PROSTATE PERFUSION IMAGING USING VELOCITY-SELECTIVE ASL

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Introduction: Arterial spin labeling (ASL) is a non-contrast, non-radioactive and non-invasive perfusion imaging method well suited for the longitudinal monitoring of prostate cancer (PCa) progression and/or treatment. Prostate perfusion studies using ASL have been performed in normal healthy volunteers with/without an endorectal coil (ERC) on 3T (1-2), and also demonstrated on 7T with the promise of increased resolution and decreased acquisition times as a motivating factor (3). Previous feasibility studies of prostate ASL perfusion imaging using FAIR method exhibited large inter-subject variability due to the inability of FAIR to accommodate the complicated, subject dependent architecture of vessels feeding the prostate (4) which results in widely varying arterial transit times (ATT) (5). FAIR is also sensitive to ATT differences between normal and diseased conditions, and possible ATT changes due to altered pathophysiologic conditions, expected during the progression of PCa and therapy, which may lead to either the overestimation or underestimation of prostate blood flow (PBF). FAIR also adversely prolongs arterial transit times, especially for the apex of the prostate. Due to the specific characteristics of vascular geometry around the prostate, labeled blood has to travel laterally down to the posterior inferior region of the prostate before it flows into immediate blood feeding arteries. Velocity-selective arterial spin labeling (VS-ASL) (6) selectively labels blood flowing above a specified cutoff velocity by using velocity-selective dephasing gradients combined with driven equilibrium RF pulses without requiring a specific spatial region for labeling. Compared to EPI, True-FISP is an appealing imaging method with improved SNR performance and, while still sensitive to B_0 inhomogenetity, no spatial distortions. In this abstract, preliminary results of prostate perfusion imaging using VS-ASL with True-FISP as imaging readout are reported. This is the first time that VS-ASL imaging method has been applied outside of the brain and in the prostate.

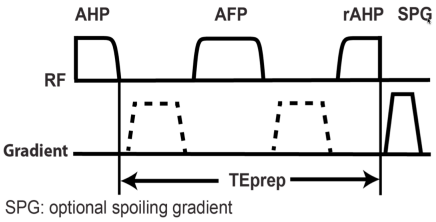

Figure 1. Velocity-selective ASL module. Dephasing gradients (represented in dash lines) will be applied only for label image acquisition.

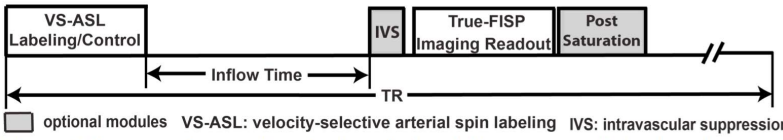

Figure 2. Sequence diagram for velocity-selective ASL prostate perfusion imaging.

Materials and Methods: The implemented VS-ASL module is based on the BIR-4 RF pulse (7-8) (Figure 1). The implemented VS-ASL prostate perfusion imaging sequence consists of a VS-ASL module followed by a specified inflow time, optional intravascular suppression (IVS) module and imaging readout followed by another optional module, post-imaging non-selective saturation (Figure 2). The IVS module can be used to suppress labeled blood spins in large arteries before imaging to avoid intravascular artifacts, and were implemented in the same way as the VS-ASL module but with a separate set of control parameters. True-FISP imaging readout was customized to allow multiple 2D imaging slices to be continuously acquired after a single VS-ASL labeling or control preparation. To reduce the sensitivity of True-FISP imaging to sporadic local motion, imaging slices can be acquired in a single shot mode using centric k-space ordering.

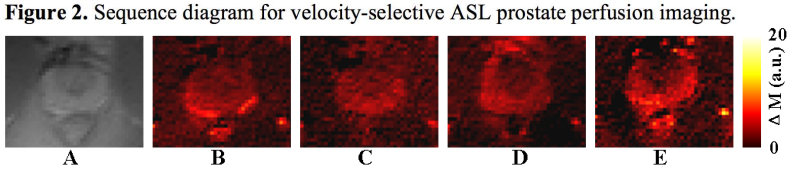

Figure 3. Proton density image (A) and perfusion-weighted images acquired with velocity-selective dephasing gradients applied along different directions: right-left phase-encoding direction (B), anterior-posterior readout direction (C), slice direction (D) and three orthogonal directions (E). Inflow time was 1.6 s, and 40 pairs of label and control images were acquired for each measurement. IVS was applied with cutoff velocity ~ 1.0 cm/s.

