI, (rows 2-3) $N_C$ and $N_R$ in PASL, (rows 4-5) $N_C$ and $N_R$ in CASL. The region of interest (outlined in yellow) in the top-left image is used for the demonstration in Fig 2.

**Fig 2.** Column-wise: PASL (left) and CASL (right). Row-wise: $N_C$ (top) and $N_R$ (bottom). Blue dotted lines and red solid lines indicate mean signal intensity and the fitted result, respectively.

## References

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