Myocardial ASL with improved sensitivity to MBF using Parallel Imaging

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Introduction: Arterial spin labeling (ASL) is a promising technique for the assessment of myocardial perfusion and perfusion reserve in humans [1,2]. Current myocardial ASL techniques, however, have low sensitivity due to high physiological noise (PN) [3]. We hypothesize that cardiac motion is the dominant source of PN and can be reduced by shortening the imaging window. This study compares the performance of myocardial ASL with and without the use of rate-2 and rate-3 parallel imaging (PI) and determines to what extent the sensitivity of ASL to myocardial blood flow (MBF) measurements can be improved by shortening the imaging window.

Methods: *Imaging Methods:* All experiments were performed on a 3T HDxt GE scanner using flow-sensitive inversion recovery (FAIR) with balanced steady state free precession (b-SSFP) image acquisition, as described in Ref [1] and Ref [2]. R1 had a 96x96 matrix size resulting in an imaging window of roughly 300 ms. The accelerated method used SENSE [4] rate-2 and rate-3 (called R2 and R3 thereafter) to shorten the imaging window to roughly 150 and 100 ms, respectively. *Experimental Methods:* Five healthy volunteers were studied (5males, 24-32 year-old, heart rate 58-73 bpm). A reference image was acquired at the beginning to estimate coil sensitivity map for SENSE reconstruction in R2 and R3. The three ASL scans were performed in R1-R2-and-R3 order. Each ASL scan took roughly 3 minutes with 7 breathholds (each one includes a baseline, a noise, and 6 pairs of control and tagged images). *Data Analysis:* Global, regional, and septal MBF and PN were computed using the method described in Ref [5]. Paired Student's t-Test was used to compare MBF and PN measured from the accelerated method with those measured from the reference method. Additionally, septal MBF and PN measured from R1 were compared with those reported in Ref [1].

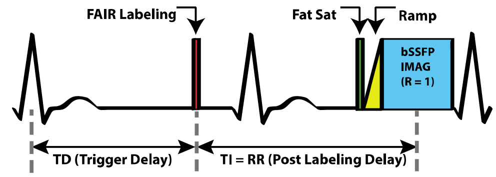

Fig 1: ***The pulse sequence diagram of R1.***

Results: Table 1 reports mean ± SD of global, septal, and regional MBF and PN across subjects. Values indicated by (*) were comparable with those reported in Ref [1]. Figure 2 shows global MBF with PN (error bars) measured from the three ASL scans. There was a 71% and a 48% PN reduction in R2 and R3 compared to R1. The PN reduction in the accelerated ASL method was found to be significant (p=0.01 and p=0.02 for R2 and R3). There was no significant difference between measured MBF from the three ASL scans (p=0.65 and p=0.52 for R2 and R3). Measured thermal noise (TN) was 0.013, 0.019, and 0.031 ml/g/min for R1, R2, and R3. The same trend was found for septal and regional MBF, PN and TN. Bland-Altman analysis (not shown) showed no significant difference between measured MBF from the 3 ASL scans.

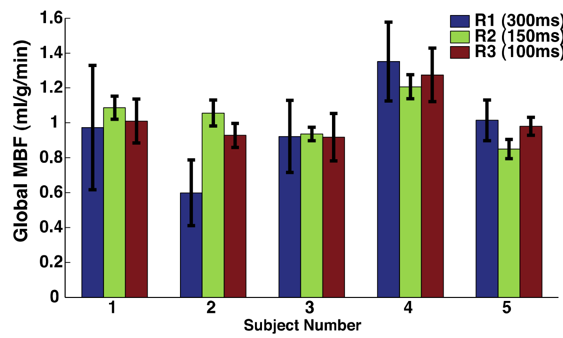

Fig 2: ***Measured Global MBF with PN (error bars).***

Discussion: There are many sources of PN including cardiac and respiratory motions, actual physiological change in MBF, artifacts associated with high signal in the left ventricular blood pool, misregistration between control and tagged images, and other unknown variations. Among all these sources, motions are most likely to depend on duration of the imaging window. Breath-hold was used in this study and therefore respiratory motion was minimized. Significant PN reduction can be achieved by shortening the imaging window using parallel imaging, which suggests cardiac motion is the dominant source of PN in cardiac ASL. The PN reduction corresponds to a 271% and 101% increase in temporal SNR (tSNR=MBF/PN) in R2 and R3, which directly translates to improved sensitivity. This result may be counterintuitive, as one would expect SNR loss due to the use of PI. TN increased by factors of 1.47 and 2.39 in R2 and R3 compared to that in R1 (expected due to increase in g-factor and reduction in imaging window). However, there was a total noise reduction because the decrease in PN (from 0.21 to 0.06 and 0.11) was much more significant than the increase in TN (from 0.013 to 0.019 and 0.031). Another unexpected result is that PN reduction in R3 was less than that in R2 in subjects 1, 3, and 4. This might be explained by noise amplification and reconstruction artifact when high acceleration factor (R=3) was used.

Conclusions: This study demonstrates that sensitivity of myocardial ASL to MBF can be significantly improved by shortening the imaging window to 150ms (or 100ms). This also suggests that cardiac motion is the dominant source of PN in cardiac ASL when the imaging window is longer than 150ms.

References: [1] Zun et al., MRM 2009; 62(4):975-83. [2] Zun et al., JACC 2011; 4(12):1253-61. [3] Epstein et al., JACC 2011; 4(12):1262-64. [4] Pruessmann et al., MRM 1998; 42(5):952-62. [5] Jao et al., ISMRM 2011; p1339.

Table 1: ***Mean ± SD (ml/g/min) of global, septal, and regional MBF and PN across all subjects.***

	Global		Septal		Regional	
	MBF	PN	MBF	PN	MBF	PN
R1 (300ms)	0.97 ± 0.27	0.21 ± 0.09	0.95 ± 0.31*	0.24 ± 0.08*	0.98 ± 0.45	0.30 ± 0.14
R2 (150ms)	1.03 ± 0.14♯	0.06 ± 0.01≠	1.02 ± 0.14♯	0.12 ± 0.04≠	1.05 ± 0.44♯	0.15 ± 0.09≠
R3 (100ms)	1.02 ± 0.15♯	0.11 ± 0.04≠	1.03 ± 0.17♯	0.15 ± 0.04≠	1.03 ± 0.44♯	0.19 ± 0.09≠

*: Comparable to Ref [1]; ♯: Not significantly different compared to R1 (p>0.41); ≠: Significantly different compared to R1 (p<0.04).