Myocardial ASL Perfusion Imaging Using Pulsed 2D Tagging of the Proximal Aorta

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Introduction

Myocardial blood flow (MBF) measurement using arterial spin labeling (ASL) [1-4] suffers from a large apparent ASL signal in the LV blood pool due to inadvertent tagging of blood in the LA and/or LV. A high LV signal adjacent to myocardium may interfere with MBF measurements because of partial voluming and k-space truncation, and is a potential source of artifact, physiological noise, and MBF measurement error [5]. We present a new pulsed tagging method using a 2D spatially selective adiabatic inversion of the proximal aorta, and compare it with conventional pulsed ASL.

Methods

<u>2D Tagging Pulse:</u> Our approach uses 2D selective inversion pulses oriented perpendicular to a standard three-chamber view, tagging blood in the proximal aorta while leaving the LA and LV undisturbed. We utilized the strategy of Conolly *et al* [6] to design 2D spatially selective adiabatic inversion pulses, and further reduced the pulse duration and peak B1 using the VERSE transform [7]. Fig. 1 shows our initial design. The composite pulse used 24 subpulses, each a small tip SLR pulse [8] with a time-bandwidth product of 3 and a duration of 0.5 ms prior to VERSE transformation. The overall sech envelope [9] has shape parameter $\mu = 2.5$. The gradient waveform uses a flyback EPI trajectory for insensitivity to flow effects and timing errors. The overall duration of the pulse is 21 ms, which is short compared to the T2 of arterial blood (275 ms).

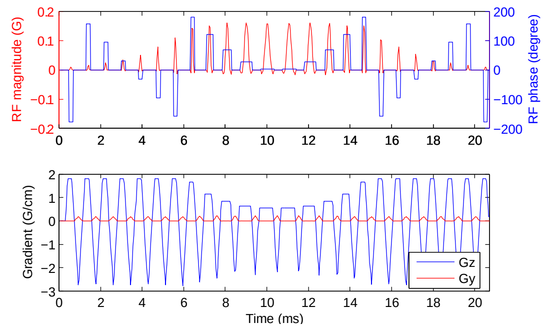

Fig. 1. 2D selective adiabatic inversion pulse. (21ms duration, 0.16G peak B1+).

<u>Experimental Setup:</u> The cardiac gated pulse sequence is illustrated in Fig. 2. Two-dimensional selective inversion occurs immediately after the aortic valve closes, and imaging is centered at mid-diastole in the following heartbeat, both determined by a CINE scout scan. One pair of control and tagged images was acquired 6 s apart during a single breath-hold, and six breath-holds (8-10 sec each) were performed for signal averaging. Image acquisition was performed using a snapshot 2DFT balanced SSFP sequence with 3.2 ms TR and 50° flip angle. In each study, a single mid-short axis slice was imaged using a 96×96 matrix over a 20-24cm isotropic FOV, with 10mm slice thickness. Experiments were performed in three healthy volunteers on a GE Signa 3.0 T EXCITE with an 8-channel cardiac array coil. For a comparison, conventional pulsed ASL using 1D adiabatic inversion was performed as well in the same subjects with the same imaging parameters.

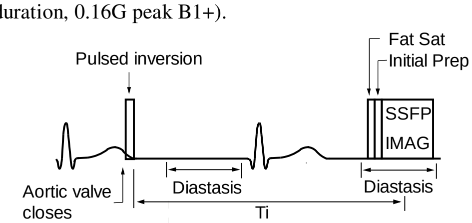

Fig. 2. Cardiac gated "pulsed" myocardial ASL sequence.

<u>Quantification:</u> Regions of septal myocardium were manually segmented for each breath-hold. We assumed that the 2D inversion tags all the blood at the root of the aorta that will travel into the coronaries during the following diastole, and hence used the equation $MBF = (C-T)/(2\alpha \cdot C \cdot RR \cdot \exp(-Ti/T1))$ derived from Buxton's general kinetic model [10] to arrive at the average perfusion rate over one R-R interval, where C, T, α, RR, Ti, and T1 refer to the mean myocardial signal in the control and tagged images, inversion efficiency, R-R interval, inversion time, and T1 of blood.

