IMPROVED SNR AT 7T FOR NON-CONTRAST ENHANCED CARDIAC PERFUSION IMAGING USING ARTERIAL SPIN LABELING

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Target audience: Arterial spin labeling researchers, cardiac imaging scientists

Purpose

Recently, arterial spin labeling (ASL) has been demonstrated and applied for cardiac perfusion imaging as an alternative approach to single-photon emission computed tomography (SPECT) and MRI-based first-pass methods due to its non-contrast enhanced characteristic[1-3]. Non-contrast enhanced ASL perfusion imaging will benefit patients with contraindications to the use of contrast agents, and is a suitable approach for repeated functional studies and longitudinal monitoring of therapeutic effect. However, previous cardiac ASL perfusion studies at 3T indicated low perfusion signal noise ratio (SNR) and large temporal/physiological errors[1]. Ultra high field (i.e. 7T) has the potential to provide higher SNR for ASL perfusion imaging due to greatly increased blood T_1 and overall imaging
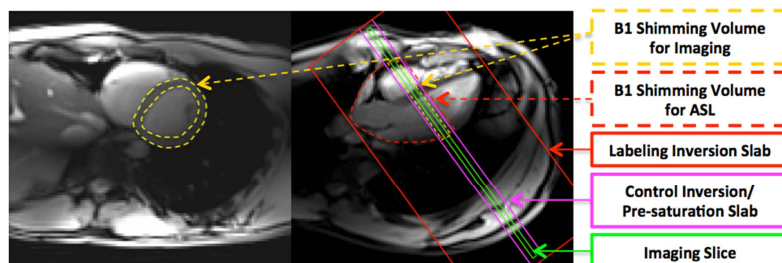

Figure 1 Spatial positions of different imaging components for arterial spin labeling cardiac perfusion imaging with dynamically applied B_1 shimming solutions at 7T.

SNR. The advantage of ASL perfusion imaging in the body at 7T was recently demonstrated in the kidneys by overcoming the various technical challenges[4]: B_1 and B_0 inhomogeneity, high specific absorption rate (SAR) and shortened T_2^*. To explore the benefits of 7T for ASL cardiac perfusion imaging, studies were performed on both 3T and 7T. The study results, for the first time, confirm that 7T can improve cardiac ASL perfusion imaging as realized by increased perfusion SNR.

Methods

All 3T studies were performed on a TIM Trio scanner (Siemens Healthcare, Erlangen, Germany), transmitting with the whole body coil and receiving with combined surface array (two rows of 3 elements) anteriorly and the spine array (two rows of 3 elements) posteriorly. All 7T studies were performed on a Siemens whole body MRI scanner with an external 16-channel transceiver TEM stripline array driven by a series of 16, 1 kW amplifiers (CPC, Pittsburgh, PA). All studies were performed under an IRB approved protocol with informed written consent.

ASL cardiac perfusion imaging followed a strategy similar to previous studies[1]. Perfusion data were acquired with cardiac triggering during breath-holds using a FAIR-based method with one optional dummy/M0 image proceeding ASL acquisition. On 7T, a dynamic B_1 shimming strategy[4] was applied using 2 solutions: **1)** one solution for the arterial spin labeling inversions (spatially selective for the control image and spatially confined for the label image) covering both the imaging slice and superior regions of the heart including the aortic root and **2)** a second solution for pre-saturation and imaging slice (Figure 1). B_1 shims were all based on tradeoff solutions between RF efficiency and B_1 field homogeneity[5]. To reduce the specific absorption rate (SAR) and to overcome limited RF peak power, an optimized GOIA pulse[6] was utilized for FAIR inversions. Two hundred noise images were also acquired by using the same imaging protocol with RF pulses turned off. Single-shot fast spin echo (ss-TSE) was used as imaging readout with the same imaging resolution, $2 \times 2 \times 10$ mm^3 on both 3T and 7T to facilitate comparisons. To minimize physiologic motion effects (which is the dominant source of measurement error), parallel imaging with acceleration factor 2 and pre-saturation were used.

ASL images across different breath-holds were pre-processed within Matlab (The MathWorks Inc., Natick, MA) using non-rigid co-registration based on the user-defined boarders of the heart[7], and then perfusion-weighted images (PWI) were obtained after pair-wise subtraction and averaging. For SNR comparison analysis across 3T and 7T, thermal noise maps were measured by using the temporal standard deviations of acquired 200 noise images. The voxel-wise SNR maps were generated by using PWI and noise maps.

Results and Discussions

Our study results showed consistent increase of perfusion SNR at 7T in comparison to 3T. The control, label, perfusion-weighted images and SNR maps from one volunteer are presented for both 3T and 7T in Figure 2. The control and label images at 7T were displayed with adjusted brightness. Compared to 3T, label and control images by ss-TSE at 7T had decreased overall signal intensities most likely resulting from either shortened myocardial T_2 and/or better static tissue suppression from the applied pre-saturation due to prolonged myocardial T_1. If the latter is found to be the predominating factor, tissue suppression could be achieved even without the application of background suppression[8] pulses at 7T, which would be quite beneficial due to SAR limitations.

In this study, ss-FSE was used as the readout strategy based on several considerations: **1)** ss-TSE can better accommodate B_0 inhomogeneity on both 3T and 7T compared to True-FISP, **2)** True-FISP could not provide consistent artifact-free images even on 3T and **3)** imaging signals of ss-TSE are based only on continuously refocused signals from the initial excitation, providing less sensitivity to cardiac motion and later inflowing blood pool signals, therefore minimizing temporal errors. Of course, the use of ss-TSE at 7T resulted in higher RF power deposition than GRE-based imaging readouts, but could be applied without short term SAR (10 s SAR limits according to the IEC guidelines) issue by using GOIA RF pulse for ASL inversions.

Conclusions: Compared to 3T, 7T improved cardiac perfusion imaging using arterial spin labeling.

References: **1.** Zun et al. MRM 2009. **2.** Wang et al. MRM 2010. **3.** Zun et al. JACC Cardiovascular Imaging 2011. **4.** Li et al. ISMRM 2011: 593. **5.** Metzger et al. MRM 2012. **6.** Tannús et al. NMR Biomed 1997. **7.** Periaswamy IEEE Transactions on Medical Imaging 2003. **8.** Garcia et al. MRM 2005.
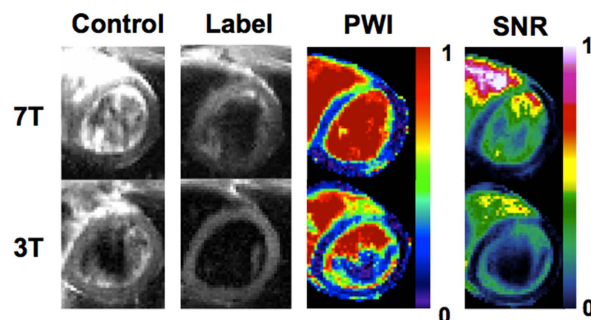
Figure 2 Control (left), label (middle left), perfusion-weighted images (PWI, middle right) and signal noise ratio (SNR) maps (left) on 7T (top row) and 3T (bottom row) from the same volunteer.