Hyperpolarized Gas MRI for Pulmonary Diagnostics

Pulmonologists at the Penn Lung Center and researchers in the Functional and Metabolic Imaging Group are conducting studies with the inhaled contrast agent hyperpolarized gas 129Xe (xenon) to better define the optimal lobe for therapy in endobronchial valve placement during bronchoscopic lung volume reduction (BLVR) therapy for COPD.

Diagnostic imaging of the lungs remains a challenge. CT and scintigraphy have distinct applications in pulmonary diagnostics, but generate sufficient risk of radiation exposure to both preclude use in children and impact longitudinal clinical follow-up in adults. Magnetic resonance imaging (MRI), while safer, is compromised because air and other gases in the lungs dramatically reduce the signal-generating proton density of lung tissue.

In studies, however, the promise of MRI in lung imaging has been greatly enhanced using hyperpolarized gas diffusion. Inhaled during a subject's normal tidal breathing, MRI with the hyperpolarized gases—isotopes of helium (3He) and xenon (129Xe)—dramatically increases the sensitivity and contrast of pulmonary MRI and offers a reliable method to detect pulmonary disease. At this time, hyperpolarized gas MRI is investigational in the United States, and because 3He is rare and costly, 129Xe is the gas used in most studies and applications.

Hyperpolarized 129Xe (or HXe) is an inert, inhaled contrast agent that serves as a surrogate for the functional pathway of oxygen movement in the lung by dissolving into lung tissue structures and entering the blood stream. It can thus provide functional imaging of regional lung ventilation and gas exchange from alveolar air spaces across the air-blood boundary into parenchymal tissue.[1]

At Penn Pulmonary Medicine, recent investigational explorations of HXe MRI have examined the physiology underlying the clinical benefit of BLVR using endobronchial valves, which have proven effective at improving lung function and quality of life in certain severely emphysematous patients. Lobar selection for bronchoscopic LVR in homogenous emphysema currently relies on perfusion scintigraphy as a surrogate marker of gas exchange. In its application at Penn in BLVR, inhaled HXe functional MRI enabled direct measurement of lobar ventilation and gas exchange, a potential aide to clinicians seeking to identify the optimal lobe for treatment. Additionally, pre- and post-BLVR HXe MRI allows for the direct assessment of the structural and physiologic changes underlying the patient's symptomatic benefits from the treatment.

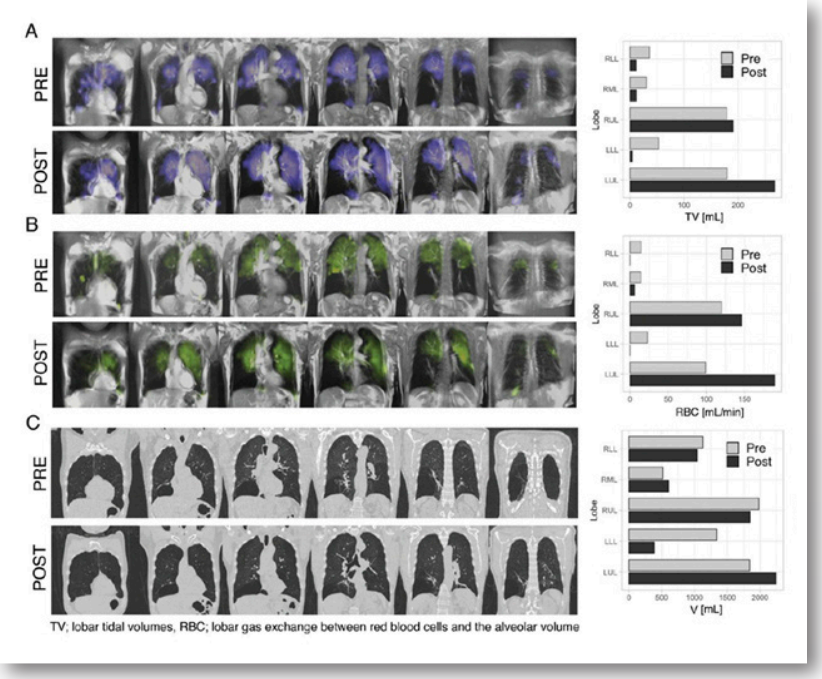

Figure 1: Ventilation and gas exchange visualized by hyperpolarized ^{129}Xe MRI in a patient before and after endobronchial valve placement for COPD.

CASE STUDY

A 67-year-old man with severe emphysema due to alpha-1 antitrypsin deficiency and progressive dyspnea underwent endobronchial lung volume reduction. Five valves (Zephyr Valve, Pulmonx Corp, Redwood City, CA) were placed into the left lower lobe (LLL) airways, producing significant improvements in spirometry, 6-minute walk distance, and symptom scores. The patient was imaged pre-treatment and 42 days post-treatment. Marked improvements in tidal volumes occurred in the left upper lobe (LUL), with complete absence of ventilation in the targeted lobe. Gas exchange almost doubled within the LUL, indicating that lobar tidal volume improvements lead to physiologic improvements in gas exchange (Figure 1). While restored ventilation in the LUL and an absence of ventilation in the LLL caused a slight reduction in lower and middle right lobe ventilation, overall lung function improved, perhaps due to improved breathing mechanics and increased gas exchange. Imaging and clinical markers correlated with reported subjective improvements, showing effectively redistributed ventilation and gas exchange to the healthier lung. [2]

References

1. Dregely, Isabel, "Hyperpolarized Xenon-129 Magnetic Resonance Imaging of Functional Lung Microstructure" (2010). Doctoral Dissertations. 549. University of New Hampshire, Durham, NH.

2. Hamedani H, Ma K, DiBardino D, et al. Simultaneous Imaging of Ventilation and Gas Exchange with Hyperpolarized 129Xe MRI for Monitoring Patients with Endobronchial Valve Interventions. Am J Respir Crit Care Med 2022; Jan 19. Online ahead of print.

ABOUT PENN INTERVENTIONAL PULMONOLOGY AT THE PENN LUNG CENTER

The Penn Lung Center is among the oldest and most advanced providers of interventional pulmonology in the nation. An affiliate program, Penn Interventional Pulmonology, employs bronchoscopy and other minimally invasive techniques to diagnose and treat advanced lung conditions and works closely with the Pulmonary, Allergy, and Critical Care Division and thoracic surgery, medical and radiation oncology, otorhinolaryngology and transplant specialists to provide seamless care for advanced lung disease.

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FY22-34911 5/22