What Is the Ideal Labeling Duration for Pseudocontinuous Arterial Spin Labeling?

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INTRODUCTION

A recently published white paper on arterial spin labeling (ASL) recommends pseudocontinuous ASL (PCASL) [1] with labeling duration (LD) of 1.8 s and post-labeling delay (PLD) of 2 s for clinical purposes. While optimal PLD may vary across subjects due to different arterial transit time, LD may be optimized regardless of subject, to increase ASL signal-to-noise ratio (SNR) efficiency. Here we performed PCASL with different LD's in healthy volunteers and demonstrated that SNR efficiency in PCASL can be improved with optimal LD.

METHODS

CBF measurement was performed in five normal volunteers using PCASL with four different LD's (1.5, 2.5, 3.5, and 4 s) and consistent PLD of 2 s. Images were acquired using fast-spin-echo 3D stack of spiral imaging with spatial resolution = 3.4 x 3.4 x 4 mm^3 and FOV = 220 x 220 x 144 mm^3. TR was 4982, 5982, 6982, and 7482 ms for LD of 1.5, 2.5, 3.5, and 4 s, respectively. Scan time with each LD was proportional to each TR. All scans were performed on a GE MR750 3.0 T.

ASL images were co-registered to each other within each subject to avoid error due to possible motion between scans. Regions of gray matter were then extracted and ASL signal (control - tagged) was averaged in the gray matter of the whole brain for each subject and for each LD. SNR efficiency was defined as ASL signal divided by square root of TR, which is sum of pre-delay (delay prior to labeling, 1 s), LD, PLD (2 s), and image acquisition (0.5 s). SNR efficiency was measured using the ASL signal averaged across subjects. SNR efficiency was also simulated using the equation of ASL signal [2],

$$C - T = 2 \cdot M_0 \cdot \lambda \cdot CBF \cdot T_{1b} \cdot e^{-\frac{PLD}{T_{1b}}}\left(1 - e^{-\frac{LD}{T_{1b}}}\right)$$

where C, T, M$_0$ are signal intensities in control, tagged, and proton density images, λ is blood/brain partition coefficient, and T_{1b} is the T_1 of blood. Measured SNR efficiency was fitted to the simulation curve by scaling. Average CBF measurement was calculated in the same ROI. One potential drawback of prolonged LD in PCASL is CBF underestimation due to the assumption of the longitudinal decay rate of T_{1b} even after tagged spins arrive at the tissue. CBF error due to this T_1 assumption was calculated for different LD, using T_{1b} = 1660 ms [3] and $T_{1tissue}$ = 1470 ms [4] and was compared with variation of measured CBF.

RESULTS

Figure 1a shows the simulated SNR efficiency of PCASL as a function of PLD and LD, and Figure 1b demonstrates good agreement between simulation and measurement. In simulation, SNR efficiency was increased by 25.0% when LD changed from 1.5 s (which is the default LD of GE product ASL sequence) to the optimal value of 3.8 s. Measured SNR efficiency gain was 28.5% and 29.2% when LD increased from 1.5 s to 3.5 s and 4 s, respectively. Figure 2a shows the calculated CBF error due to the time-invariant T_1 assumption in the quantification. When LD changed from 1.5 s to 4 s, simulated CBF reduction was -4.5% for all four arterial transit times while measured CBF increased by 7.2% (see Figure 2b). Example ASL images in one subject with the identical noise level are shown in Figure 3 for LD = 1.5 s and 4 s.
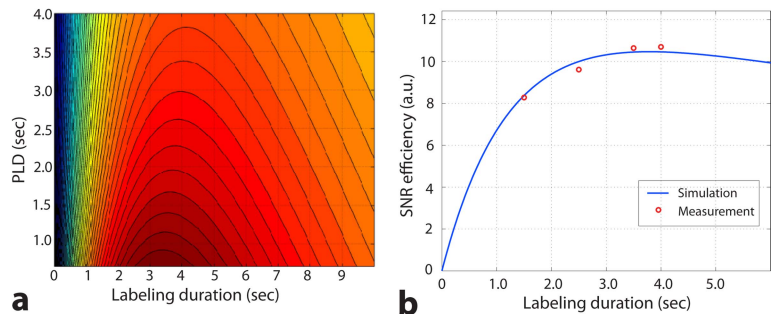

Figure 1. *(a) Simulated SNR efficiency. (b) Measured SNR efficiency fitted to simulation.*
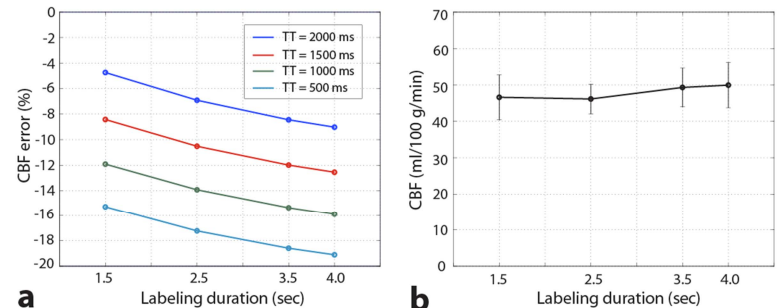

Figure 2. *(a) Simulated CBF error due to T1 assumption in CBF quantification for different LD for different arterial transit times (TT). (b) Average CBF measurements for different LD. Error bars correspond to standard deviation across subjects.*
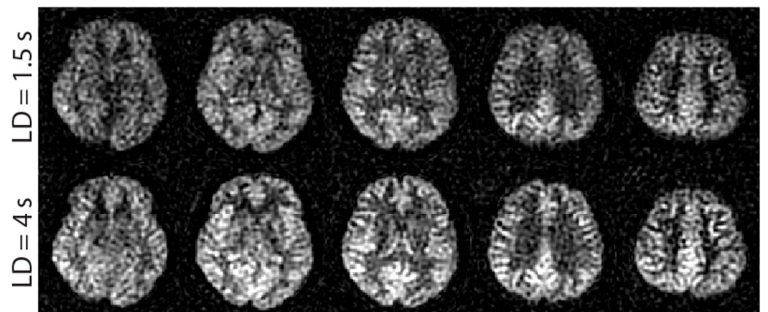
CONCLUSION

We demonstrated that SNR efficiency in PCASL can be improved by optimizing LD without showing a significant CBF measurement error due to the longer time the tagged spins spend in the tissue relative to blood. Optimal LD was found to be 3 – 4 s depending on other parameters such as pre-delay and PLD. The only downside we can see to a prolonged LD is that the reduced number of averages may increase error caused by subject motion or intrinsic physiological fluctuations in resting blood flow.

REFERENCES [1] Dai *et al*, MRM 60: 1488, 2008. [2] Buxton *et al*, MRM 40: 383, 1998. [3] Lu *et al*, MRM 52: 679, 2004. [4] Ethofer *et al*, MRM 50: 1296, 2003.

Figure 3. *Example ASL Images acquired with two different LD but with the same scan time in one subject. Images are windowed such that images from both methods have the same noise level. Difference in the blood flow signal reflects the SNR efficiency difference between two methods.*