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Functional Airway Obstruction Observed with Hyperpolarized ^{129}Xe -MRI

Erin J. Song, B.S.¹, Chris R. Kelsey, M.D.¹, Bastiaan Driehuys, Ph.D.², and Leith Rankine, M.S.^{2,3}

¹Department of Radiation Oncology, Duke University Medical Center, Durham, NC

²Center for In Vivo Microscopy, Duke University, Durham, NC

³Department of Radiation Oncology, University of North Carolina at Chapel Hill, Chapel Hill, NC

Abstract

Hyperpolarized ^{129}Xe -MRI (HP ^{129}Xe MRI) is an emerging imaging modality that allows assessment of both ventilation and gas transfer. Most research to date has focused on non-malignant pulmonary diseases. However, the capability of evaluating the two primary physiological processes of the lung (ventilation and gas transfer) makes HP ^{129}Xe MRI a promising imaging modality in the management of patients with lung cancer.

Keywords

Lung cancer; hyperpolarized ^{129}Xe -MRI; magnetic resonance imaging; airway obstruction; radiation therapy; ventilation; gas transfer

Background

Hyperpolarized (HP) ^{129}Xe MRI is an emerging technology that affords a non-invasive, quantitative 3D-mapping of pulmonary function. Hyperpolarization enhances the ^{129}Xe signal ~100,000-fold to enable imaging its 3D distribution in a single breath-hold. Moreover, ^{129}Xe is tissue-soluble and freely diffuses from the alveolar space into the interstitial barrier, from which it diffuses into the capillary red blood cells (RBCs). It can be separately quantified in these three compartments by virtue of its unique MRI signal frequency in each(1). These properties make HP ^{129}Xe MRI uniquely applicable to the study of radiation therapy, where it has recently become of interest.

Corresponding Author: Chris Kelsey, M.D., Department of Radiation Oncology, 30 Duke Medicine Circle, Room 05125A, Durham, NC 27710, christopher.kelsey@duke.edu, 919-668-5213 (tele), 919-668-7345 (fax).
DR. CHRISTOPHER KELSEY (Orcid ID : 0000-0002-4961-8982)

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Conflicts of Interest-BD is founder of Polarean that makes ^{129}Xe hyperpolarization equipment (an active conflict management plan is established through the Duke Office of Research Integrity). The other authors report no conflicts of interest.

Case Report

A 64-year-old male presented with dyspnea. Chest CT revealed a 7 cm right lung mass with mediastinal invasion and compression of the right mainstem bronchus. Bronchoscopy showed a 90% obstructing mass in the right mainstem bronchus. Pathology was consistent with adenocarcinoma. The mass was hypermetabolic on PET/CT (Figure 1A–B) with involvement of mediastinal lymph nodes. With T4N2M0 disease, concurrent RT and chemotherapy were pursued.

The patient enrolled on an institutional review board approved prospective study (NCT02478255) evaluating HP ^{129}Xe MRI before and after RT. His planning CT (Figure 1C) demonstrated new partial lung atelectasis. Pulmonary function testing (PFTs) indicated FEV1=56%, FVC=57%, and DLCO=59%. Subsequent HP ^{129}Xe MRI revealed no ventilation to the right lung despite it appearing expanded on CT (Figure 1D). The patient began treatment eight days later at which time he complained of increasing dyspnea. At that time, cone-beam CT (CBCT) revealed nearly complete right lung collapse (Figure 1E). A few days after initiating radiation therapy his breathing had improved dramatically and CBCT confirmed lung re-expansion (Figure 1F). On the final day of treatment, CBCT showed reduced tumor size and sustained lung expansion (Figure 1G). Post-treatment HP ^{129}Xe MRI established that the physically expanded right lung was re-ventilated (Figure 1H), at which time the patient PFTs had risen to FEV1=100%, FVC=101%, and DLCO=82%.

Discussion

Dyspnea from obstructing tumors is a common presenting symptom in locally-advanced lung cancer and can be improved with RT(2, 3). In this case, the right lung was completely expanded at diagnosis, yet the patient had significant dyspnea. HP ^{129}Xe MRI found the right lung to be unventilated despite fairly normal radiographic appearance on CT.

The unique properties of HP ^{129}Xe MRI are well-suited to evaluate pulmonary function in patients with lung cancer. HP ^{129}Xe MRI has a potential advantage over other imaging modalities such as a ventilation-perfusion (VQ) scan since both gaseous *and* dissolved phases can be measured to provide a more comprehensive 3D evaluation of ventilation, interstitial barrier thickening, and RBC transfer. To date, HP ^{129}Xe MRI has been used to assess gas exchange in patients with asthma and COPD(4) and more recently to evaluate functional impairment in idiopathic pulmonary fibrosis (IPF)(5). Future applications in the setting of lung cancer might include assessing the distribution of regional ventilation and gas exchange prior to surgery or RT, evaluating radiation dose-dependent functional changes, and functionally-guided RT planning to limit incidental dose to highly functional regions in the lung, thereby potentially reducing long-term side effects of therapy.

Abbreviations

MRI	magnetic resonance imaging
CT	computed tomography

PET	positron emission tomography
CBCT	cone-beam CT
RBC	red blood cells

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Figure 1.

Staging CT (A) and PET (B) showing right lung tumor. Radiation therapy planning CT (C) demonstrates interval development of partial right lung collapse (dashed arrow); same-day Xenon-MRI (D) indicates ventilation is absent from the right lung. CBCT (E) obtained 8 days later on the first day of radiation shows nearly complete lung collapse. Subsequent CBCTs on the third day of radiation (F) and post-treatment (G) demonstrate re-expansion of right lung. Post-treatment HP ^{129}Xe MRI (H) confirms re-ventilation.