Image Functional Modeling of the Lung Using Hyperpolarized ^{3}He MRI

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INTRODUCTION

•Asthma is a chronic respiratory disease characterized by inflammation of the bronchial lining and constriction of airway smooth muscle (ASM).

•Identifying the regions of airway closure is critical for determining target sites for anti-inflammatory drugs.

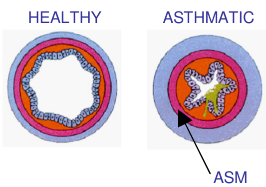

Figure 1. Healthy and asthmatic airway lumen are depicted. In an asthmatic, constriction of ASM and inflammation of bronchial lining results in airway diameter reduction and decreased alveoli ventilation.

•One way to assess asthmatic lung structure is through a new imaging modality, Hyperpolarized (HP) ^{3}He MRI.

•Whereas traditional MRI utilizes the protons in water to capture various body tissue, HP ^{3}He MRI is able to image airspace through the inhalation of polarized noble gas.

ANATOMICALLY-BASED MODELING

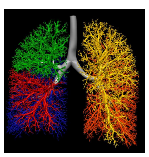

Figure 2. The image on the left represents a 3D Human Model of the Lung developed by Tawhai et al. in 2000.

•This model is able to predict whole lung mechanics based on a generic airway tree with asymmetric bifurcations.

•Each airway is modeled as a function of diameter and thickness with an alveolar tissue element attached to each terminal airway.

•The properties of each airway are combined in serial and parallel fashion to get a total lung resistance and lung elastance as a function of frequency.

PROJECT GOAL

•The goal of this project is to use HP ^{3}He MRI to determine ventilation distribution for baseline and post-Methacholine (Mch) challenge conditions.

•Comparisons between measured lung mechanics and model-based simulations will be used to asses the size and location of airways that can or cannot be constricted in an asthmatic lung.

PATIENT SPECIFIC DATA

LUNG MECHANICS

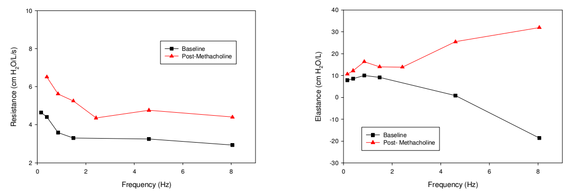

Figure 3. Plotted above are measured lung mechanics using the optimal ventilator waveform (OVW). Elevated resistance and elastance values are evident in the post-Mch challenge.

HP ^{3}He MRI IMAGES

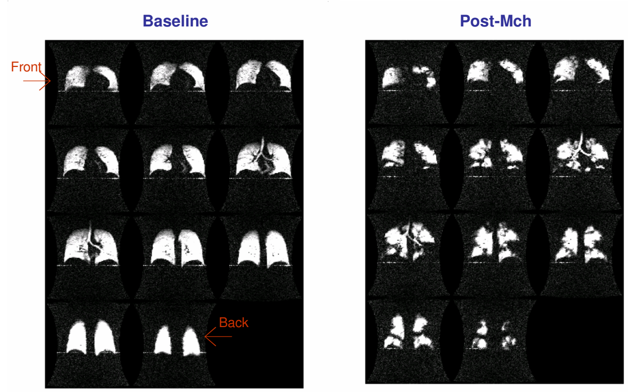

Figure 4. Coronal slices (13 mm thick) are taken prior to and after Mch challenge. On the left, full ventilation of the lungs is indicated by the higher intensity pixels (white). In the post-Mch challenge (right), distinct dropout regions, or areas of no ventilation are evident.

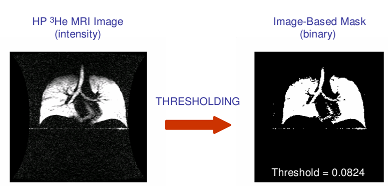

Figure 5. The first step in MRI image analysis requires thresholding the baseline image to isolate the healthy lung boundary

EXTRACTION OF VENTILATION

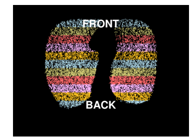

Figure 6. Shown to the left are the terminal branches in the generic 3D model of the lung. This model was divided into the same number of slices as the MRI images.

• Each terminal branch slice is then morphed to the size and shape of its corresponding HP ^{3}He MRI baseline image mask.

• Ventilated terminal branches for each slice are then identified and used to find the post-Mch condition ventilation.

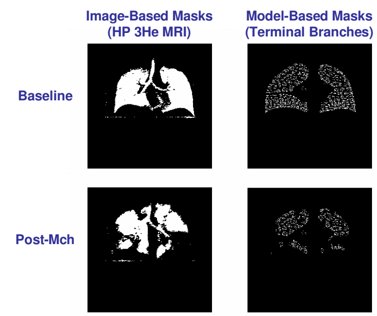

Figure 7. Zoomed in on the left is one slice from the baseline and post-Mch images. Note that the size, shape, and areas of ventilation in the terminal branch masks correspond to the image-based masks.

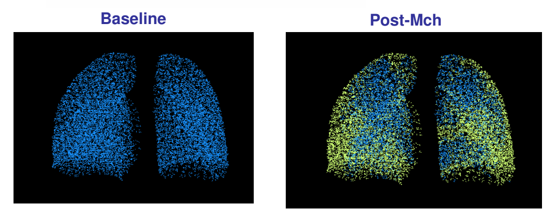

Figure 8. 3D ventilation distribution are plotted above for baseline and post-Mch challenge. Full ventilation is represented in blue, hypo-ventilation in green.

FUTURE WORK

• Pattern matching baseline and post-Mch model data to OVW lung mechanics. Specifically, we hope to identify the constriction patterns (generation and degree of constriction) that correspond to the measured lung mechanics while staying consistent with the ventilation distribution.

• Integrating airway smooth muscle analysis in asthmatics through deep inspiration imaging.

ACKNOWLDEGEMENTS

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