Results

Figure 3 illustrates in-vivo 1D and 2D tag profiles and corresponding ASL difference images for one representative subject. Tag profiles were measured by dividing two snapshot images (2DFT gradient echo, center-out view order); images with and without inversion pulse immediately prior to imaging. Table 1 contains the results from all subjects. The average inversion efficiency of 2D tagging was 67 %, and the residual LV signal on difference image of 1D tagging was reduced by 78 % using 2D tagging. We estimated MBF measurements considering this inversion efficiency, and estimated the confidence which is a probability of MBF measurement error being < 0.1 ml/ml/min based on Gaussian model of physiological noise. Using 2D tagging, MBF estimates decreased by 47 %, and measurement confidence increased from 37 % to 53%.

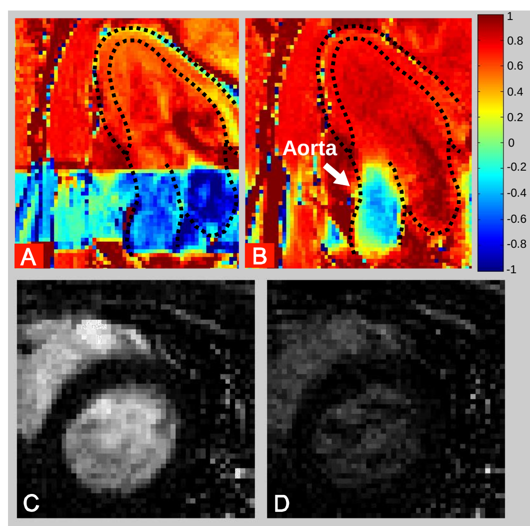

Fig. 3. In-vivo tag profiles for **A:** 1D tagging and **B:** 2D tagging of the proximal aorta. Identically windowed difference images for **C:** 1D tagging and **D:** 2D tagging.

Discussion

2D spatially selective adiabatic inversion pulses can be used to efficiently tag blood in the proximal aorta while leaving the LA and LV unperturbed. These pulses achieved inversion efficiency only 12% lower than that of 1D inversions, and may be improved by further optimization of the pulse parameters. This approach also improved the confidence in the measured MBF values, suggesting that the spurious LV signal is an important source of physiological noise in myocardial ASL. We are currently investigating the reason for reduced MBF estimates.

scan	1D tagging				2D tagging			
	Inv. effi.	LV signal	MBF	Conf.	Inv. effi.	LV signal	MBF	Conf.
1	77.7%	39.6%	1.93	38.7%	68.4%	8.5%	0.69	60.9%
2	78.9%	42.9%	1.85	31.5%	71.3%	10.3%	1.36	47.8%
3	80.2%	36.3%	1.32	40.3%	60.1%	7.4%	0.64	50.1%

Table 1. Inversion efficiency across the proximal aorta, residual LV signal, MBF measurements (ml/ml/min), and measurement confidence for 1D and 2D tagging schemes.

References [1] Poncelet BP *et al,* MRM 41:510, 1999. [2] Wacker CM *et al,* JMRI 18:555, 2003. [3] An J *et al*, 13th ISMRM p253, 2005. [4] Zhang H *et al*, MRM 53:1135, 2005. [5] Zun Z *et al*, MRM submitted, 2008. [6] Conolly SM *et al*, MRM 24:302, 1992. [7] Conolly SM *et al*, JMR 78:440, 1988. [8] Pauly JM *et al*, IEEE TMI 10:53, 1991. [9] Silver MS *et al*, Phys. Rev. A 31:2753, 1985. [10] Buxton RB *et al*, MRM 40:383, 1998.