# Non-Contrast Pulmonary Perfusion using pseudo-Continuous Arterial Spin Labeling of the Inferior Vena Cava

Joshua S. Greer[1,2], Yue Zhang[2], Ivan Pedrosa[2,3], and Ananth J. Madhuranthakam[2,3]

[1]*Bioengineering, UT Dallas, Dallas, TX, United States,* [2]*Radiology, UT Southwestern Medical Center, Dallas, TX, United States,* [3]*Advanced Imaging Research Center, UT Southwestern Medical Center, Dallas, TX, United States*

**Introduction:** Chronic obstructive pulmonary disease (COPD) affects lungs non-uniformly by disrupting pulmonary ventilation and perfusion. Non-invasive measurement of regional changes in pulmonary perfusion will aid in proper characterization and monitoring of COPD. Contrast-enhanced MRI (CE-MRI) provides pulmonary perfusion, but requires the administration of contrast agent, which restricts repeated measurements, confounds quantitative measurements, and can be contraindicated in patients with impaired renal function. Arterial spin labeling (ASL) based non-contrast pulmonary perfusion (e.g. FAIRER[1,2]) has been demonstrated in normal volunteers at 1.5 T. However, pulsed ASL approaches such as FAIRER are lower in signal to noise ratio (SNR) compared to continuous-ASL (CASL) based methods, such as pseudo-continuous ASL (pCASL).[3] In recent years, pCASL has been successfully applied to study cerebral and renal perfusion by labeling the carotid arteries[4] and abdominal aorta,[5] respectively, where blood velocity is relatively high. The extension of pCASL to study pulmonary perfusion has been non-trivial due to the complex anatomy of the lungs posing a significant challenge in identifying the vessel of interest for successful labeling. In this work, we demonstrate pulmonary perfusion using pCASL labeling specifically targeting the inferior vena cava (IVC) by optimizing the labeling parameters to achieve high labeling efficiency and compare against the established pulsed ASL approach, 2D FAIRER.

**Methods:** A pCASL pulse sequence was implemented on a 3 T Ingenia scanner (Philips Healthcare, The Netherlands). The sequence began with saturation pulses applied axially to cover the lungs and destroy magnetization build-up from previous repetitions. After a delay, venous blood flowing through the IVC was labeled using pCASL applied axially below the diaphragm (fig. 1a) for labeling duration, LD. The labeled blood then passes through the right heart before being delivered to the lungs. After a post-label delay (PLD) to allow labeled blood to perfuse the lungs, a single-shot turbo spin echo (SShTSE) acquisition was used to minimize the susceptibility artifacts due to $B_0$ inhomogeneities in the lungs. Other imaging parameters were FOV=300x300 mm$^2$, slice thickness=15 mm, TE=46 ms, TR=6 s. A proton density weighted ($M_0$) image was also acquired as reference for absolute perfusion quantification.[6] Using similar acquisition parameters, 2D FAIRER images were also acquired at 3 T with an inversion delay equal to one cardiac period.[2] For both acquisitions, 4 pairs of label/control images were acquired using a timed-breathing approach in approximately 1:00 minute.

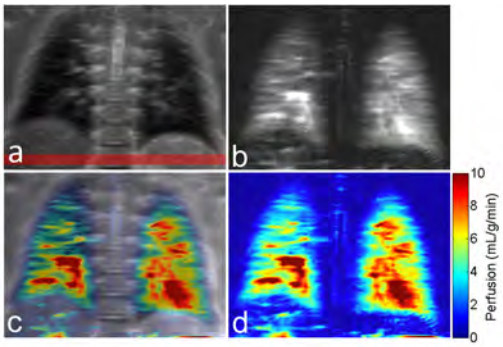


**Figure 1:** (a) $M_0$ image with axial labeling plane, (b) pCASL perfusion-weighted image (LD = 2000 ms, PLD = 500 ms), (d) pCASL perfusion-quantified image, and (c) Quantified perfusion overlaid on $M_0$ image.

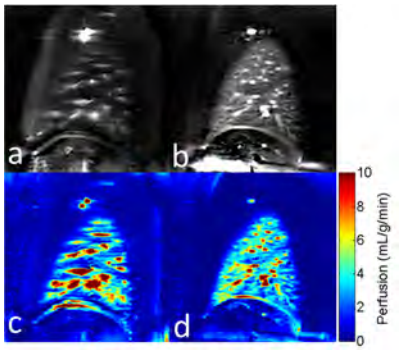


**Figure 2:** Sagittal perfusion-weighted images (a, b) and perfusion-quantified images (c, d) acquired with FAIRER (a, c) and with pCASL (b, d).

**Results:** Fig. 1 shows a representative pCASL perfusion-weighted image (fig. 1b) and the corresponding perfusion-quantified image (fig. 1d) in the coronal plane. In a different volunteer, compared to the FAIRER perfusion-weighted image (fig. 2a), the pCASL perfusion-weighted image (fig. 2b) has higher SNR, reduced pulmonary vasculature signal and improved signal homogeneity throughout the parenchyma. Average pulmonary perfusion quantification for both FAIRER and pCASL were measured to be 4-6 mL/g/min, and in agreement with previously reported values.[1,2]

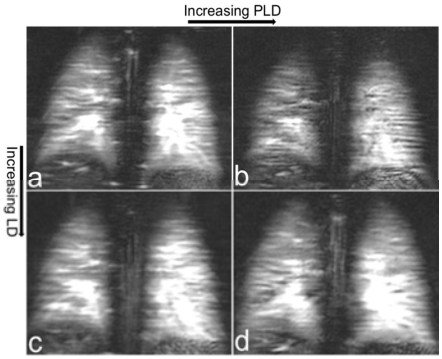


**Figure 3:** Perfusion-weighted images acquired with different combinations of LD/PLD: (a) 1500/1000 ms, (b) 1500/1500 ms, (c) 2500/1000 ms, and (d) 2500/1500 ms.

**Discussion:** To our knowledge, this is the first report of pulmonary perfusion using pCASL by specifically targeting the IVC. Since the amount of blood delivered to the lung parenchyma depends upon the LD and PLD (fig. 3), further optimization of these parameters will improve labeling efficiency and can be used to accurately measure pulmonary perfusion at 3 T without the need for exogenous contrast agent administration. Additionally, pCASL is amenable to volumetric maps using 3D acquisitions, unlike pulsed ASL approaches (e.g. FAIRER), and will be a considerable benefit in evaluating and monitoring COPD.

**References:** [1] Mai, V.M., et al. JMRI 1999. [2] Bolar, D.S., et al. MRM 2006. [3] Dai, W., et al. MRM 2008. [4] Pfefferbaum, A. et al. Psychiatry Research (2010) [5] Robson et. al. MRM 2009 [6] Buxton, R.B., et al. MRM 1998.