Dynamic Contrast Enhanced Pulmonary Perfusion with Undersampled Stack-of-Stars and Iterative Highly Constrained Back-Projection

N. S. Artz[1], R. L. O'Halloran[2], M. Schiebler[3], J. H. Holmes[4], and S. B. Fain[1,3]
[1]Medical Physics, University of Wisconsin-Madison, Madison, WI, United States, [2]Radiology, Stanford University, Stanford, CA, United States, [3]Radiology, University of Wisconsin-Madison, Madison, WI, United States, [4]Applied Science Laboratory, GE Healthcare, Madison, WI, United States

INTRODUCTION: The purpose of this study was to demonstrate the feasibility of obtaining high spatial and temporal resolution 3D data for pulmonary perfusion measurements. A radial stack-of-stars acquisition was used because of the ability to capture temporal dynamics by azimuthal under-sampling while mitigating tradeoffs in spatial resolution [1]. Moreover, further under-sampling is achievable in radial acquisitions by sharing data from proximal time frames with View Sharing [2,3], but with necessary reduction in temporal fidelity. In this work, an Iterative Highly Constrained Back-Projection (I-HYPR) reconstruction technique [4] was used to further mitigate spatial-temporal resolution tradeoffs in the challenging setting of lung perfusion.

MATERIALS AND METHODS: Two healthy volunteers were scanned in a supine position on a 1.5 T MRI system (Signa HDx, GE) using an eight-channel cardiac array coil (GE). After initially acquiring a baseline "mask" image, 17 mL (0.1 mmol/kg) of Gd contrast (Omniscan, GE) was injected at a rate of 4 mL/s. The acquisition was a 3D stack-of-stars GRE sequence with TR/TE = 2.7/1.2 ms, FOV = 48 cm, 128 readout points (3.7 x 3.7 mm in-plane resolution), 12 slices, 20mm slice thickness, and 30° flip. Consecutive groups of 32 angles were reconstructed with I-HYPR for a temporal resolution of ~1s. A sliding window of six time frames was used to reconstruct the constraining image using filtered back projection. The temporal dynamics of I-HYPR was then compared to View Sharing which used a sliding window of six time frames. Mean Transit Time (MTT), relative Pulmonary Blood Volume(rPBV), and relative Pulmonary Blood Flow (rPBF) maps were calculated from the mask subtracted tissue curves using equations 1-3 in which S = signal, t = time, and AIF = Arterial Input Function. The pulmonary artery was used for the AIF.

$$(1)\ MTT = \frac{\int S(t)tdt}{\int S(t)dt} \qquad (2)\ rPBV = \frac{\int S(t)dt}{\int AIF(t)dt} \qquad (3)\ rPBF = \frac{rPBV}{MTT}$$

RESULTS: Signal vs. time curves have been plotted for both I-HYPR and View Sharing reconstruction techniques in three different regions of interest (ROI's): the pulmonary artery (PA), parenchyma, and left atrium (LA). The signal vs. time curves shown for one volunteer (Fig 1) demonstrate an expected trend with the PA peaking first, followed next by the parenchyma and later the LA. I-HYPR also appears to improve temporal fidelity in the three ROI's, yielding a later arrival time, steeper uptake slope, and higher peak signal compared to View Sharing with a sliding window. MTT, rPBV, and rPBF maps can be seen in Figure 2 for one volunteer. The MTT maps calculated from these two volunteer scans demonstrated mean transit times from 3-5 s after the main pulmonary artery trunk and are in agreement with values previously reported [5]. Gravity related effects, as noted by Levin et al. [6], are also visible in Figure 2 with shorter MTT's in the posterior region.

