**Increased contrast-to-noise ratio for perfusion studies using sinusoidally modulated CASL**

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## Introduction

It has been shown, that dynamic arterial spin labeling provides a tool for quantitative mapping of CBF-related parameters (1). The approach uses a time-varying degree of arterial spin labeling (the labeling function, LF) by switching the labeling RF on and off for certain periods. A true sinusoidally modulated LF would allow a simplification of frequency filtering associated with a gain in contrast-to-noise ratio, because the frequency spectrum of the LF contains only a single peak. Our study demonstrates an easy way to obtain a sinusoidally modulated LF for dual-coil CASL at the human common carotid artery (2,3). With this method, perturbations in the CASL time series can be eliminated very effectively. The thereby achieved gain in contrast-to-noise ratio may also be useful for high-resolution perfusion studies.

## Method

All experiments were performed using a 3-T whole-body scanner (*Bruker Medical, Ettlingen, Germany*) with a helmet resonator for image acquisition. For perfusion imaging, a spin-echo EPI sequence with a 64 x 64 acquisition matrix was used (acquisition bandwidth 100 kHz, TE = 50 ms, echo position = 50 % ). For CASL, a circular coil of 6-cm diameter was used under pulse-program control. This coil was placed over the left or right common carotid artery of the subject. A continuous RF pulse with a power of approximately 1.0 W was applied during the labeling period. The labeling gradient strength was adjusted to 2 mT $m^{-1}$. Labeling was applied for a period of 3.5 s within each repetition (TR = 6 s) during the entire experiment of 165 repetitions. Slices were acquired after a post-labeling delay of 1.5 s. The frequency offset of the labeling RF was sweeped over a range of 9 kHz within a cycle of 11 steps. This choice was based on simulations of the adiabatic spin inversion (4). Frequency filtering was performed using the LIPSIA software package (5).

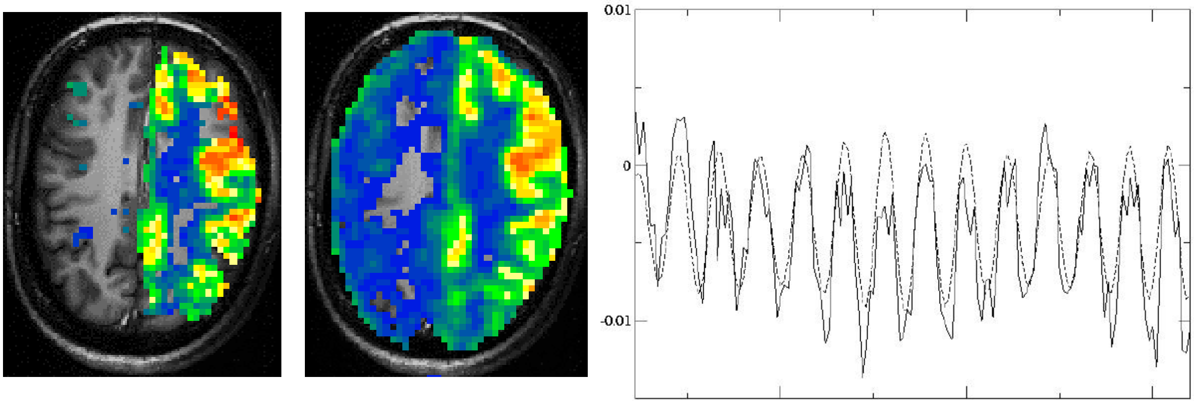


Fig. 1. Left: Map of CASL signal change for the experiment with sinusoidally modulated LF. CASL was performed at the right common carotid artery. Middle: CASL signal change for the same threshold obtained after narrow-band frequency-filtering. Right: Time course of sinusoidal CASL without (solid) and with narrow-band frequency-filtering.

## Results

Figure 1 shows two maps of CASL signal change for a sinusoidally modulated LF. The map on the right side shows the influence of the narrow-band frequency filtering. For both maps, the same preprocessing (motion correction and Gaussian filter) was applied. The maps are thresholded at the same correlation coefficient (0.2) to a sinusoidal design function. Although both maps show similar CASL signal changes, the number of voxels above the given threshold is increased drastically. The time courses of sinusoidally modulated CASL without and with narrow-band frequency filtering are shown on the right side of Figure 1. The filter effectively removes high-frequency noise while the time course related to sinusoidally modulated CASL remains unaffected. The gain in contrast-to-noise ratio can be explained by the relationship between the filter bandwidth and noise. The sensitivity to perfusion-related signal changes is increased substantially and permits, e.g., an estimate of white-matter CBF (~25 % of the gray-matter value).

## Conclusion

A simple way to obtain a quasi-sinusoidally modulated continuous arterial spin labeling (CASL) experiment is the sweep of the frequency offset of the labeling RF while the RF irradiation is applied during all repetitions of the experiment. Compared to a standard CASL experiment, sinusoidally modulated CASL offers the possibility of more efficient filtering of the CASL time series, which leads to a gain in contrast-to-noise ratio. In future, this may allow to observe more subtle effects in perfusion experiments such as the amount of collateral flow from the labeled to the unlabeled hemisphere in single-sided dual-coil CASL.

## References

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