## FEASIBILITY OF SINGLE BREATH-HOLD RENAL PERFUSION IMAGING AT 7T

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Introduction: Without the need for contrast agents and the risk of ionizing radiation, renal arterial spin labeling (ASL) perfusion imaging is a well-suited imaging modality for renal disease studies and longitudinal evaluation of renal function after transplantation (1-2). Due to the intrinsically low signal noise ratio nature of ASL imaging, lengthy signal averaging and correspondingly long imaging acquisition times are usually needed in renal perfusion imaging at lower fields, which not only makes imaging sensitive to physiological motion but also imposes critical limitations on its application in patients (2). The increased SNR, prolonged longitudinal relaxation times, and better parallel imaging performance (3) of ultra high field provide the potential to reduce image acquisition time and motion-associated artifacts. The feasibility of single breath-hold renal ASL perfusion imaging at 7T was evaluated, and the results of renal perfusion imaging using single shot fast spin echo (ss-FSE) as imaging readout with both pulsed arterial spin labeling (PASL) and pseudo-continuous arterial spin labeling (pCASL) are reported. FAIR ss-FSE pCASL ss-FSE



Td: delay time between imaging readout and ASL preparation

measurements is a dummy scan to establish spin steady state.

Materials and Methods: All volunteers have provided written consent forms prior to imaging studies according to the local IRB approved protocol. Studies were performed on Siemens 7T 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). PASL renal perfusion imaging used flow-sensitive alternating inversion recovery (FAIR) method with adiabatic HS4 RF pulses, and pCASL method used the balanced gradient approach (4) (see Figure 1 for sequence diagrams). For renal perfusion imaging using FAIR, 20 mm and 180 mm selective inversion slabs were used for control and labeling image acquisitions respectively with several inversion times: e.g. 1.2, 1.5 and 1.8 s, and 3 s TR. For pCASL, a 10 mm labeling plane was placed perpendicular to the descending aorta and a large B<sub>0</sub> shimming volume covering the aorta region for spin labeling was used to minimize off-resonance

effects, results from which were compared with a  $B_0$  shimming volume covering only the imaging slice. Other typical acquisition parameters for pCASL included 4.0-4.5 s TR, 1.5 s labeling time, 15 degree labeling RF pulse flip angle and 1.2 and 1.5 s post-labeling delays. The ss-FSE imaging parameters for a single oblique coronal imaging slice were: TE = 16 ms, FOV = 256 x 256 mm<sup>2</sup>, matrix size = 128 x 128, in-plane resolution = 2 x 2 mm<sup>2</sup>, slice thickness = 5 mm, phase encoding direction = left to right with 50-80% oversampling, parallel imaging reduction factor = 4 with 24 separately acquired reference lines, hyper echo flip angle = 90 degree, and partial Fourier = 5/8. Local B<sub>0</sub> shimming was achieved by using volumetric phase maps acquired within a single breath hold (5). B<sub>1+</sub> shimming was performed based on small flip angle, calibration scan (6-7). For FAIR, tradeoff B<sub>1</sub>+ shimming solution was used over user-defined ROIs covering the kidneys and the feeding arteries; for pCASL, B<sub>1</sub>+ optimization used two B1+ shimming solutions: (1) maximal RF efficiency solution for the spin labeling region



covering the aorta and (2) tradeoff  $B_1$ + shimming solution for the region covering both kidneys. Imaging acquisitions were Figure 2. Imaging slice, labeling plane performed within a single breath-hold after moderate expiration. While 10 to 12 ASL images (excluding the first dummy image) and B<sub>0</sub> shimming volume for renal were possible for some subjects, the results using a total of 8 ASL images (4 pairs of label and control images) are presented. Post-imaging processing, including motion correction for small drifts, was performed within SPM.

perfusion imaging using pCASL.

## **Results and Discussion**

One subject's renal perfusion imaging results using both FAIR and pCASL methods are presented in Figures 3 and 4, respectively. Dramatically increased imaging SNR and prolonged longitudinal relaxation



times made single breath-hold renal Figure 3. Results of renal perfusion imaging using FAIR: proton density (a), control (b), labeling (c) and perfusion weighted ASL perfusion imaging feasible at 7T. images acquired with 1.5 s inversion time and with perfusion signal normalized to the first dummy (proton density) image. The use of a large B<sub>0</sub> shimming volume covering the aorta for spin labeling improved pCASL perfusion imaging quality, however FAIR was still better. This may be result from the pCASL labeling plane being near the coil edge where peak B<sub>1</sub>+ is limited even after B<sub>1</sub>+ shimming. A transmit coil with a distribution of elements along

the foot-head direction may help overcome this limitation by providing higher B<sub>1</sub>+ field over the aorta while simultaneously decreasing RF power deposition. Echo planar imaging has been used as imaging readout for multi-slice renal perfusion imaging at 7T without SAR issues (9). In contrast, the RF power deposition from ss-FSE was significantly higher even when a single slice was used, although ss-FSE can better handle B<sub>0</sub> inhomogeneity and associated susceptibility artifacts. Because the total imaging time for one ASL measurement was short, the major limiting factor was found to be short-term specific absorption rate (SAR), requiring the use of high parallel imaging reduction factor and hyper echo for ss-FSE, which unfortunately made imaging SNR lower than what otherwise could be achieved. Compared to FAIR, pCASL required longer TR to limit short-term (10 s) SAR, resulting in increased total imaging time even when allowing subjects to hold their breath after the dummy image acquisition, which may limit pCASL's future application in patients. Conclusions

Single breath-hold renal ASL perfusion imaging using FAIR and pCASL with ss-FSE can be achieved at 7T. Compared to pCASL, FAIR may be a better choice due to its lower short-term SAR and shorter total imaging time.

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## References

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Figure 4. Results of renal perfusion imaging using pCASL: renal perfusion-weighted images with signals normalized to the mean of control images and acquired without (a) and with (b) B<sub>0</sub> shimming volumes covering the labeling region over the aorta.