Volumetric Non-Contrast Pulmonary Perfusion using pseudo-Continuous Arterial Spin Labeling

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Introduction: Arterial Spin Labeling (ASL) provides a means to measure pulmonary perfusion without the administration of exogenous contrast agents. The pulsed ASL (PASL) technique FAIRER has been developed and evaluated in normal volunteers to study pulmonary perfusion at 1.5 T.[1] However, PASL approaches, such as FAIRER, are fundamentally limited to 2D acquisitions due to their reliance on the blood flow from outside the imaging volume, and cannot be extended to volumetric acquisitions. This limited spatial coverage has been a considerable restriction in assessing chronic lung diseases that affect lungs non-uniformly. The introduction of pseudo-continuous ASL (pCASL) has enabled volumetric perfusion imaging of the brain[2] and kidneys[3] by labeling the carotid arteries and abdominal aorta using clinical scanner hardware. In addition, pCASL labels blood outside the imaging volume and is readily amenable to 3D acquisitions. In this work, we present such an approach to acquire non-contrast volumetric pulmonary perfusion maps using pCASL labeling of the inferior vena cava (IVC) combined with a segmented 3D turbo spin echo (TSE) acquisition.

Methods: A pCASL sequence was combined with a 3D TSE acquisition on a 3 T Ingenia scanner (Philips Healthcare, The Netherlands) and 3 normal volunteers were scanned with IRB approval and written informed consent. Briefly, the sequence begins with saturation pulses applied axially to cover the lungs and destroy magnetization build-up from previous repetitions. Following a delay, pCASL labeling was applied axially across the IVC (fig. 3a) for 2 seconds to invert blood via adiabatic inversion.[4] The pCASL labeling parameters were optimized to increase labeling efficiency considering slower blood flow in the IVC compared to the carotid arteries and abdominal aorta. Following a post-label delay of 1 second to allow labeled blood to perfuse the lungs, a segmented 3D TSE acquisition was used. Other parameters of the sagittal acquisition covering the right lung were: FOV=300x300 mm^2, slab thickness=160mm, resolution=2x2x3 mm^3, TE=44ms, TR=6s. 24 control and label slices were acquired in approximately 4:30 minutes using a timed-breathing approach and a single average. The images were reconstructed offline using complex k-space subtraction to increase the signal to noise ratio (SNR). A proton density (M_0) image was separately acquired in a 2:15 minute acquisition for absolute perfusion quantification using the standard model for continuous-ASL.[5] For comparison, 2D images with pCASL labeling of the IVC and 2D FAIRER were also acquired using a single-shot TSE (SShTSE) with similar acquisition parameters: slice thickness = 15 mm, resolution = 2x2 mm^2, TE=46 ms, TR=6s. Four signal averages were acquired for 2D images in approximately 1:00 minute using the timed-breathing approach, followed by a 2D M_0 image in a single breath hold for perfusion quantification.

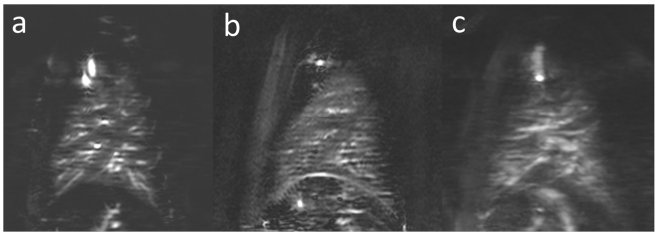

Figure 1: Sagittal perfusion-weighted images acquired using 2D FAIRER (a), 2D pCASL (b), and 3D pCASL (c).

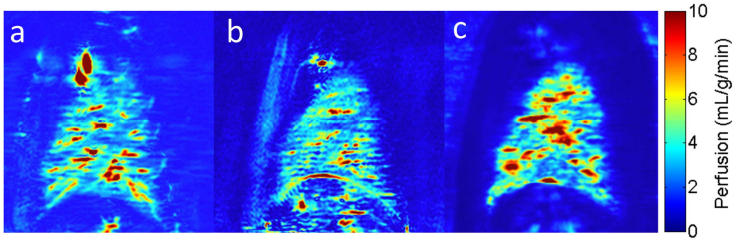

Figure 2: Sagittal perfusion-quantified images acquired using 2D FAIRER (a), 2D pCASL (b), and 3D pCASL (c) corresponding to figure 1.

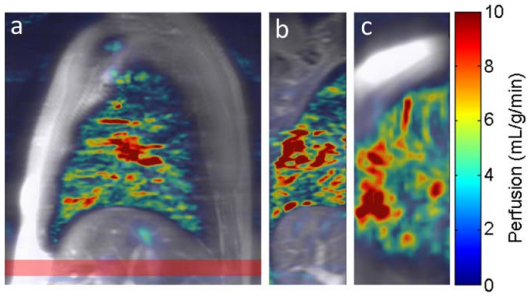

Figure 3: Perfusion-quantified images overlaid on M_0 images in the sagittal (a), coronal (b) and axial (c) orientations. The axial labeling plane is displayed in (a) below the diaphragm.

Results: Representative perfusion-weighted images in the sagittal plane are shown in fig. 1 and their corresponding perfusion-quantified images are shown in fig. 2. Perfusion quantification showed similar values with all three approaches and measured to be 4-6 mL/g/min, and was in agreement with values in the literature.[1] Further, the volumetric acquisition enabled by pCASL labeling of the IVC and 3D TSE allows perfusion mapping of the entire right lung (fig. 3).

Discussion: Optimized pCASL labeling of the IVC enabled successful volumetric perfusion mapping of the entire right lung without the administration of exogenous contrast agent. Further optimization of the labeling parameters and the 3D TSE acquisition should enable volumetric mapping of both lungs in a single acquisition, providing a means for non-contrast perfusion measurement of whole lungs for characterization and monitoring of chronic lung disease.

References: [1] Bolar, D.S., et al. MRM 2006. [2] Pfefferbaum, A. et al. Psychiatry Research 2010. [3] Robson et. al. MRM 2009 [4] Dai, W., et al. MRM 2008. [5] Buxton, R.B., et al. MRM 1998.