Determining the optimal label duration of pseudo-continuous ASL at 7 Tesla

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Introduction: High field MRI (7T) holds great promise for arterial spin labeling perfusion imaging, because of the intrinsic higher SNR and the prolonged T1 relaxation time of blood as compared to medium field strengths. Due to the prolonged T1 of blood, a longer label duration (τ) should theoretically be applied to provide optimal SNR (1). Pseudo-continuous ASL (pCASL) is, however, a SAR-intensive technique which limits the possibilitity to increase the labeling duration without an even larger increase in the repetition times necessary to stay within SAR limits; i.e. the trade-off between a longer label duration versus the number of averages will shift to shorter labeling durations. Furthermore, at higher magnetic field strengths other factors, such as physiological noise and B_1 inhomogenieties (2), can hamper the stability of the labeling efficiency, also potentially changing the optimal label duration. In summary, it is currently uncertain what the optimal label duration is at 7T. In the present study we examined the effect of the label duration on the ASL signal by first calculating the theoretical optimal label duration and later experimentally determining the relationship between label duration, SAR, ASL signal and SNR per a given amount of scan time (SNR/unit scan time).

Methods: Using the General Kinetic Model (GKM) proposed by Buxton et al (3) the relationship between the pCASL-signal and label duration was calculated ($T_{1,Blood}$= 2616ms, $T_{1,GM}$=2000ms, transit delay=1500ms and post-labeling delay=1550ms). For the experimental part four subjects (two males and two females; range 23-26 years) were scanned on an Achieva 7 Tesla MRI scanner (Philips Healthcare) using a 16 channel head coil (Nova Medical) (for the planning see Figure 1). Scans were made at eight different label durations: 500, 1000, …, 4000 ms, while keeping the SAR below 3.5 W/kg as determined by the SAR model of the scanner (necessitating an increase in TR as TR≈655ms + 2.2· τ). Total scan time of all scans was kept around 5 minutes by reducing the number of dynamics (other labeling parameters: delay=1550ms, gradient strength=6mT/m, mean gradient=0.6mT, RF duration=0.5ms and pulse repetition time=1.2ms; EPI readout with TE=11.35ms and SPIR; a saturation pulse preceded the labeling pulses). For every individual a region of interest (ROI) was calculated by applying a threshold on the average CBF map of all the eight perfusion scans.

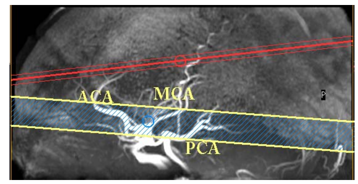

Figure 1: Planning of the labeling (blue) and imaging (red) slabs on the TOF-survey.

Results: The results of the simulations are shown in Figure 2 demonstrating increasing ASL-signal for increasing label duration, with an optimum SNR/unit scan time for a label duration between 2500 and 3500ms. Figure 3 shows example ASL-images, also showing increased ASL signal for longer label durations. Figures 4 and 5 display the averaged results of the measurements of the ASL signal and the SNR/unit scan time vs. label duration. The SNR/unit scan time peaks at 1500 ms labeling.

Discussion and Conclusions: Whereas the ASL-signal intensities increase as a function of label duration as predicted by the Buxton model, the SNR/unit scan time was found to peak at a much shorter label duration. Different processes could explain this apparent discrepancy. First, background suppression as performed by a single saturation pulse preceding the labeling, is most effective for the shortest labeling duration, leading to an SNR-advantage. Secondly, SAR-constraints forced us to use longer TRs than dictated by the longer labeling durations. However, this effect was taken into account for the simulations of Figure 2 (blue curve). Finally, it is possible that at these field strengths the labeling efficiency of pCASL is less stable than at medium field strengths. In particular efficiency fluctuations during the last part of the labeling would influence the SNR. Shorter label duration in conjunction with more averages would make ASL scans less susceptible to these effects. These experiments confirm our current experience that the optimal label duration at 7T is between 1500 and 2000ms and therefore comparable to 3T.

References: 1. Luh et al, ISMRM: 3339 [2008]. 2. Teeuwisse et al, IJIST 20(1): 62 [2009]. 3. Buxton et al, MRM 40: 383 [1998].

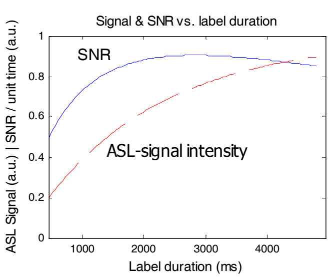

Figure 2: Buxton plot of the ASL signal and SNR per unit time as a function of label duration. While the ASL-signal increases with increasing label duration, showing an optimal duration of 3000ms.

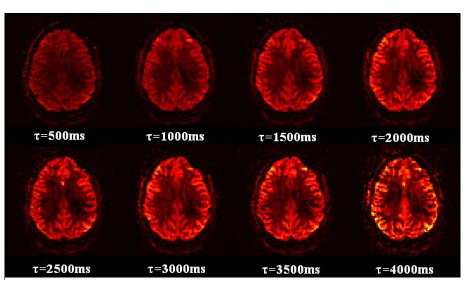

Figure 3: An example of CBF maps obtained with different label durations as measured in a representative subject.

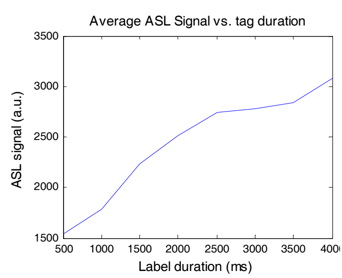

Figure 4: Averaged ASL signal as measured over all subjects as a function of label duration: the ASL-signal intensity increases for longer label durations.

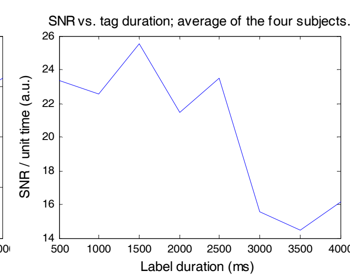

Figure 5: Averaged SNR per unit scan time vs. label duration for all subjects. SNR per unit time peaks around 1500 ms.