Dynamics of Pulmonary Ventilation Distribution at Steady State via 19Fluorine-Enhanced MRI: Initial Experiences and Future Developments

Ahmed F Halaweish[1,2], W. Michael Foster[3], Richard E Moon[4], Neil R MacIntyre[3], James R MacFall[1], and H. Cecil Charles[1,2]

[1]*Radiology, Duke University School of Medicine, Durham, NC, United States,* [2]*Duke Image Analysis Laboratory - Radiology, Duke University School of Medicine, Durham, NC, United States,* [3]*Medicine - Pulmonary, Duke University School of Medicine, Durham, NC, United States,* [4]*Anesthesiology - GTVU Divison, Duke University School of Medicine, Durham, NC, United States*

Purpose

Single-breath assessments of pulmonary ventilation provide a static snapshot of the underlying distribution and heterogeneities within, while multi-breath steady-state equilibrium assessments facilitate a more robust dynamic evaluation. The renewable nature of the fluorine (^{19}F) signal in conjunction with fast imaging sequences, presents itself as a non-invasive technique to assess pulmonary ventilation at equilibrium, providing regional assessments of ventilation efficiency and wash-in and wash-out rates. Through the use of perfluoropropane (PFP), we demonstrate 19F MRI's ability in assessing steady-state equilibrium ventilation in a cohort of normal and disease lung disorders.

Methods

All Imaging was performed following IRB approval, complied with HIPAA regulations and informed consent was obtained from all subjects.

Twenty-nine subjects between the ages of 18 and 71 were recruited for imaging and classified based on spirometry and medical history. Imaging was carried out in the feet first supine position on a Siemens TIM Trio 3T MRI Scanner, utilizing 3D GRE VIBE pulse sequence (Coronal, TR/TE =13/1.62 ms, 15 mm slice thickness, 64x64 acquisition matrix, 70 flip angle, 6.25x6.25 mm pixels, 130 Hz/Pixel bandwidth). Subjects performed several breatholds interleaved with 3-5 breaths of PFP. Respiratory waveforms and physiological signals of interest were monitored throughout the imaging sessions, utilizing our in-house respiratory monitoring and gating apparatus (Physiorack). Steady-state Ventilation (SS_{VE}) maps were created through the summation of the wash-in phase breath-holds.

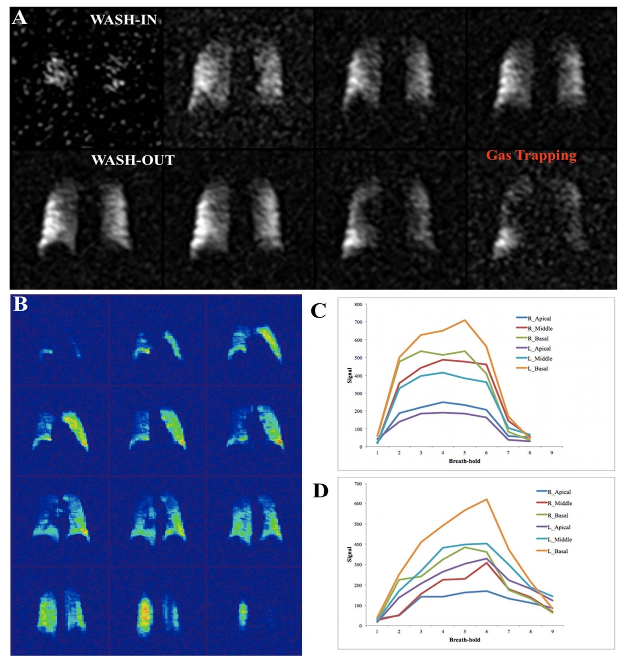

Figure 1. Wash-in / Wash-out assessment of a single slice from a COPD patient demonstrating severe gas trapping (A) and a SS_{VE} map of an asthma patient (B). Wash-in and wash-out ROI analysis from an asthma (C) and COPD (D) patient respectively, demonstrate different degrees of wash-in /wash-out and gas trapping.

Results

All subjects tolerated the gas mixture well with no adverse side effects. Images of normal intact lungs demonstrated a homogeneous distribution of the gas, while lung images from emphysemic lungs demonstrated increased heterogeneity and ventilation defects. Wash-in SSVE maps demonstrated a clear difference between normal and emphysemic lung, where the latter demonstrated a weaker ventilation signal throughout the lungs. The maximum ventilation within the airspaces was significantly lower, with patchy areas of minimal to no ventilation. Subjects with COPD demonstrated a higher degree of gas-trapping following completion of the imaging sessions.

Discussion

We have demonstrated ^{19}F MRI's ability in assessing regional ventilation through gas-trapping analysis and steady-state equilibrium ventilation assessments. Future developments include the fitting of an exponential function to the wash-in and wash-out data and extraction of ventilation dynamics and time-constants on a pixel-by-pixel basis. These results in conjunction with the recent developments in gradient hardware and pulse-sequences provide a radiation-free alternative to early techniques utilizing CT and xenon gas.