Perfusion Imaging of Renal Tumors at 3 Tesla using Pulsed Continuous Arterial Spin Labeling

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Purpose: Arterial spin labeling (ASL) is an advantageous technique to measure renal perfusion, especially in patients with compromised renal function who are not able to receive gadolinium based contrast agents. Various groups have investigated ASL techniques combined with different acquisition schemes for renal perfusion imaging, both at 1.5T (1,2) and 3T (3). Pulsed-continuous labeling (PCASL) has been shown to have relatively high labeling efficiency and when combined with background suppression has produced high quality renal perfusion images at 1.5T (4). ASL images are inherently low in signal to noise ratio (SNR) and often require repeated measurements to achieve sufficient SNR. In this work, we explored PCASL with background suppression at 3T to achieve high image quality by taking advantage of the increased SNR and prolonged T_1 of blood. The technique was optimized on normal volunteers and later used to acquire perfusion images of renal tumors in five patients.

Methods: The schematic of the pulse sequence is shown in fig. 1 (4). Briefly, the sequence starts by saturating the signal in the kidneys using four quadratic phase saturation pulses applied axially at 4.1 s prior to imaging. After 1.1 s of recovery, a FOCI pulse is axially applied to selectively invert the same region. Following that, a PCASL module is applied for 1.5 s in an axial orientation across the upper abdominal aorta approximately 8 cm above the center of the kidneys. After a 1.5 s post-labeling delay, a single slice coronal plane image was acquired using a single shot fast spin echo (SSFSE). During the post-

Fig. 1. Schematic of the PCASL pulse sequence along with background suppression and SSFSE acquisition.

labeling delay, four global inversion pulses are applied to suppress the background signal along with three saturation pulses applied superiorly above the labeling plane to suppress the inflowing blood signal. To minimize sensitivity to B_0 inhomogeneities that are commonly encountered in body imaging at 3T such as those caused by air in the bowel, we used an SSFSE acquisition.
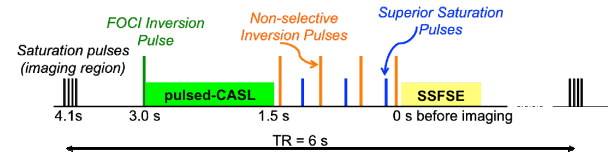
The pulse sequence was initially optimized on five normal volunteers using a Philips Achieva 3T scanner. Later, the optimized sequence was used to acquire perfusion images of renal tumors in five patients using a 16-channel phased array coil. The imaging parameters were: coronal acquisition, FOV 350×380 mm^2, slice thickness 10 mm, matrix size 116×128, partial Fourier acquisition, 16 pairs of label/control, TE 80 ms and TR 6000 ms. The data were acquired using a timed breathing approach, where the subjects were continuously coached during the scan to breath during the labeling period and hold their breath during the acquisition. The total acquisition time was approximately 3 min 12 s.
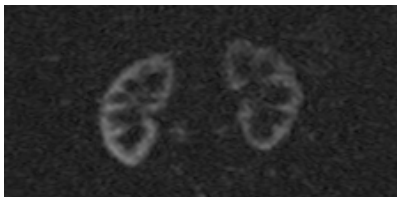

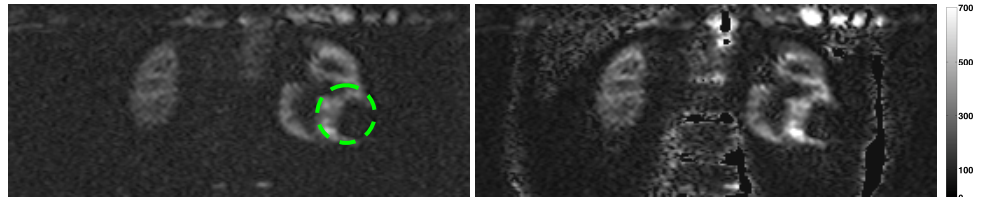Fig. 2. Renal perfusion image of a normal volunteer.

Fig. 3. Renal perfusion image (a) and the corresponding perfusion map (b) expressed in mL/100g/min of patient #1, showing heterogeneous perfusion in the renal tumor (green circle).
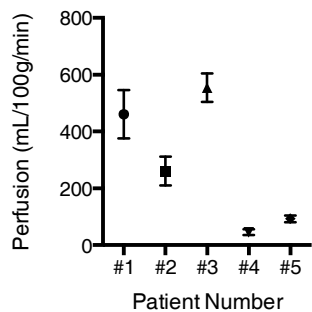

Fig. 4. Tumor perfusion

Results: Representative renal perfusion image of a normal volunteer with clear cortex to medulla differentiation and excellent background suppression is shown in fig. 2. Perfusion image of patient #1 with a clear cell renal cell carcinoma along with the corresponding perfusion map is shown in fig. 3. Averaged across all volunteers and patients, perfusion was measured to be 235±72 mL/100g/min in cortex and 134±25 mL/100g/min in medulla and was in agreement with the values previously reported in the literature (1,4). Mean±SD of tumor perfusion in each patient is reported in fig. 4. As expected (2), perfusion values vary dramatically among different histopathologic subtypes.

Discussion: PCASL combined with background suppression and SSFSE generated high quality renal perfusion images at 3T. Preliminary results show the feasibility of this approach to quantify perfusion in kidneys and renal tumors at 3T. Our future work will explore the implementation of this approach with 3D FSE acquisition. As such, this technique may become clinically important in assessing renal perfusion of the entire kidneys particularly in patients with compromised renal function.

References: (1) Fenchel M et. al. Radiology 2006; 238: 1013-1021. (2) Lanzman RS et. al. Radiology 2012; epub. (3) Wu WC et. al. Radiology 2011; 261: 845-853. (4) Robson PM et. al. MRM 2009; 61: 1374-1387.