

Ultrahigh temporal resolution dynamic imaging of He-3 MRI using bolus delivery

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Introduction: Rapid dynamic hyperpolarized (HP) He-3 MRI has been shown to measure lung ventilation in humans [1]. High temporal resolution methods utilizing EPI [2], spiral imaging [3], or projection imaging [4,5] have demonstrated the potential for true quantitative, dynamic HP He-3 MR imaging of the lung. Furthermore, the independence of the technique on breath-hold ability and use of a smaller quantity of He-3 contrast make dynamic imaging a favorable option for assessment of regional lung function. Under-sampling the data allows considerable acceleration at the expense of image artifact. Previous approaches have used view-sharing to mitigate these artifacts however this reduces the temporal resolution. The iterative highly-constrained back-projection (I-HYPR) reconstruction method has previously been shown to maintain temporal fidelity while diminishing under-sampling artifact, allowing dynamic projection MRI at high spatial and temporal resolution [6]. In this work a 2D radial acquisition paired with I-HYPR reconstruction are used to acquire and reconstruct dynamic images of the inhalation of a compact bolus of He-3 gas at 50 frames per second. Parametric mapping is used to better depict the regional differences in filling in the time series.

Methods: Imaging of healthy volunteers (n = 3) was performed using a clinical 1.5T MRI system (Signa Hdx, GE Healthcare) with a coil tuned to the resonance frequency of He-3. A 2D radial SPGR imaging acquisition was implemented with 8 projections per image, TR/TE = 2.5/1.2 ms, flip angle = 2°, BW = ±62.5 kHz, Matrix = 128x128, FOV = 48 cm, with a non-slice selective RF pulse. 100 ml of HP He-3 gas was introduced to a 3.3 m length of 6.4 mm inner-diameter plastic tube. The healthy volunteer was asked to take a deep breath through the tube until full inspiration and then to breathe normally for the remainder of the exam. Just before inhalation, the ends of the tube were opened to room air. The I-HYPR reconstruction algorithm was implemented with a 20 time-frame moving window composite with reconstructed time-frames consisting of 8 angles for a frame-rate of 50 frames-per-second (20 ms temporal resolution). Two parametric maps were calculated for the reconstructed time-series [7]. The delay time (td10) is defined as the time between when the signal in a pixel reaches 10% of its maximum value and the time when the trachea signal reaches 50% of its maximum value. The signal rise time (tsr) is defined as the time between when the signal in a pixel reaches 10% and 90% of its maximum value.

Results and Discussion: The first 20 frames, representing 0.38 seconds of the scan, from Subject 1 are shown in Fig 1. The main bronchi begin to fill approximately 0.04 s after the first signal in the trachea appears (Fig 1 top row). The 2 boundaries between the 3 right lung lobes are clearly depicted (Fig 1 arrows). The signal is almost entirely cleared from the trachea by 0.34 s after the initial signal appears in the trachea. (Fig 1, bottom row). Delay time and signal rise time maps are compared for all three subjects in Fig 2. Note that the right lung of Subject 2 appears to have filled asymmetrically. Fig 3 depicts the differential filling in Subject 2 in more detail. The right middle and lower lobes don't appear to fill at all in the dynamic exam. However, a breath-held exam immediately before this study showed uniform spin-density throughout the lungs for this subject (not shown). It is unclear whether these differences are ephemeral or due to pathology not visualized during passive breath-hold.

Conclusion: This technique provides high in plane spatial and temporal resolution in 2D dynamic MRI of an inhaled bolus of gas. The high temporal of the technique allows visualization of asymmetric filling in a respiratory maneuver. This resolution may be important in pediatric cases where filling can be quite rapid, and patient breath-hold times and motion can be problematic. Additionally the technique requires very little He-3 compared to conventional He-3 scanning. Future work will study the dynamics of ventilation defects and gas trapping in asthmatics and normals under methacholine challenge.

References: [1] Schrieber et al. Fortschr Röntgenstr 2000 [2] Pai et al. Proc. ISMRM 2006. [3] Salerno et al. MRM 2001. [4] Wild et al. MRM 2003. [5] Holmes et al. JMRI 2007. [6] O'Halloran et al. MRM 2008. [7] Gast et al. Invest. Rad. 2008.

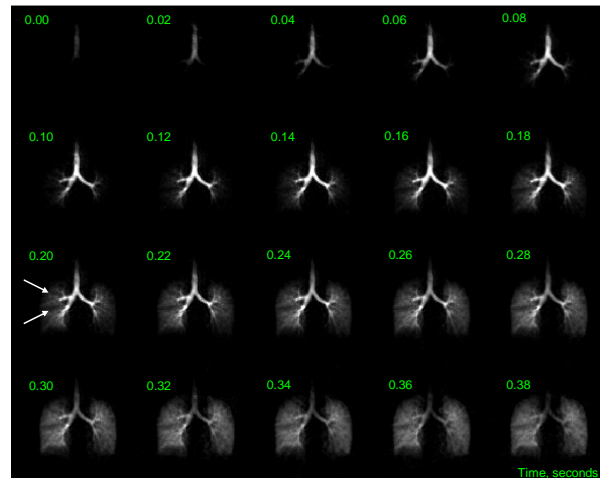


Figure 1: Reconstructed time series depicting the inflow of gas into the trachea (top row) followed by the smaller airways and finally by the lung parenchyma in Subject 1.

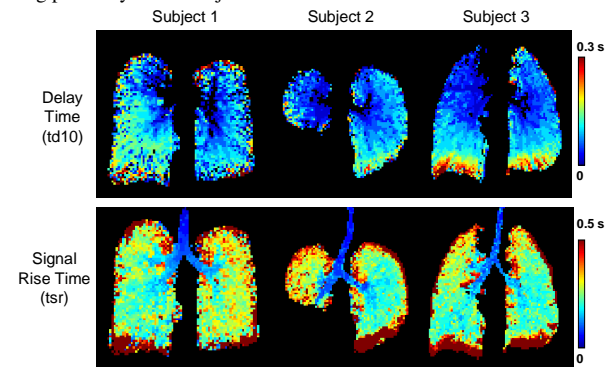


Figure 2: Comparison of td10 and tsr maps for each subject.

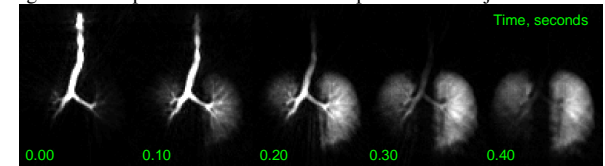


Figure 3: Frames every 0.1 showing the differential filling in Subject 2.

	Delay time (td10)	Signal Rise Time (tsr)
Subject 1	0.11 (0.04)	0.29 (0.06)
Subject 2	0.08 (0.03)	0.25 (0.08)
Subject 3	0.08 (0.03)	0.23 (0.05)

Table 1: Comparison of mean td10 and tsr values measured in all subjects.