All healthy male subjects provided written consent forms prior to imaging studies according to a local IRB approved protocol. Studies were performed on a 3T Siemens TIM Trio, 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. In the preliminary studies to explore proper VS-ASL parameters for prostate perfusion imaging, a single slice with resolution 2 x 2 x 10 mm^3 was used. Multi-slice prostate perfusion imaging with high resolution 1.5 x 1.5 x 6 mm^3 was also performed using descending slice acquisition order. For all performed studies, the following parameters were used: 5 s TR, minimal TE, 50~70 degree flip angle, parallel imaging factor 2 with 24 reference lines, and 6/8 partial Fourier. To minimize the total acquisition time for high resolution multi-slice True-FISP imaging, small field of view 96 x 96 mm^2 was used with 100% phase oversample, giving slice acquisition time less than 200 ms. The duration of VS-ASL preparation module and the amplitude of unipolar gradients were adjusted simultaneously to minimize diffusion effects in static tissue for typically targeted cutoff velocity 1.5 cm/s. Since long TR was used, post-imaging non-selective saturation was not applied for presented studies. Post-imaging processing of the ASL data was performed with SPM, and perfusion weighted images were generated by using Matlab scripts.

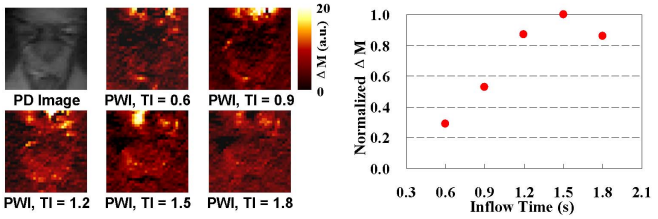

Figure 4. Proton density (PD) image and perfusion-weighted images (PWI) using different inflow times (TI) from one healthy volunteer. Total 60 pairs of label and control images were acquired for each measurement. Perfusion signals were measured from entire prostate.

Results and Discussion: Our preliminary results indicated that applying velocity-selective dephasing gradients simultaneously along three orthogonal directions gave better perfusion results than those along one direction, which is most likely a result of the large variation in the orientations of arteries supplying the prostate (Figure 3). The results represented in Figure 4 are from one study using multiple inflow times, indicating that an inflow time around 1.5 s results in the highest perfusion signals. Although sporadic local motions made high-resolution imaging a challenge, after removing volumes with motions and volume co-registration, high-resolution perfusion-weighted images could be obtained (Figure 5). Due to a relatively long slice acquisition time for True-FISP imaging, in multi-slice imaging, slices acquired at longer intervals after labeling (inferior slices in Figure 5), presented with lower perfusion SNR. With an ERC, the quality and SNR of VS-ASL prostate perfusion imaging can be greatly improved while simultaneously shortening total acquisition time. Recent studies indicated the existence of eddy current effects induced by the velocity-selective dephasing gradients applied in VS-ASL labeling (9), the small gradient amplitudes used (e.g. ~8 mT/m) helped minimize these effects. Further optimization of VS-ASL prostate perfusion imaging and comparisons with FAIR-based ASL perfusion are under investigation.

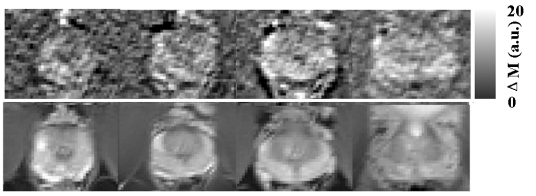

Figure 5. Perfusion-weighted (top) and corresponding proton density images with resolution 1.5 x 1.5 x 6 mm^3. 86 out of 100 pairs of label and control images were used.

Conclusions: Prostate perfusion imaging using VS-ASL is feasible and promising. **Acknowledgements:** Funding Provided by R01 CA131013, P41 EB0158994, S10 RR026783 and WM KECK Foundation.

References: 1. Li et al., Proc. ISMRM 2011;3062. **2.** Li et al., Proc. ISMRM 2011;3063. **3.** Li et al., Proc. ISMRM 2011;593. **4.** Clegg et al., J Anat. 1955;89(2):209-216. **5.** Li et al., NMR Biomed;2012 (online in press). **6.** Wong et al., MRM 2006;55(6):1334-1341. **7.** Garwood et al., JMR 2001; 153(2):155-177. **8.** Wong et al., Proc. ISMRM 2010; 2853. **9.** Meakin et al., Proc. ISMRM 2012; 576.