How Long to Tag? Optimal Tag Duration for Arterial Spin Labeling at 1.5T, 3T, and 7T

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Introduction

It has been shown theoretically and experimentally that at 1.5T both continuous and pulsed arterial spin labeling techniques (CASL and PASL) with multi-slice and quantitative capability provide nearly the same SNR efficiency per unit of time with optimal tagging duration (1). Since the tagging efficiency with the amplitude-modulated control CASL is about 0.75 compared to 0.98 for PASL, the ideal SNR advantage (=*e*) of CASL over PASL did not realize. With the increase in field strength, higher SNR can be achieved for ASL because of increases in T1 values. The optimal duration of the tag will also increase with field strength; however, it becomes more difficult to achieve longer tag duration at higher field strength due to higher SAR for CASL and limited labeling coil size for PASL especially for whole brain coverage (2). In this paper, we estimated the optimal tag duration for 1.5T, 3T, and 7T for both techniques theoretically and verified the CASL results at 3T experimentally with pseudo-continuous ASL (PCASL) (3, 4).

Methods

The relationship of SNR per unit time versus tag duration was calculated using the General Kinetic Model (5) as in (1). The assumed T1 of blood and gray matter were 1300/900, 1600/1300, 2300/1900 ms for 1.5T, 3T, and 7T, respectively. The tagging efficiencies of 0.75/0.98 were applied for CASL/PASL. Two sets of post-labeling delay (*w*) (CASL) and ΔTI (PASL) were used: 1000/700 ms with 5 slices as in (1) and 1200/1200 ms for 9 slices to represent whole brain coverage and to be in line with the fact that PCASL can be applied as close as PASL. The time of exchange (Tex) were assumed to be *w*+200 ms for CASL and ΔTI+200 ms for PASL for each slice. The Calculated SNR/√TR as a measure of SNR efficiency per unit of time from all slices were then averaged.

Experiments were conducted on a GE 3T Excite scanner with a 16 channel receiver coil on 5 healthy subjects under approved protocols. Labeling tag widths (τ) of {1000, 1500, 2000, 2500, 3000, 3500, 4500} ms were used with PCASL and *w*=1200 or 1400 ms for a 4 min scan for each τ. Parameters for PCASL include 800 μs RF with 0.05 G amplitude (interval=1708 ms) and 0.8/0.06 G/cm maximum/mean gradient strength. Nine 5 mm axial slices with 4.5 or 4.6 mm gap covering the whole brain were acquired using EPI with TE=25 ms. Gray matter ROIs were selected based on T1 values estimated from EPI-based inversion-recovery experiments covering 50% of the masked brain area.

Results

The calculated SNR efficiency is shown in **Fig. 1** with *w*/ ΔTI =1000/700 ms and 5 slices (left) and with *w*/ ΔTI =1200/1200 ms and 9 slices (right). The optimal tag duration is shown with open circles whereas the close circles represent the operating points with less SAR and higher temporal resolution for less than 2% off the peak and summarized in **Table**. **Fig. 2** shows the experimental PCASL data ($\Delta M/M_0$) with respect to tagging duration and is consistent with theoretical calculation.

Table	*w*/ ΔTI =1000/700 ms and 5 slices				*w*/ ΔTI =1200/1200 ms and 9 slices			
	CASL(peak)	CASL(<2%)	PASL(peak)	PASL(<2%)	CASL(peak)	CASL(<2%)	PASL(peak)	PASL(<2%)
1.5T	1905	1600	862	700	2032	1704	912	742
3T	2505	2099	1097	886	2661	2232	1168	948
7T	3387	2831	1507	1211	3586	3002	1611	1302

Discussion and Conclusion

The T1 relaxation time increases with field strength but not the transit time and results in increases in SNR efficiency almost 3 fold from 1.5T to 7T, providing that longer tag duration can be achieved. Higher SNR efficiency can be used to reduce total scan time or to increase spatial resolution and slice coverage (prolonging transit time and therefore requiring longer post-labeling delay). However, for PASL, tagging below the brain for whole brain coverage suffers from reducing available tag duration toward higher magnetic field due to both limited RF coil size and faster blood velocity in the proximal arteries. PCASL can provides longer tag duration at 3T as CASL while with body coil labeling without special hardware and higher tagging efficiency (6), and can be achieved at 7T, providing that the labeling coil size is smaller than 3T body coil with comparable scaling as SAR increases from 3T to 7T.

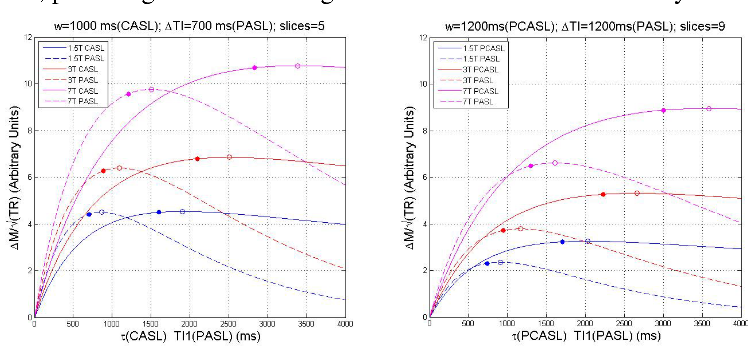

Fig. 1. Calculated ASL SNR efficiency vs. tag duration for *w*/ ΔTI =1000/700 ms with 5 slices (left) and *w*/ ΔTI =1200/1200 ms with 9 slices (right).

References

1. Wong et al., *MRM* 40: 348 (1998). 2. Luh et al., *HBM*: 262 (2006). 3. Garcia et al., *ISMRM*: 37 (2005). 4. Wong, *ISMRM*: 668 (2006). 5. Buxton et al., *MRM* 40: 383 (1988). 6. Wu et al., *ISMRM*: 375 (2007).

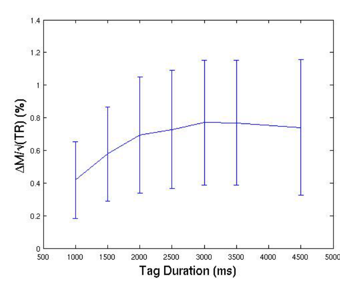

Fig. 2. Normalized PCASL SNR efficiency vs. tag duration at 3T. Error bars represent standard deviations within gray matter ROIs.