# Imaging 3D Respiratory Dynamics Using Hyperpolarized He-3 Multi-echo HYPR VIPR


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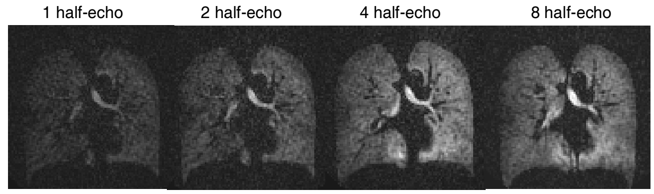
**Introduction** Dynamic lung HP (hyperpolarized) He-3 imaging using 2D PR trajectories has been demonstrated for detection of ventilation abnormalities including airway obstruction [1] and gas trapping [2]. Recent work has been presented using multi-echo PR trajectories to improve data collection efficiency allowing high resolution 3D imaging of the lungs [3]. In contrast enhanced angiography, the use of an 8 half-echo trajectory has been demonstrated to improved data collection efficiency in time-resolved studies [4]. This work exploits the variable sampling density of VIPR for time-resolved imaging as well as improved utilization of the finite HP gas signal by acquiring multiple echos per TR. This allows sufficient data collection efficiency to enable 3D dynamic imaging of the lungs for improved visualization and evaluation of ventilation abnormalities.

Figure 1. Imaging results for multi-echo PR trajectories in separate volunteer studies with identical scan time and 5.6 mM HP He-3 doses.




**Methods** Imaging was performed on a 1.5 T clinical scanner (GE HealthCare, Milwaukee, WI). An excite/receive vest coil tuned to 48 MHz, the resonance frequency of He-3, was used (Medical Advances). Scan parameters included 42 cm FOV, BW = +/- 125 kHz, $128^3$ matrix and a modulated RF flip angle to make use of all the available magnetization and mitigate signal variation due to RF-depletion [5]. To further improve sampling efficiency and minimize the echo time, ramp sampling was performed. Point Spread Function (PSF) analysis was performed in conjunction with volunteer studies to compare the performance of an 8 half-echo trajectory with 1, 2 and 4 half-echo trajectories for fixed 20 s acquisition times and 5.6 mM inhaled HP He-3 doses. A 40 s ventilation maneuver comprised of ~20 s inspiration and ~20 s expiration was imaged using the 8 half-echo PR acquisition. Dynamic data was acquired using a TR/TE of 4.4 ms / 0.216 ms with 8960 excitations sampling 71680 unique projection angles. A subsample, or 'dither,' of 1792 unique angles covering the full sphere of k-space was acquired during each 1s time-frame. This dithered acquisition also helps to distribute motion and uncorrected signal modulation due to RF depletion of $M_z$ and $T_1$ decay of the gas. Gradient deviations in the k-space trajectory were corrected using a calibration scan acquired in a water phantom using the method outlined by Duyn et al. [6]. A concern of HP He-3 rapid imaging is poor SNR. To compensate for reduced SNR due to angular undersampling, HYPR reconstruction [7] was implemented to allow improved visualization of the respiratory dynamics by decreasing aliasing artifact. To minimize for motion of the diaphragm, a 5 s sliding window composite image was used for the HYPR reconstruction.

Table 1. Comparison of PSF simulations with volunteer imaging studies (Fig 1).

| Number of half-echos | PSF figure of merit | SNR in trachea | SNR in parenchyma |
|---|---|---|---|
| 1 | 301 | 33.8 | 17.1 |
| 2 | 394 | 45.4 | 21.3 |
| 4 | 508 | 57.2 | 36.1 |
| 8 | 460 | 77.6 | 33.3 |

