Signal-to-noise ratio of perfusion mapping using multiphase pseudocontinuous arterial spin-labeling MRI

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Introduction

Pseudocontinuous arterial spin-labeling (PCASL) has been previously shown to offer a good balance between signal-to-noise ratio (SNR) and labeling efficiency (α) (1). However, the α of PCASL is more sensitive to field inhomogeneity than that of pulsed labeling. Multiphase PCASL (MP-PCASL) (2), one of the several schemes (3-5) proposed to remedy or calibrate α, estimates the undesired phase accrual (ϕ_{bg}) as a consequence of background field by tracking image intensities with varied phase offsets (ϕ) in the labeling pulses. The choice of ϕ's depends on the trade-off between scan time and the accuracy of ϕ_{bg} estimation. In the present study, we investigated the feasibility of generating flow maps by combining the images obtained at a subset of ϕ's. For a given scan time, SNR was compared with single-phase PCASL (SP-PCASL) using numerical simulation and experimental data.

Materials and Methods

A. SNR Simulation. The SNR ratio of MP-PCASL to SP-PCASL can be expressed in Eq. [1] where α_0 is the optimal efficiency that is to be determined in MP-PCASL by estimating ϕ_{bg}. For SP-PCASL, SNR was calculated from the average difference image (dM). For MP-PCASL, $2K$ phase offsets were equidistantly distributed from 0 to 2π, which rendered K dM images and k of which were combined using a scaling factor W. The dM's combined were those with the k smallest W_i^2. Given that dM is proportional to α, W_i ($i = 1,2,\ldots,k$) is the ratio of fitted peak dM to dM$_i$, and was approximated by $\sec(\phi_{bg} + \phi_i)$ in this study. B. MRI Experiment. The Institutional Research Ethics Committee approved this study. Five healthy volunteers (3 females, 2 males; age = 21-34 yrs) provided individual written informed consent before participation. All MR imaging was conducted on a 3T system (Siemens, Erlangen, Germany). RF energy was transmitted by the body coil and received by a 16-channel phased array. PCASL imaging was based on a single-shot gradient-echo echo-planar readout and the following parameters: TR = 4.3 s, TE = 20 ms, labeling duration = 2 s, post-labeling delay = 1.5 s, field-of-view = 20 cm, matrix = 64x64, twelve 5-mm axial slices, 72 measurements. MP-PCASL was performed with 18 ϕ's varied from 0^0 to 340^0 in steps of 20^0 (4 measurements for each ϕ). Two reference images were acquired for coil sensitivity correction and flow calculation (3). A gray matter mask was generated by segmenting the reference image received with the body coil. Within the mask, the average signal change over ϕ's was used to estimate ϕ_{bg}.

$$\frac{SNR_{MP}}{SNR_{SP}} = \frac{k}{\sqrt{K\sum_{i=1}^{k} W_i^2}} \cdot \frac{\alpha_0}{\alpha} \qquad [1]$$

Results and Discussion

Fig. 1

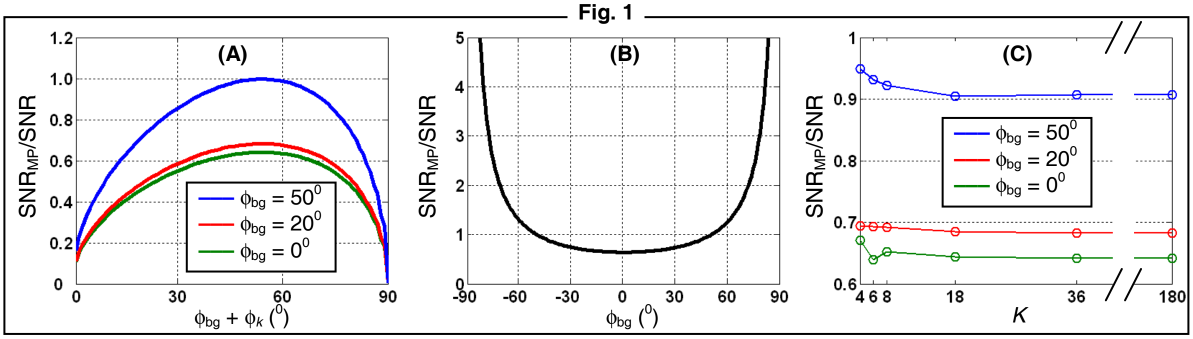
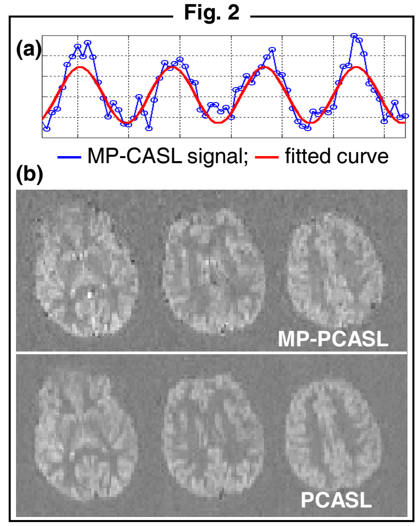


Fig 1 shows the simulated SNR ratio between MP-PCASL and SP- PCASL. In (a), SNR$_{MP}$ increases with k (the number of dM's combined) and peaks when the absolute value of W_k' is approximately 1.7 (i.e., $\phi_{bg} + \phi_k \sim \pm 55^0$, or $\pm 125^0$). Including dM's with a W greater than 1.7 deteriorates SNR$_{MP}$ because of their low SNR. In (b), SNR$_{MP}$/SNR$_{SP}$ is less than 1 when ϕ_{bg} is within $\pm 50^0$ (or $n \cdot 180^0 \pm 50^0$, n = integers) beyond which combined MP-PCASL starts to have the SNR gain relative to SP-PCASL. In (c), SNR$_{MP}$ slightly decreases when K increases. Of note, with fixed scan time (or fixed total number of measurements), a larger K provides more samples over phase offsets but each sample is more sensitive to noise (because of less measurements for average). **Fig 2** shows the data from a representative subject. In (a), ϕ_{bg} was estimated to be 29^0. In (b), dM maps obtained with combined MP-PCASL and SP-PCASL are comparable although noise is more noticeable in the MP-PCASL maps. In summary, the measurements of individual phase offsets in MP-PCASL can be combined to provide perfusion mapping with SNR ≥ 0.6-fold of SP-PCASL. The gain of SNR is expected to appear when the background phase exceeds 50^0.

Fig. 2



References

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