Optimization of the Labeling Time for Continuous Arterial Spin Labeling MRI

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Introduction

Arterial spin labeling (ASL) MRI is a complete noninvasive technique for quantifying cerebral blood flow (1). Since the perfusion signal change is very small, signal averaging can be used to improve the SNR. In continuous ASL (CASL) scheme, the SNR increases exponentially with the labeling time until reaching steady state but the total imaging time is increased as well. Theoretically, the SNR per unit time can be optimized through the labeling time (2) but this has not been experimentally verified. Here, we systematically changed the labeling time to evaluate the optimal values for perfusion and functional studies using ASL.

Materials and Methods

Five healthy volunteers (4 females; ages 23 – 56) were studied under an NIH approved IRB protocol on a GE 3T system (Milwaukee, USA). CASL perfusion images were acquired with a 3-coil configuration (3). Briefly, it involves a birdcage head coil for excitation, an occipital surface array (4 channels combined to 1) for signal reception, and a neck coil placed above the carotid artery for spin labeling. Five 12-min sessions, each with a different labeling time varied from 500, 1000, 1500, 2500, to 4000 ms, were scanned in each subject. Number of repetition (Nrep) in each session was varied with the labeling time to keep the total imaging time the same. Three slices were acquired in 500 ms by gradient echo EPI with TE = 17 ms, FOV = 19 cm, matrix size = 64x64, slice thickness = 3 mm, and gap = 7 mm. A long post-labeling delay of 1500 ms was used to minimize the effect of transit delay (4). Head motion was minimized by a vacuum bag.

The perfusion SNR was calculated by dividing the averaged ASL difference signal (ΔM) by the standard deviation in a 10x10 ROI in the background. Mean SNR was measured in 4 ROIs in the gray matter. Since the total imaging time is the same, the mean SNR corresponds to the SNR per unit time. The temporal SNR (tSNR) of each pixel was calculated by dividing the average ΔM by the standard deviation of the ΔM time course. Mean tSNR was measured in the same ROIs in the gray matter. Then, $\text{tSNR}\times\sqrt{Nrep}$, which is proportional to *t* statistics, was calculated.

Results

Figure 1 shows the averaged ΔM perfusion maps acquired in 12 min at 3x3x3 mm^3 resolution and with labeling time of 4 s, 1 s, and 0.5 s, respectively, from one subject. Averaged SNR of the 5 subjects is shown in Figure 2. Maximum SNR per unit time of 35 is reached at labeling time of 2500 ms, which is close to the theoretical value using T1 = 1250 ms (dashed line). Averaged tSNR (Figure 3) increases with the labeling time with a time constant of 1250 ms, which is close to the gray matter T1at 3T, and is about 0.75 at 4000 ms labeling time. The $\text{tSNR}\times\sqrt{Nrep}$ shows a similar trend as SNR per unit time and peaks at about 2500 ms (Figure 4).

Discussion

The relation between the SNR per unit time and the labeling time agrees with the expected $\Delta M/\sqrt{TR}$ dependency but with large inter-subject variation. This may be due to individual differences in the gray matter T1, transit delay, and labeling efficiency.

Although the variance of the ΔM time course increased a little at longer labeling time, the change of tSNR was still close to the trend of ΔM. Therefore $\text{tSNR}\times\sqrt{Nrep}$, which is proportional to *t* statistics in functional analysis, has a similar trend as SNR per unit time. Since the tSNR was a bit lower at longer labeling time, the peak region of $\text{tSNR}\times\sqrt{Nrep}$ became quite broad. This relation can be used to optimize the statistical power for a specific task design. For instance, one can double the temporal resolution by decreasing the labeling time to 1000 ms with only slight reduction of the *t* statistics.

Reference

1. Williams DS, et al., *Proc Natl Acad Sci* 1992; 89:212-6. 2. Wong EC, et al., *Magn Reson Med* 1998; 40:348-55. 3. Barbier E, et al., *Proc ISMRM* 2001, p. 102. 4. Alsop DC, et al., *J Cereb Blood Flow Metab* 1996; 16:1236-49.

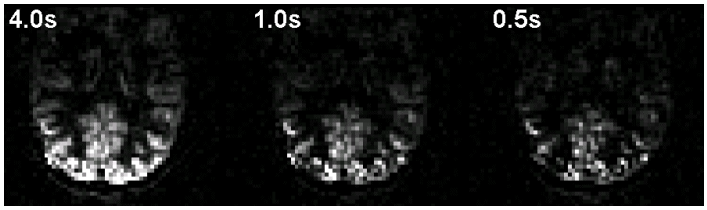

Figure 1. Averaged ΔM perfusion maps with different labeling time from a subject.

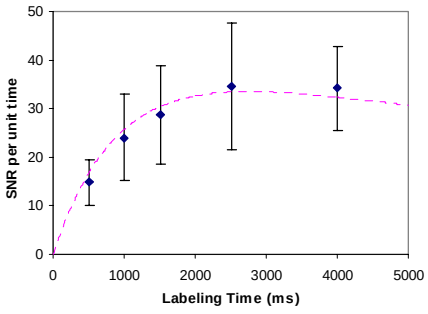

Figure 2. Mean SNR in gray matter vs. labeling time. Dashed line represents theoretical prediction.

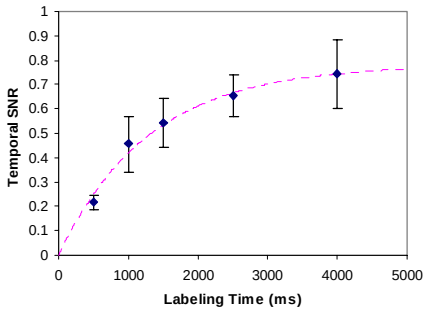

Figure 3. Mean tSNR in gray matter vs. labeling time. Dashed line is an exponential fit.

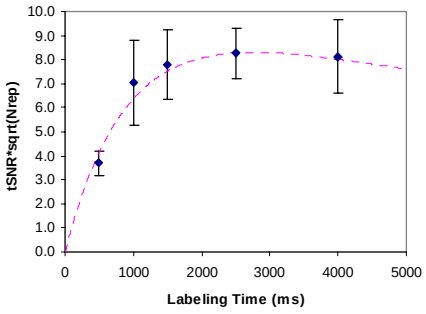

Figure 4. $\text{tSNR}\times\sqrt{\text{Nrep}}$ vs. labeling time.