**Results** Volunteer studies (Fig. 1) showed improved SNR in the parenchyma for increasing number of echos acquired per TR, up to 8 half-echos (Table 1). The 8 half-echo trajectory shows only a slight decrease in the SNR in the parenchyma for non-time resolved spin-density applications due to $T_2$* blurring, while maintaining the advantage of increased data sampling for dynamic studies. Simulation results corroborate the volunteer studies and are reported with a 'figure of merit' (the PSF peak normalized to the standard deviation of the background artifact) (Table 1). Individual time frames are shown for a dynamic ventilation study (Fig. 2) demonstrating inflow of the HP He-3 into the large airways (Fig. 2a) followed by parenchymal enhancement (Fig. 2c). The beginning of exhalation is observed (Fig. 2d) and movement of the diaphragm and clearance of the gas is evident in subsequent frames (Fig. 2e,f). Individual time-frames are significantly angularly undersampled by a factor of 28 below the Nyquist criterion; however use of HYPR allows significant reduction of the undersampling artifact, SNR in the parenchyma was 9 using HYPR vs. 4.2 for a standard reconstruction. A rotated view of a single time-frame is depicted in Fig. 3 demonstrating the 3D isotropic resolution capabilities of this technique.

Figure 2. Subset of coronal MIP data from 3D time resolved ventilation depicting dynamics. Note time frames have been individually windowed and leveled to allow better detection of signal differences in each frame.

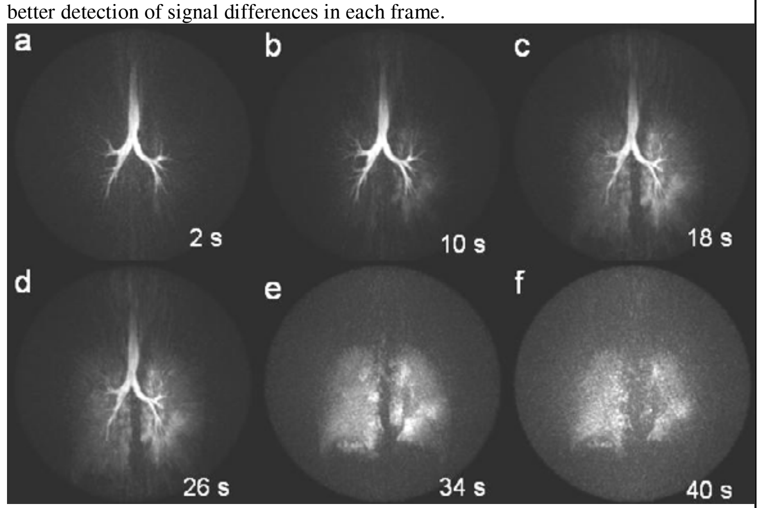
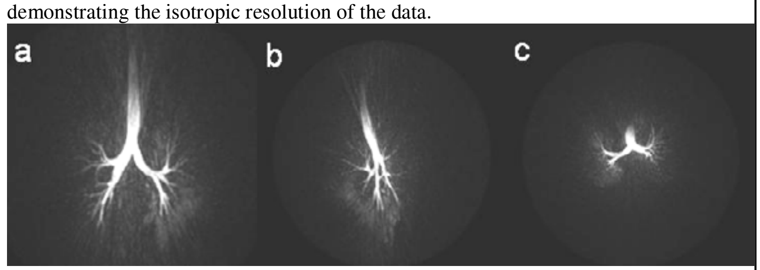



Figure 3. Rotated ventilation MIPs from 10s time-frame (from Fig. 2b) demonstrating the isotropic resolution of the data.




**Conclusions and Discussion** The improved data collection efficiency in time and with RF excitation of the 8 half-echo PR trajectory allows 3D visualization of respiratory dynamics. Further, use of the HYPR reconstruction for improving the SNR in these highly undersampled data mitigates artifact and improves visualization. These results demonstrate the potential for 3D visualization of respiratory dynamics using HP He-3. Moreover, the early inspiratory period allows visualization of the airway tree that may be useful for 3D airway segmentation [8]. Future work will explore the advantages of the multi-echo VIPR sequence for quantitative assessment of dynamic ventilation in conjunction with refinement of the HYPR algorithm, particularly in the lower lungs were diaphragm motion is present.


**References**

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