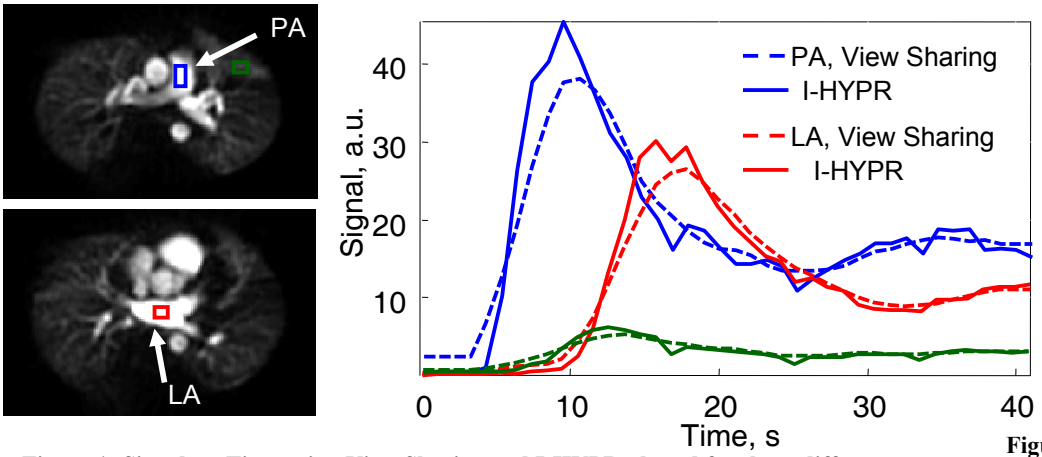

Figure 1: Signal vs. Time using View Sharing and I-HYPR plotted for three different regions of interest: pulmonary artery (blue), left atrium (red), and parenchyma (green).

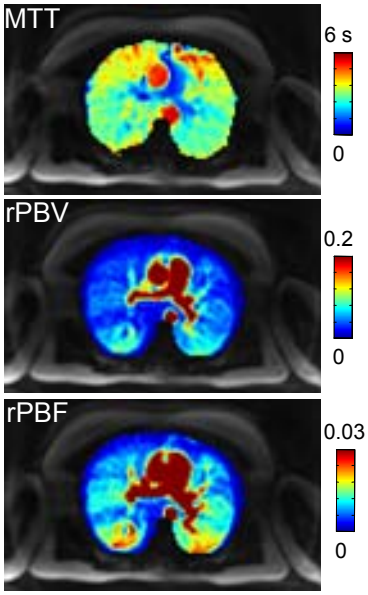

Figure 2: Example Mean Transit Time (MTT), relative Pulmonary Blood Volume (rPBV), and relative Pulmonary Blood Flow (rPBF) maps for one healthy volunteer.

DISCUSSION AND CONCLUSIONS: This work is a specific example of the more general framework of using under-sampling and constrained reconstruction algorithms to enable functional imaging. The feasibility of performing accelerated 3D pulmonary perfusion measurements with under-sampled radial acquisition and I-HYPR reconstruction was demonstrated in two healthy volunteers. Both spatial coverage and temporal resolution were improved by a factor of four compared to a fully sampled acquisition and a factor of three compared to partial Fourier, while mitigating tradeoffs in signal to noise typically encountered in fast imaging applications. Future work will be directed at determining the accuracy in preclinical studies with microspheres and/or realistic perfusion phantoms. The combination of under-sampled radial acquisition and I-HYPR has been successfully used in other challenging functional pulmonary imaging applications, such as oxygen mapping, dynamic imaging, and diffusion weighted imaging using contrast enhanced He-3 MRI. Future work will focus on using the pulmonary perfusion measurements in tandem with the He-3 applications to measure ventilation to perfusion ratio to better identify ventilation-perfusion mismatch in pulmonary embolism.

REFERENCES: [1] Peters *et al.* MRM. 2000; 43(1):91-101. [2] Song *et al.* MRM. 2000; 44:825-832. [3] Barger *et al.* MRM. 2002; 48:297–305 [4] O'Halloran *et al.* MRM. 2008; 59:132-139. [5] Ohno *et al* JMRI. 2004; 20:353-365. [6] Levin *et al.* MRM. 2001; 46:166–171.
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